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SENEGAL

Challenges and Recommendations for Water Security in Senegal at National Level and in the Dakar-Mbour-Thiès Triangle

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Global Water Practice

Africa Region

Abreviation and acronyms

AAAS	Senegalese Association of Sanitation Stakeholders (*Association des Acteurs de l'Assainissement du Sénégal*)
ADM	Municipal Development Agency (*Agence de Développement Municipale*)
AGEROUTE	Highway Management Agency (*Agence de Gestion des Routes*)
AIBD	Blaise Diagne International Airport (*Aéroport International Blaise Diagne*)
ALG	Alginate
ANAT	National Land Use Planning Agency (*Agence Nationale de l'Aménagement du Territoire*)
ANCAR	National Agency for Rural and Agricultural Consulting (*Agence nationale du conseil agricole et rural*)
ANIDA	National Agricultural Inclusion and Development Agency (*Agence Nationale d'Insertion et de Développement Agricole*)
ANSD	Senegalese National Statistical and Demographic Agency (*Agence Nationale de la Statistique et de la Démographie*)
APD	Public Development Aid (*Aide Publique au Développement*)
APIX	Major Works Investment Promotion Agency (*Agence pour la Promotion de l'Investissement des Grands Travaux)*
BAME	Macro-Economic Research Institute (*Bureau d'Analyses Macro-Économiques*)
BARVAFOR	Retention Basin and Well Development (*Bassin de Rétention et Valorisation des Forages*)
CCE	Municipal Water Committee (*Comité Communal de l'Eau*)
CCR	Large Rural Hub (*Gros Centre Rural*)
CFAF	African Financial Community Franc
CGPE	Water Management and Planning Committee (*Comité de Gestion et de Planification de l'Eau*)
CSE	Water High Council (*Conseil Supérieur de l'Eau*)
CSS	Senegalese Sugar Corporation (*Compagnie Sucrière Sénégalaise*)
CT	Continental Terminal
CTE	Water Technical Committee (*Comité Technique de l'Eau*)
DBRLA	Directorate of Catchment Basins and Artificial Lakes (*Direction des Bassins de Rétention et des Lacs Artificiels*)
DGPRE	Directorate General of Water Resources Planning and Management (*Direction Générale de la Planification et de la Gestion des Ressources en Eau*)
DMT	Dakar-Mbour-Thiès
DPGI	Directorate of Flood Prevention and Management (*Direction de la Prévention et de la Gestion des Inondations*)
DWS	Drinking Water Supply
GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Reduction and Recovery
ICS	Senegalese Chemical Corporation (*Industries Chimiques du Sénégal*)
ISRA	Senegalese Agricultural Research Institute (*Institut Sénégalais de Recherches Agricoles*)
IUWM	Integrated Urban Water Management
IWRM	Integrated Water Resources Management
KMS	Keur Momar Sarr
LPDSEA	Letter of Development Policy for the Water and Sanitation Sector (*Lettre de Politique de Développement du Secteur de l'Eau et de l'Assainissement*)
MAER	Ministry of Agriculture and Rural Development (*Ministère de l'Agriculture et de l'Équipement Rural*)
MAR	Managed Aquifer Recharge
MEA	Ministry of Water and Sanitation (*Ministère de l'Eau et de l'Assainissement*)

OLAC	Lakes and Waterways Agency (*Office des Lacs et des Cours d'Eau*)
OLAG	Lac de Guiers Management Agency (*Organisation en Charge de la Gestion du Lac de Guiers*)
OM	Oligo-Miocene
OMVG	Gambia River Development Agency (*Organisation de Mise en Valeur du Fleuve Gambie*)
OMVS	Senegal River Development Agency (*Organisation de Mise en Valeur du Fleuve Sénégal*)
ONAS	Senegalese National Sanitation Agency (*Office National de l'Assainissement du Sénégal*)
PADEN	Niayes Land Use and Economic Development Program (*Programme d'Aménagement et de Développement Économique des Niayes*)
PAEP	Drinking Water Access Program (*Programme d'Accès à l'Eau Potable*)
PAGEP	Stormwater Sanitation and Management Program (*Programme d'Assainissement et de Gestion des Eaux Pluviales*)
PAGIRE	Integrated Water Resources Management Action Plan (*Plan d'Action de Gestion Intégrée des Ressources en Eau*)
PDA	Sanitation Master Plan (*Plan Directeur d'Assainissement*)
PDGI	Ten-Year Flood Management Program (*Programme Décennal de Gestion des Inondations*)
PDMAS	Senegalese Agricultural Market Development Program (*Programme de Développement des Marchés Agricoles du Sénégal*)
PDU	Project Development Unit
PGE	Water Management Plan (*Plan de Gestion des Eaux*)
PGIRE	Integrated Water Resources Management Program (*Programme de Gestion Intégrée des Ressources en Eau*)
PL	Public Lavatory
PNDDAA	National On-Site Sanitation Sustainable Development Program (*Programme National de Développement Durable de l'Assainissement Autonome*)
PNDS	National Sanitation Development Plan (*Plan National de Développement Sanitaire*)
PNES	Senegalese National Water Partnership (*Partenariat National de l'Eau du Sénégal*)
PNIASAN	National Agricultural Investment Program (*Programme National d'Investissement Agricole*)
PPP	Public-Private Partnership
PRACAS	Senegalese Agricultural Development Acceleration Program (*Programme d'Accélération de la Cadence Agricole du Sénégal*)
PROGEP	Stormwater Management and Climate Change Adaptation Project (*Projet de Gestion des Eaux Pluviales et d'Adaptation au Changement Climatique*)
PRV	Pressure Reducing Valve
PSDAK	Special Dakar Region Supply Improvement Program (*Programme Spécial d'Amélioration de la Desserte de la Région de Dakar*)
PSE	Emerging Senegal Plan (*Plan Sénégal Emergent*)
PSMRE	Strategic Water Resources Mobilization Plan (*Plan Stratégique de Mobilisation des Ressources en Eau*)
PSP	Pilot Support Program (*Programme Support de Pilotage*)
RCP	Representative Concentration Pathway
RGE	General Business Census (*Recensement Général des Entreprises*)
SAED	Senegal River Delta Land Use and Operation Corporation (*Société d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal*)
SAPCO	Coastal Management and Promotion Corporation (*Société d'Aménagement et de Promotion des Côtes*)

SDAGE	Water Development and Management Master Plan (*Schéma Directeur d'Aménagement et de Gestion de l'Eau*)
SDE	Senegalese Water Corporation (*Sénégalaise des Eaux*)
SDG	Sustainable Development Goal
SIIE	Integrated Water Information System (*Système Intégré d'Information sur l'Eau*)
SNAGCR	National Sanitation Development Strategy for Large Rural Hubs (*Stratégie Nationale de Développement de l'Assainissement pour les Gros Centres Ruraux*)
SNAR	National Rural Sanitation Strategy (*Stratégie Nationale de l'Assainissement Rural*)
SNAU	National Urban Sanitation Strategy (*Stratégie Nationale d'Assainissement Urbain*)
SNSAR	National Food Security and Resilience Strategy (*Stratégie Nationale de Sécurité Alimentaire et de Résilience*)
SOCOCIM	Commercial Cement Corporation (*Société Commerciale du Ciment*)
SODAGRI	Agricultural and Industrial Development Corporation (*Société de Développement Agricole et Industriel*)
SODEFITEX	Senegalese Textile Fiber Development Corporation (*Société de Développement des Fibres Textiles du Sénégal*)
SONES	National Senegalese Water Agency (*Société Nationale des Eaux de Sénégal*)
SPEPA	Public Drinking Water and Sanitation Service (*Service Public d'Eau Potable et d'Assainissement*)
STBV	Fecal Sludge Treatment Plant (*Station de Traitement des Boues de Vidange*)
STEP	Sewage Treatment Plant (*Station d'Épuration*)
STP	Sludge Treatment Plant
UGP	Management and Planning Unit (*Unité de Gestion et Planification*)
USAID	United States Agency for International Development
US$	United States Dollar
WRM	Water Resources Management
WSS	Water Supply and Sanitation
CFAF	CFA Franc
ZESI	Integrated Special Economic Zone (*Zone Économique Spéciale Intégrée*)

EXECUTIVE SUMMARY

Water security is "the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies."[1]

Water Security Key Facts in Senegal :

- *Senegal is already water stressed and current water withdrawals are projected to increase by 30 to 60 percent by 2035*
- *Water-related extreme events and pollution already cost Senegal over 10 percent of GDP every year, threatening the country's ambition to become an emerging country, even more so following the COVID-19 pandemic.*
- *The Greater Dakar area is especially at risk, concentrating 50 percent of Senegal's GDP production and close to a third of its population, and will need to diversify water sources and improve cross-sectoral coordination*
- *Senegal urgently needs to prioritize water security to achieve and sustain its development objectives (PSE)*

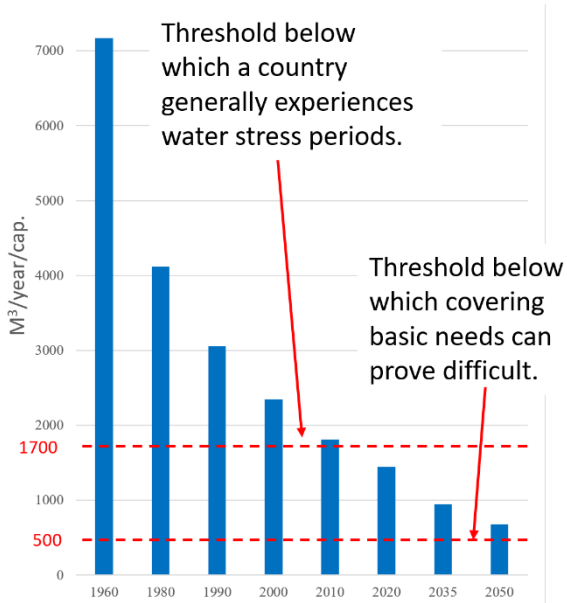
1. **Water security is the bedrock of Senegal's development and key to its socio-economic development goals.** Water security depends on the management of water resources for service delivery and risk mitigation. While the national socio-economic development plan (Plan Senegal Emergent - PSE) aims to mobilize "*abundant*, good quality water for all, everywhere and for all uses, in a healthy sustainable living environment, for an emerging Senegal" by 2035, it does not take into account constraints linked to water resources availability or management. Against this backdrop, the Government of Senegal, through the Ministry of Water and Sanitation (*Ministère de l'Eau et de l'Assainissement,* MEA), requested World Bank support to carry out a study on water security. This study first assesses the attention given to water resource management at the national level and identifies barriers to achieving water security, building on an overview of available resources and the institutional framework. It then takes a closer look at the Greater Dakar region where achieving water security will be most critical to development. The analysis of available water resources data (groundwater and surface water) for Senegal clearly shows that the Greater Dakar area presents a situation of aggravated water stress, with renewable water availability between 20 and 40 m^3/inhabitant/year. Furthermore, withdrawals assessed in the area are around 268,000 m^3/day, while the natural recharge capacities are estimated at only 83,000 m^3/day.

2. **Deteriorating water resources and an inadequate institutional framework are threatening water security in Senegal.** This study shows that the steadily decreasing renewable water availability per capita already falls below the 1700 m^3/capita/day threshold defined by the Food and Agriculture Organization (FAO), under which a country experiences periodic water stress. However, a complementary analysis will be made by the Senegalese party under the coordination of the Directorate of Water Resources Planning and Management (*Direction de Gestion et de Planification des Ressources en Eau*, DGPRE) to allow updating and validating a final ratio. In this respect, support has already been mobilized as part of an ongoing operation financed by the World Bank for the benefit of the Government of Senegal (through the Rural Water and Sanitation Project, PEAMIR). This average situation of water resources in Senegal masks very significant geographic and temporal variations, meaning that water availability does not necessarily coincide with demand and makes meeting growing water needs sometimes complex, difficult and

[1] Grey and Sadoff 2007.

expensive. This situation is compounded by the degradation of water quality, significant spatio-temporal variability, limited exploitability – both technical and economic – the largely transboundary nature of water resources, and climate change trends. Surface water represents the majority of renewable resources (about 90 percent) and is the main water source for agriculture, but is already insufficient to meet needs in dry years. In particular, it has become difficult to fulfill irrigation water demand in the Senegal River Basin during the dry season. Groundwater supplies 85 percent of potable water and most industrial uses but is threatened by overuse and pollution. Current water withdrawals are projected to increase by 30 to 60 percent by 2035, further exacerbating water stress and straining the country's ability to meet the water demand of a quickly urbanizing population and achieve its socio-economic development goals. The current legal and organizational framework for water resources management (WRM) deserves an in-depth overhaul if the country wants to establish a modern WRM policy and achieve its water security objective in the medium and long term. Bold measures will be necessary to address the main constraints identified: obsolete texts, overlapping responsibilities, organizational weaknesses, hierarchical positioning of the structure in charge of WRM, and lack of human and financial resources.

Figure 1: Yearly available renewable water resources per capita.



3. **Water insecurity poses serious constraints on the country's economic growth and the COVID-19 crisis further heightens the urgency.** Today, the cost of the water resources management status quo already impacts more than 10 percent of Senegal's GDP, due to water-related extreme events and pollution. Flooding costs associated with damage of infrastructure and habitat and premature deaths have been estimated over US$ one billion, or 6.3 percent of GDP, while the cost of a year of drought is in the order of US$ 500 million, or 3 percent of agricultural GDP.[2] Water pollution costs associated with untreated domestic wastewater discharges, taking into consideration impacts on the environment and on health, are estimated at 3.8 percent of annual GDP, far exceeding the order of magnitude for middle-income countries (losses of 2.5 percent of GDP). Supply-focused water source development has driven the marginal cost of water to triple since the late 1990s. Already the Government has spent millions on emergency measures to meet demand gaps for water supply and to remedy flood damages to people, infrastructure and the environment. Such pressures could jeopardize the acceleration of growth and poverty reduction Senegal had finally achieved after weak past performances that fell below the regional average, a trajectory which has already been put under considerable duress by the COVID-19 crisis.

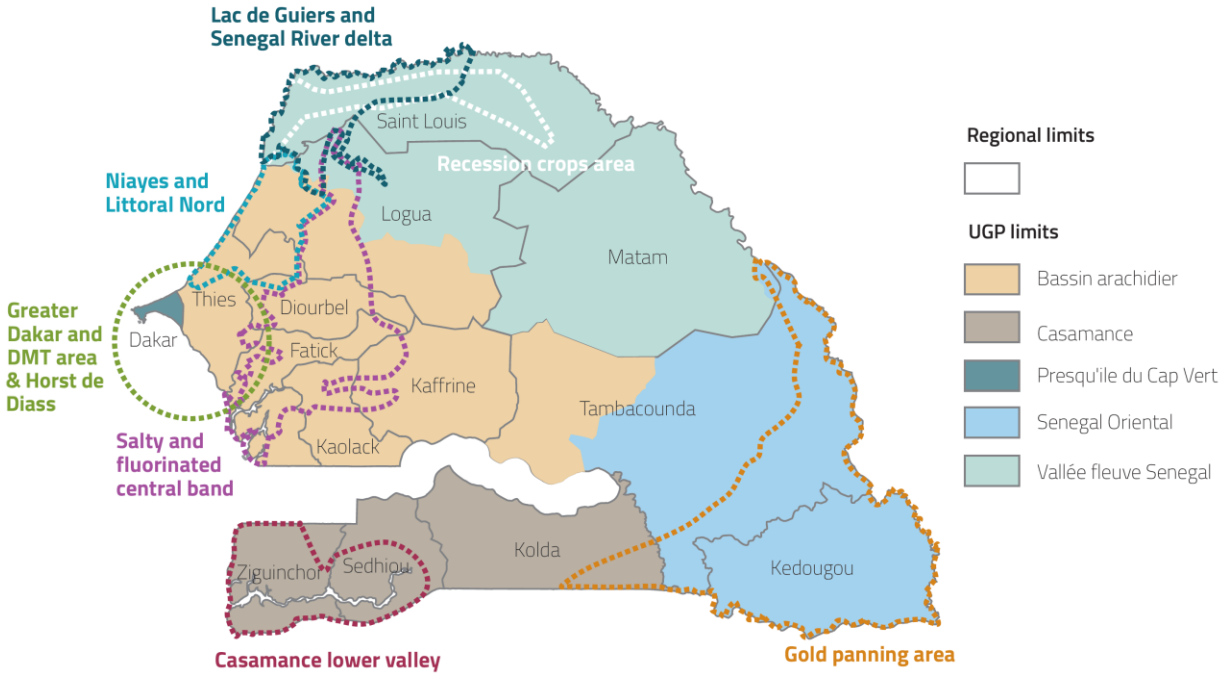
4. **Water availability and its management will shape the Senegalese recovery and future socio-economic development.** Senegal's growth has historically been exposed to significant vulnerability to climatic and exogenous shocks, making water security a top priority to protect the country's long-term recovery. Given the essential role of access to water and sanitation in responding to pandemics like COVID-19 and the role of agricultural livelihoods in economic recovery and self-sufficiency in Senegal, water

[2] Croitoru, Lelia; Miranda, Juan José; Sarraf, Maria. 2019. *The Cost of Coastal Zone Degradation in West Africa : Benin, Côte d'Ivoire, Senegal and Togo*. World Bank, Washington, DC. © World Bank.

security is essential to the achievement of PSE objectives and a building block of building back better for the country. Water availability will also shape how much urbanization can drive Senegal's development moving forward and whether the country can reap the positive dividends of urbanization. Further, water stress limits the nation's booming, thirsty private sector development – especially agribusiness, mining and tourism. Agriculture is the main water user in the nation (82 percent of withdrawals) while the mining sector accounts for 20 percent of total exports in value, contributes 2 percent of GDP and consumes 13 million m^3/year, mostly from groundwater.

5. **Addressing water security will require managing water resources as a non-renewable and degradable resource with significant economic value.** The existing system is overburdened and showing its limits, hampered by uncoordinated and disparate sectoral strategies and plans. At the national level, water security requires a combination of institutional measures and investments focusing on the eight major hotspots where socio-economic importance and water security risks are most critical, as shown in Figure 1. These are: the Niayes and Littoral Nord, Greater Dakar, the Horst de Diass, the salted and fluorinated central band, the lower Casamance valley, the gold panning area, the recession crops area, and Lac de Guiers and the Senegal River delta. The success of this agenda will depend on the reinforcement of the capacities and resources of the DGPRE so it can become the leading water resources authority, with a permanent abstraction fee-based financial foundation and presence in all regions, and the revision of the legal framework to focus on WRM, which is not limited to the management of the public water domain. The strengthening of intersectoral coordination requires giving a legal scope to the water resources management strategy in relation to the development strategies of the different sectors. In turn, these elements would strengthen the DGPRE's position to ensure that water resources availability and management are accounted for in sectoral plans, coordinating future services development around these key inputs.

Figure 2: Map of the eight (8) identified hotspots overlain with the DGPRE's existing planning units (UGP)



6. Characterization of the eight (8) identified hotspots:

- The Greater Dakar area concentrates 32 percent of the population, 55 percent of the country's economic activity and represents a hotspot for water security. Water demand there has long exceeded local availability and continues to grow rapidly. The water supply in this area is essentially based on water transfers from Lac de Guiers, the Littoral Nord and on the overexploitation of local aquifers. This leads to a constant increase in the cost of water and investment losses due to the abandonment of boreholes following the saline intrusion. The area also suffers from flooding, partly due to poor urban planning and fierce land use competition between different economic activities with a negative impact on water resources.

- The **Horst de Diass** provides a third of the water supply for Greater Dakar. The Maastrichtian and Paleocene aquifers are heavily overexploited there, leading to very low water levels in seasonal coastal rivers no longer supported by these depleted aquifers. There is thus a loss of vegetation cover due to gullying, soil erosion and heavy sedimentation. The large number of actors coexisting in this area also presents a high risk of conflicts around land and the use of water resources.

- The **Niayes and Littoral Nord** area is at the heart of national horticultural production and the mining industry. Its microclimate is favorable to horticulture, which accounts for 60 percent of national production, and represents the vast majority of exports. Industrial poultry farming and the breeding of small ruminants are growing in the area. The mining sector is also booming, particularly for phosphates, zircon and quarries. Due to these intense economic activities and urbanization, the aquifers are very vulnerable to agricultural, industrial and domestic pollution, particularly threatening the future of horticulture which uses shallow wells. Conflicts are already erupting between users over the availability of the resource and climate change will exacerbate these trends.

- The **salted and fluorinated central band** suffers from poor water quality and depends on rain-fed agriculture to produce groundnuts, the country's main export crop. Groundwater there is excessively salty and fluorinated, which affects access to drinking water for around one million people, causing serious epidemiological problems. Rainfed agriculture is very important in the area as water quality and scarce surface water resources impede the development of irrigation and livestock farming, but it is affected by climate change and unreliable rainfall.

- **Lac de Guiers and the Senegal River delta** are strategic water resources for water supply, agriculture and the environment, and already face significant risks. They supply the big cities on the Keur Momar Sarr-Dakar axis and many villages. The city of Saint-Louis gets its water from the Bango freshwater reserve fed by distributaries from the Senegal River delta. The area is home to major agro-industrial facilities, numerous village irrigation schemes, a protected area and several RAMSAR sites, where wetland health is threatened. Certain uses are threatened by the quality of lake water due increased pollution. Domestic pollution and drainage water contribute to the eutrophication of more than 30 percent of the lake area. The progressive clogging of hydraulic axes and water bodies due to sedimentation and invasive plants creates shortages as lake access becomes difficult. Waterborne diseases such as malaria and schistosomiasis persist. The multiplicity of uses leads to competition and in some cases to conflicts between users.

- The **Lower Casamance Valley** will be central to future socio-economic development, but it currently faces serious water quality problems. The area also faces a serious challenge regarding access to drinking and irrigation water because all its aquifers (Maastrichtian, Oligo-Miocene and Continental Terminal) are saline and, in some areas, fluorine levels exceed the drinking water standards. The region is home to large cities with high tourist potential such as Ziguinchor, Bignona, Oussouye and Cap Skirring. Its great potential for fishing, agriculture, biodiversity, fruit and forestry production and zircon extraction has barely been exploited. However, excess salt leads to the loss of arable and forest land, thus affecting the fish fauna and leading to loss of income and impoverishment of the population.

- The **gold panning area** hosts several important activities that threaten the water resources on which they depend, like the significant industrial and artisanal extraction of gold, iron and marble. Water resources are often polluted by mining, posing risks to people, livestock and wildlife. Agricultural and livestock activities are also consequential, and the expansion of irrigated agriculture is marked by the presence of rural development management companies. It is also home to the forestry and tourist activities of the Niokolo Koba National Park.

- The flood **recession crops area** is a multipurpose area bordering the banks of the Senegal River from Saint-Louis to Bakel, where fishing, agriculture and livestock farming take place. It offers ideal conditions for the reproduction of fish and is home to important forest resources. Flood recession crops increase the agro-ecological potential of the floodplain of the Senegal River, which has regressed following the construction of the Manantali dam. Poor water quality also affects the performance of floodplains because the soil is less loamy and the obstruction of streams and marshes by siltation affects their flood conditions. Flooding also contributes to the recharge of aquifers. Hydroelectric production is prioritized during dry years in accordance with the charter of the *Organisation de Mise en Valeur du Fleuve Sénégal* (OMVS), which could lead to the reduction or even the disappearance of artificial floods due to a significant drop in debits. Finally, a reduction in rainfall could further impact flood recession crops.

7. **Nowhere are water security issues more prevalent than in the Dakar-Mbour-Thies (DMT) triangle, which comprises more than a third of the Senegalese population and economic activity.** Concentrating 50 percent of Senegal's GDP production and boasting a growth rate of four percent per year over the last decade, the DMT triangle faces key water security risks, including overexploited and polluted aquifers and endangered wetlands and ecosystems. The Lac de Guiers provides about 40 percent of the area's water supply and is threatened with regard to both quality and security of access. The share of the Lac de Guiers in DMT water supply is projected to increase to 60 percent, with serious implications were the transfer infrastructure to be damaged or the lake water irreversibly polluted, especially given growing conflicts around land and water use on its shores. Competition is growing between different uses for the development of space and the use of water resources. The urbanization of agricultural land drives land and water prices up while urban development invades the beds of intermittent streams, worsening flooding with dire consequences (damages of US$67 million in 2009 in Dakar alone[3]). As demand for drinking water and irrigation already exceeds the available resources, it is essential that water sources diversification be explored, including loss reduction and efficiency measures, fit-for-purpose source allocation and the development of non-conventional resources such as desalination and wastewater reuse or recycling.

[3] USAID. 2017. Climate Change Risk Profile – Senegal.

8. **The DMT has been facing a water deficit since 2011 and could greatly benefit from a circular economy approach to water security.** For the water sector, the circular economy approach promotes refocusing urban centers as users within a broader WRM perspective and closing the resource cycle by looking for efficiencies. Its key principles consist in delivering resilient water-related services, designing out waste and pollution and regenerating natural systems.[4] For urban water security, this will also require diversifying water sources to hedge against growing risks and harmonizing across water using sectors. The DMT triangle is at the center of Senegal's territorial planning and development scheme and, as such, a leading recipient for major structuring projects already under way or in the pipeline, around the Blaise Diagne international airport and the special integrated economic zone (ZESI). While the Government has developed plans outlining required investments to strengthen water availability and services to 2035, channeling these plans into innovative "circular" solutions will require better integration across sectors through a harmonized strategic framework for water security and the consolidation of a coordination platform to bring together fragmented institutions.

9. **Existing plans must be prioritized into an Integrated Government Program for Water Security in the DMT following circular economy principles.** This program would support improved coordination for planning and water resources management in the area through the consolidation of a cross-sectoral stakeholder group or water platform. A set of multi-sectoral investments focused on addressing the main water security challenges for the DMT triangle were identified, namely: support to finalize key institutional reforms, developing new water sources to diversify the portfolio and hedge against risks to current supply, improve service provision efficiency, roll out sanitation services and develop wastewater reuse for aquifer recharge and irrigation, and capitalize on wetlands and green infrastructure to improve stormwater management and capture. In addition to the development of unconventional sources, particular attention will be paid to safeguarding the Lac de Guiers as a strategic resource and protecting and replenishing groundwater resources. Given the uncertainties and risks faced by the DMT area today, planned investments will be subject to a thorough resilience analysis following the latest international best practice. The program will have positive impacts to fight future pandemics and increase human capital through the implementation of the sanitation component and the provision of improved WASH services in schools and health centers located in the area. Thousands of jobs will be created on construction sites and farms, mostly for youth and young 'agripreneurs.' Disruptive technology will be used to monitor water resource and quality and strengthen citizen engagement through digital interactions between service providers and citizen

10. **An analysis of the proposed Integrated Government Program for Water Security in the DMT triangle shows that integrating circular economy principles as outlined above yields economically sound investments.** From a public finance perspective, the draft investment plan identified for the period 2021-2050 (US$1,530 million including US$500 million for drinking water) is sustainable in the long term as the annual investment value for all sectors combined is US$54 million, or about 0.5 percent of the GDP produced in the DMT triangle, significantly below the current costs of poor sanitation and floods in Senegal (about 10 percent of GDP[5]) and within the current range of sector spending in Africa.[6] However, this draft multi-sectoral investment plan should be underpinned by a detailed in-depth analysis integrating the technical design, environmental, social, economic and financial aspects. SONES (*Société Nationale des*

[4] World Bank, upcoming. Water in Circular Economy and Resilience (WICER) Position Paper.
[5] Own calculation based on Croitoru et al. 2019 et WSP 2012.
[6] A review of 18 African countries estimated their economic losses due to poor sanitation at US$5.5 billion per year - which represents between 1 and 2.5 percent of the GDP of the countries reviewed (Economic Impacts of Poor Sanitation in Africa, WSP World Bank, 2012)

Eaux du Sénégal) has the financial capacity to support a significant portion of the sector's debt service: over the last twenty-five years, the water service provider has invested an equivalent of US$51.5 million per year in the Dakar region. Further, the existing sector financial model has allowed costs sharing for investment and operations between the State, SONES and users, while maintaining a socially and politically acceptable tariff. During the same period, water tariff increases below 1 percent per year allowed SONES to maintain financial equilibrium. The recently signed contract of the private operator running until 2035 includes substantial investments and incentives to reduce non-revenue water and water losses and improve bill collection ratio.

11. **Failure to implement the investment program could have a considerable impact on the economy of the DMT triangle** in terms of lost income for agriculture and industry, public health and the well-being of the population confronted each year with recurrent floods. Water insecurity already affects economic growth and recovery at the national level through significant GDP losses linked to damages, lost income and public health. The three drought episodes that occurred over the past 20 years caused a fall in GDP of between 11 and 26 percent compared to the ten-year average and a rise in the number of persons affected by food insecurity of between 300,000 and 800,000. In the Greater Dakar area, flooding cost US$63 million in damages in 2009 and affected 290,000 people in 2012.[7] Specific measures are proposed to preserve the quality and availability of the city's groundwater resources, which are being rapidly depleted and polluted, and protect the Lac de Guiers, where drinking water standards are exceeded due to the presence of pesticides, heavy metals and bacteriological germs, from nearby agricultural activity and untreated wastewater discharge.

12. **Achieving water security in Senegal will thus require key actions around institutions and investments for resilient growth.**

Strengthening WRM Institutions

While strengthening DGPRE's financial and human resources is a prerequisite to efficient management of water resources, Senegal will not be able to meet the current and future water security challenges without in-depth reforms of the legal and organizational frameworks for WRM.

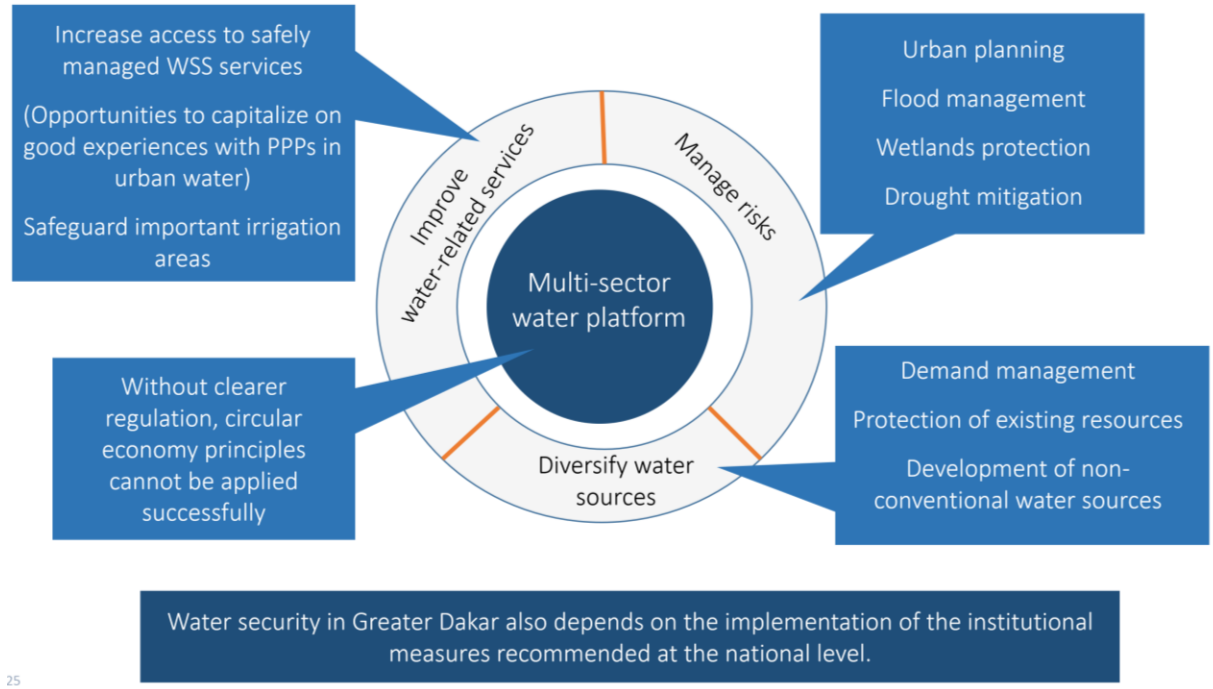
- The draft Water Code should be revised to align with international good practices and refocus the text on WRM.
- **The status of DGPRE could be raised** as it currently has a fairly low hierarchical rank and autonomy level in the public administration, considering international practices in countries with similar water security issues. At the same time, the management of water resources quality and quantity, for groundwater and surface water, should be overseen by a single institution as they are different facets of the same resource.
- **The "upgraded" DGPRE** could benefit from a presence in all regions, have adequate staffing and be permanently financed from abstraction fees, which must be extended to all users and the generated revenues be fully allocated to the management of the resource.
- The reactivation of the *Conseil Supérieur de l'Eau* (CSE) must be considered, by linking it to the presidential council, and its real functions duly defined in the revised Water Code, to give it the political and legal support to ensure water security issues are reflected in the national socio-

[7] Croitoru, Lelia; Miranda, Juan José; Sarraf, Maria. 2019. *The Cost of Coastal Zone Degradation in West Africa : Benin, Côte d'Ivoire, Senegal and Togo*. World Bank, Washington, DC. © World Bank.

economic development plan and promote effective inter-sectoral coordination nationally.

- At the decentralized level (five management and planning units - UGP) and in the sub-UGPs corresponding to the hotspots, the stakeholder committees must be put in place. To facilitate their role as effective and sustainable entities, their functions, composition and financing must be defined in the revised Water Code.

Figure 3: Achieving Water Security in Greater Dakar



Investments in water security for resilient growth

- To ensure long-term water security in the DMT triangle, the application of the circular economy principles helped identify priority actions:
    a. Set up a multisectoral and multi-actor collaboration platform with a view to strengthening water governance in the DMT aiming to restore and maintain the balance between the use of water resources today and their protection for future uses
    b. Diversify water supply sources
        i. Better protect the Lac de Guiers from pollution by increasing its monitoring and management through institutional strengthening and the creation of an associated management and planning committee, strengthen the water transfer from the lake and obtain the required allocations from the OMVS Permanent Water Commission to transit raw water to the Dakar region.
        ii. Implement a voluntary groundwater replenishment program starting in 2024 to allow the safeguarding of key depleted aquifers that supply the DMT triangle.
        iii. Increase volumes of wastewater being treated and promote the reuse of treated wastewater in agriculture and for groundwater recharge
        iv. Promote the capture and use of rainwater in agriculture in the Niayes area
    c. Increase the population's access to safely managed sanitation services while solving the recurring flooding problems in Greater Dakar through a managed aquifer recharge and

wetlands restoration program using treated wastewater and rainwater, complemented with water from dams and retention basins.

d. Preserve the agricultural Niayes area through urgent precautionary measures, including through legal acts to protect the agricultural land base, land use control, the prohibition of precarious settlements in depressions and stream beds and strict management of real estate development in this area.

- Water Security in the remaining six hotspots. This report provides preliminary recommendations to address the water security issues of the remaining hotspots, particularly with regard to strengthening the decentralized presence of the DGPRE in risk areas, the application of legal instruments that could support the reduction of the use or pollution of sensitive resources, and the improvement of the water information system (details are presented in Annex IV). Those recommendations would be fine-tuned through the Water Development and Management Master Plans (SDAGE) and the detailed plans being financed by a World Bank project at sub-UGP level. By addressing the issues identified in the other six hotspots, the WRM analysis and proposals, combined with the SDAGEs, should ensure the achievement of the socio-economic goals stated in the PSE.

Table of Contents

I. Introduction

1. **Senegal is an arid country that has experienced strong economic growth in recent years combined with increasing water scarcity.** Senegal has posted higher than 6 percent growth since 2014, driven mainly by three factors: agriculture boosted by support programs, robust external demand, and major infrastructure investments undertaken as part of the country's plan for its socioeconomic development by 2030 (Emerging Senegal Plan – PSE). The poverty rate is 19.3 percent in the Dakar urban area, 45 percent in the country's other cities, and 83.9 percent in rural areas.[8] Prior to the COVID-19 crisis, the drop in the number of poor people that began in 2016 was expected to accelerate thanks to the dynamism of the agricultural sector. While the crisis has upended projected growth projections, agriculture can be expected to continue to play a critical role in the country's recovery and in the longer-term perspective of poverty reduction in Senegal. In turn, this can be expected to create additional pressure on water resources. Indeed, due to growth in water-intensive sectors such as irrigated agriculture, mining, and tourism along with the lack of demand-side management measures, there has been a gradual decline in the country's water availability since 1960s, a phenomenon exacerbated by accelerated urbanization and climate change. According to the working data of the experts mobilized for the study, water availability per capita is below the 1700 m^3/year/person, threshold below which the country experiences periodic water shocks. This ratio will be validated through an in-depth and concerted study to be carried out by the Directorate of Water Resources Management and Planning (*Direction de Gestion et de Planification des Ressources en Eau*, DGPRE). Nevertheless, the ratio demonstrates a real threat to the availability of resources given the current trend scenario in terms of water demand. In fact, nearly half of the country's 16.3 million inhabitants (2019[9]) are concentrated around Dakar and the other urban areas, and land use planning rarely accounts for water availability. Ensuring sufficient availability and sustainable use of water resources is essential to achieving the country's socioeconomic objectives.

Water security consists in "the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies."
(Grey and Sadoff, 2007).

2. **Water security is the bedrock of Senegal's development and achieving it will require a comprehensive approach.** Based on the definition of water security provided above, realizing water security objectives should be based on sound risk analysis and an evaluation of the trade-offs between water and other sectoral and environmental policies. In other words, water security means learning to live with an acceptable level of water-related risk. From this perspective, every country faces specific conditions for managing water security. These should take cultural and social values into account, ensure that the implemented measures are proportional to the magnitude of the risk, and identify the high-priority areas to target in view of the higher risk levels they represent.

3. **The Dakar-Mbour-Thiès (DMT) triangle is critical to the Senegalese economy and socio-economic development.** The DMT triangle, commonly known as Greater Dakar, is currently home to 32 percent of the country's population and nearly 51 percent of its urban population. This area will continue to play a major long-term economic role with the extension of the Diamniadio special economic zone, the new airport, and tourist activities along the Petite Côte, tourism being the largest contributor to Senegal's foreign exchange earnings. The high growth rate of the DMT population is expected to continue (about 4.5 percent by 2025) due in part to the expanding areas outside the capital city of Dakar. The DMT triangle currently relies on water transfers from the Lac de Guiers and groundwater as its main water sources. The Government has started developing seawater desalination capacity for the region in order to diversify its

[8] ANSD 2018. La Pauvreté Multidimensionnelle au Sénégal. Version provisoire du Rapport National de Présentation de l'Indice de Pauvreté Multidimensionnelle (IPM).
[9] Banque mondiale, 2020

water sources portfolio. However, the emergence of water shortages, particularly in the cities of Dakar and along the Petite Côte, could jeopardize the area's economic outlook. Until now, water services and sources development has been addressed through a project-centered approach, with very short 10-year planning horizons and a focus on emergency measures to play catch-up to urbanization.

4. **The present study responds to a Government request to seek a solution to these challenges.** In the face of the aforementioned constraints, the Government of Senegal through the Ministry of Water and Sanitation (*Ministère de l'Eau et de l'Assainissement,* MEA) sought support from the World Bank to conduct a water security study. The Bank, given the lack of attention given to water resources management at the national level and the pressing issues facing the DMT region in securing water for development, thus conducted a study focused on two dimensions: a first part on assessing water resources management at the national level, and a second on integrated water resources management (IWRM) in the DMT area.

5. **Objectives.** The objective of the study is to assess how water resources contribute to Senegal's socio-economic development, to identify and characterize the main current and future challenges and *hotspots* related to the quantity, quality and use of water resources, to assess the performance and adequacy of the existing institutional framework (i.e., organizations and rules) to meet the challenges, and, finally, to make recommendations to address them. One of the key "hotpots" identified was the Dakar-Mbour-Thies area, and hence the report evaluates water management issues that may threaten water security by 2050, particularly potable water access, and proposes an integrated urban water management plan that will help ensure water security in the area, for all sectors.

6. **Audience**. The MEA is the primary audience for this study. More broadly, the audience for this report also extends to the Ministries of Finance and the Budget and of the Economy, Planning, and Cooperation, other sectoral ministries conducting water resources-related activities like the Ministries of Agriculture, Urbanism, Tourism, Mining and Industry, and various stakeholders in the water sector including local authorities, service providers, major users, and players whose activities pollute the water resources. To strengthen the integrated approach and the creation of a national platform focused on addressing water security challenges, a steering committee bringing together all the sectoral ministries was established during the study.

7. **Approach**. The analysis was undertaken by a multi-disciplinary team of local and international experts, World Bank and Government personnel. The study built on a documentary review, expert judgments, interviews with key informants and several workshops with the aim of validating the data and recommendations in a participatory and iterative manner.

8. **Structure of the Report.** After this brief introduction, Section II addresses nationwide water security-related challenges by presenting the availability of water resources and their current uses, the risks that threaten them, and an analysis of the existing legal and organizational framework for water resources management. The section also identifies the major geographic hotspots where water security is most threatened in Senegal and makes specific recommendations for each one. Section III focuses on water security in one of these hotspots, the DMT zone, and offers a detailed analysis of the challenges, existing policy frameworks, recommendations, and solutions by sub-sector. It begins with DMT-wide water resources management and then covers drinking water, sanitation, stormwater and flood management, and irrigation. It describes the investment program that will improve water security in the DMT zone and presents an economic analysis of the various options proposed. Finally, Section IV summarizes the report's findings and recommendations in their entirety.

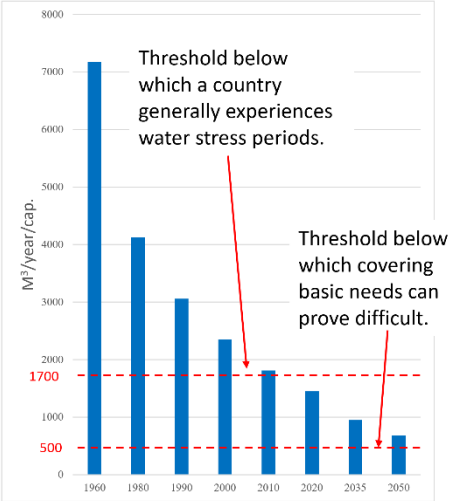
II. National Water Security Needs an Improved Water Resources Management

II.1. Deteriorating Water Resources Threatens Water Security

9. This section presents the water resources situation in Senegal by highlighting the constraints on these resources and the opportunities for the country's socioeconomic development, in particular for the achievement of the political objectives set in the Emerging Senegal Plan (PSE) by 2035. It identifies and characterizes the priority areas (or "hotspots") for water resources management, which consist of geographic areas that are critical for the country's socioeconomic development and which at the same time experience water resources-related challenges that significantly compromise their development potential.

II.1.1. Water Stress is increasing

Figure II.1: Water Availability per Person in Senegal



10. **Senegal is experiencing a growing and worrisome water stress situation.** This study estimates the current renewable fresh water resources in Senegal at between 22.5 and 25 billion m³, or below the 1,700 m³/year/person[10] threshold at which a country experiences periodic water stresses.[11] By 2050, or within a generation, the availability of renewable freshwater will decline by 50 percent,[12] coming dangerously close to the threshold of 500 m³/year/person, below which basic needs coverage may prove difficult (Figure 1). These figures are overestimated. Indeed, they include all incoming transboundary waters to Senegal, without subtracting a share for Mauritania and Gambia. The transboundary agreements in the Senegal and Gambia basins do not provide for water sharing between countries. For illustrative purposes only, if the international waters were to be equally shared between Senegal and Mauritania for the Senegal River and between Senegal and Gambia for the Gambia River, today's renewable water resources would be between 12.5 and 14 billion m^3/year, which is equivalent to 780 and 880 m^3/year/person, respectively. However, a complementary analysis will be made by the DGPRE to allow updating and validating a final ratio. In this regard, support has already been mobilized as part of an ongoing operation financed by the World Bank for the benefit of the Government of Senegal, the Rural Water and Sanitation Project, PEAMIR.

11. **Almost 88 percent of the renewable water resources in Senegal are transboundary,** making them vulnerable to withdrawals and pollution from upstream countries and limiting how they can be used given the risk of compromising their use by downstream countries. As we shall see, this characteristic further complicates water resources management.

12. **Current withdrawals represent about 15 percent of available resources and are**

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[10] Assuming a population of 16.3 million people in 2019 (datacatalog.worldbank.org), the annual renewable water availability per capita ranges from 1,380 to 1,539 m^3.

[11] See Damkjaer and Taylor (2017) for recent review of some alternative indicators and the debates surrounding the WSI and the origins of the stress/scarcity thresholds. In particular, these thresholds were defined based on the water demand and supply in a very specific and non-generalizable context: water demand and supply in Israel during the 1980s as empirically examined in Falkenmark (1986). The index and thresholds are not necessarily valid for comparison across space and time, especially as technology changes and the ways water is used for economic activity evolves.

12 Assuming no change in water availability (and therefore, not considering the impacts of climate change and demand growth in upstream countries in the Senegal River basin) and a population of 33 million inhabitants in 2050 (worldpopulationreview.com), the annual availability of renewable water resources in Senegal would be between 680 and 760 m^3/person.

predominantly for agriculture. Furthermore, using the same assumption regarding transboundary water as the one described in paragraph 10, for illustrative purposes only, current withdrawals would represent an even larger portion of annually available water resources and would reach 23 percent of the total. Today, withdrawals are estimated at 2.9 billion m³/year on average, of which 2.5 billion m³/year from surface water and 417 million m³/year from groundwater. Irrigation is by far the main consumer (83 percent), with rice, a water-intensive crop, alone accounting for 80 percent of agricultural withdrawals. Drinking water supply (14 percent) comes in second, followed by mining and industrial activities (3 percent).

Significant space-time variability in the availability and quality of the resource as well as water withdrawals

13. **The above-mentioned average water resources situation in Senegal conceals significant space-time variability, which means that water availability does not necessarily coincide with demand, which sometimes makes it costly and complex to meet growing water needs.**

Surface Water

14. **Surface water accounts for nearly 90 percent of the country's renewable water resources, of which 97 percent originates from beyond the country's borders**. These resources have been estimated on the basis of a synthesis of current knowledge at between 20.9 and 23.5 billion m³/year. Annex 2 presents the major watersheds, their water balance, the risks to which they are subject, and recommendations for improving their management. Maps 1 and 2 summarize this information.

15. **Most of the surface water is located along the country's borders**, with the Senegal River in the North, its major tributary the Falémé River in the East, and the Gambia and Kayanga rivers in the South. The Senegal River alone provides 82 percent of the country's surface water (without considering water sharing with the other riparian countries). The country's central areas have very little to no surface water. There, flows are highly erratic and localized depending on how significant the rainfall is. However, the country's central area, which lacks significant surface water, has significant runoff water collection potential.

16. **There is a significant potential for better harnessing runoff particularly for rainfed agriculture**. The Ferlo Valley, which covers a 70,000 km² area, or more than one-third of the national territory, is progressively subject to desertification. Yet it has unexploited runoff water potential, which, if it were exploited, would make it possible to regulate and maintain rain-fed agriculture.

17. **The exploitation of surface water is limited on the one hand by significant inter- and intra-annual flow variability and on the other by the salinity of the water in the maritime reaches**. The Senegal River illustrates well this variability, where annual natural flows at Bakel fluctuated between 42.83 billion m³/year in 1950 and 7.27 billion m³/year in 1984, a factor of 6. Variation in seasonal flows is also significant given that the rains are solely concentrated during 3 to 4 months of the year. Dam construction on the Senegal and Kayanga rivers has made it possible to partly regulate flows so as to better secure water resources and meet water needs for various uses over the year. Other structural works are planned on the Gambia and Senegal rivers and their tributaries.

18. **Surface waters are often saline in the western part of the country** in areas up to 200 km from the coast due to seawater intrusion caused by the tides, helped by very flat topography and low flows, particularly during the dry period. Agricultural production in the Casamance River basin has been seriously affected by the loss of more than 50,000 hectares of irrigated and non-irrigated cropland due to salination. The construction of the Diama anti-salt dam has helped regulate the salinity of the Senegal River upstream of the dam, but other waterways do not have the benefit of such infrastructure, which is expensive. Finally, the effects of climate change could exacerbate the salination of the coastal areas due to rising sea levels on the one hand and accelerating decline in runoffs on the other, especially during dry periods.

19. **Pollution is also increasingly affecting surface water's exploitation**. Its contamination is due to drainage water discharge containing fertilizer and phytosanitary products' residues, unregulated gold mining upstream of the watersheds in the bedrock area, and to insufficient collection and treatment of the

waste produced by riparian communities. This contamination is having an impact on water quality in Lac de Guiers and the Saint Louis reservoir. Lac de Guiers is a strategic resource that supplies drinking water to nearly 4 million inhabitants, most of whom are concentrated in Dakar and its suburbs, and this is a major concern. Drinking water standards are compromised by the presence of pesticides, heavy metals, and bacteriological germs. The Senegalese Sugar Corporation (CSS), which manages nearly 10,000 hectares of sugar cane fields along the lake, is one of the major sources of pollution.

20. **The expansion of irrigation is constrained by the availability of water resources.** The paucity and variability of the flow as well as the salinity of the water in its coastal areas hamper the possibility of a significant increase in irrigation withdrawal from the Gambia and Kayanga/Anambe rivers. In the Senegal River basin, the minimum guaranteed dry season flow would allow the irrigation of 40,000 ha. This limit has already been exceeded during the dry seasons (50,000 hectares cultivated on average over the last ten years out of 138,000 hectares equipped for irrigation), and it continues to increase. This limit may only be raised by the construction of new structures on the uncontrolled tributaries, in particular the Falémé River, or through substantial reduction in water consumption per hectare. However, the potential of irrigable lands in the rainy season, during which there are no constraints on the availability of water, is far from being fully exploited due to insufficient control of the crop calendar: only 52 percent of the irrigated surface is actually exploited.

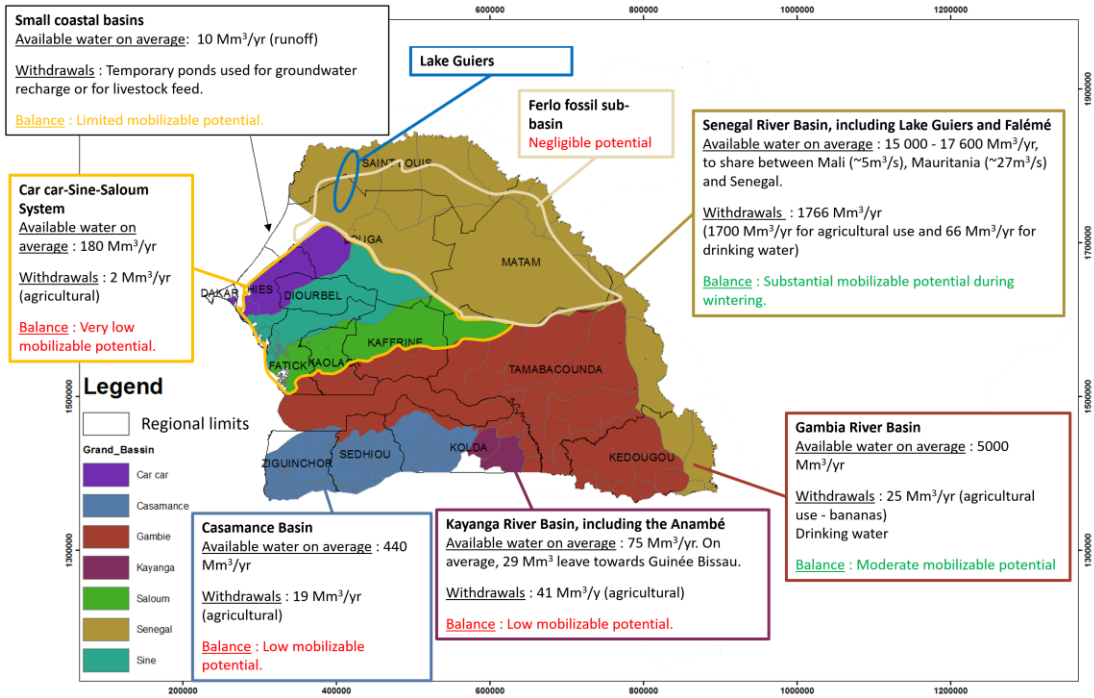
21. **Large hydraulic installations on the Senegal River resulted in the proliferation of invasive aquatic plants** in the Delta, Lac de Guiers, and the *trois Marigots* in the Ndiael Basin, with a consequent reduction in the hydraulic capacity of the canals supplying the irrigated perimeters, difficulty of livestock access to the riverbanks for drinking, a drastic reduction in the quantity and variety of fish, and an increase in the prevalence of diseases caused by water-borne parasites such as malaria and bilharziasis.

22. **Riverbank erosion and the sand build-up in the waterways affects the functioning of the hydraulic infrastructures and flood management.** These phenomena are the result of droughts in combination with human actions, in particular poor agricultural practices, excessive tree felling, charcoal production, bush fires, and mineral extraction.

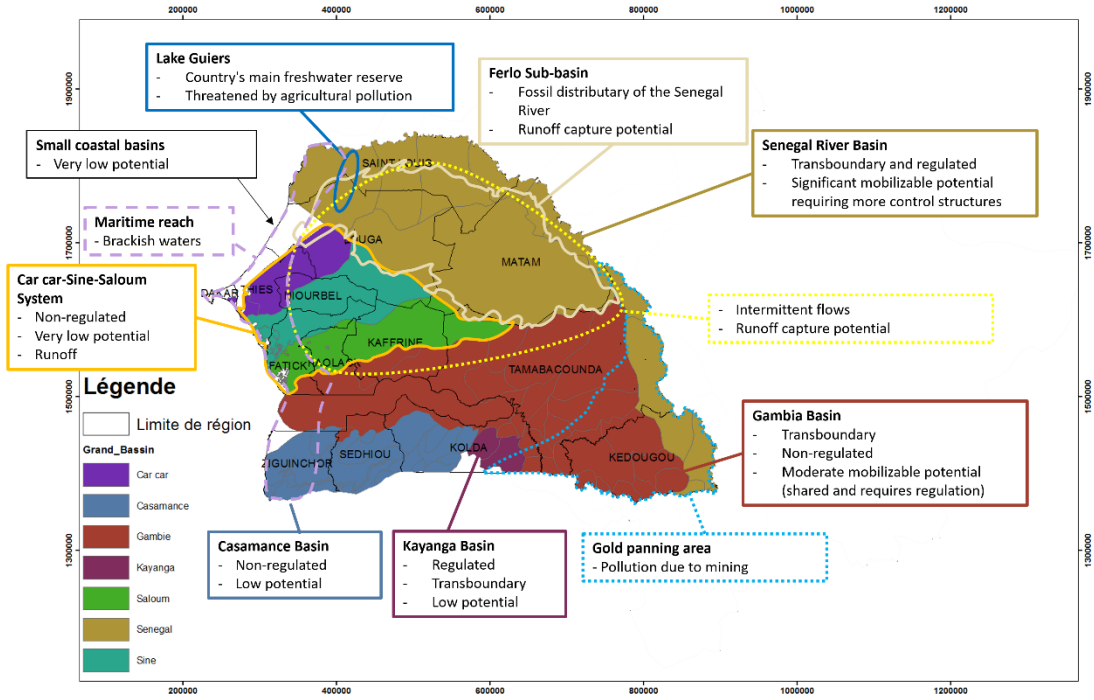
23. **Insufficient consideration in urban planning of the difficulties linked to rainwater management is at the origin of violent flooding.** The risk of flooding is a regular news issue. Among other things, it includes questions relevant to civil security (destruction of persons and goods), ecology (impacts on the ecosystem of the mouth of the Saint-Louis breach), urban organization (obstruction of run-off routes), and industrial development (disruption of flood forecasting systems caused by dredging the Falémé River). In 2009, flooding cost over US$100 million (or CFAF 58.4 billion) in damage, US$67 million (or CFAF 39 billion) of which occurred in Dakar, affecting (among others) homes and transportation.[13] Likewise, the urbanization of coastal streams causes recurring flooding in the towns of Guédiawaye and Pikine (north-east of Dakar). In September 2019, nearly 1,000 homes (or approximately 9,000 people) were displaced by flooding caused by heavy rains, causing six deaths and a general destruction of means of livelihood due to the destruction of farms in the area. Section II.1.3 estimates the cost of flooding in Senegal.

[13] USAID. 2017. Climate Change Risk Profile – Senegal.

Map II.1: Overview of hydraulic potential of surface water



Map II.2: Overview of challenges related to surface water



Groundwater

24. **Renewable groundwater resources represent only 10 percent of total annual renewable resources in Senegal, but they play a strategic role in the country's water security.** Based on a summary of current knowledge, its renewable potential would be between 1.61 and 1.65 billion m^3/year without considering bedrock aquifers. Its strategic role is due to the fact that it provides for approximately 85 percent of drinking water and virtually all industrial, mining, and tourism need. In addition, a small but growing part of the irrigated areas depends on groundwater, especially for horticulture – and one of the objectives of the PSE is indeed to further develop these areas and crops. Maps II.3 and II.4 summarize this information. Though present throughout the national territory, the exploitation of this resource is often limited by its quality, or depth.

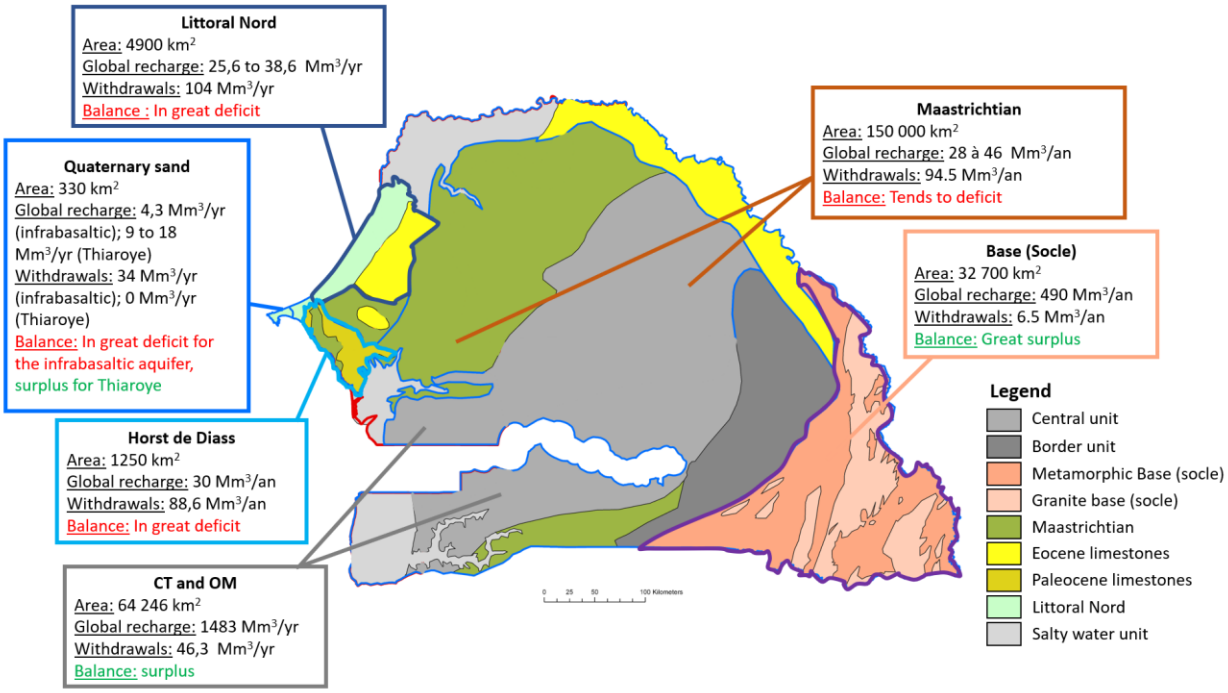
25. **The resource is increasingly overexploited and polluted in the coastal zone from Thiès to Saint Louis, threatening the security of uses that depend on it.** These uses are essentially those of Dakar and its suburbs as well as those of the country's main horticulture area and source of most of the agricultural related exports in the areas of Thiès and Niayes.

- Dakar and its suburbs: The aquifers supplying Dakar and its suburbs (Infra-Basaltic, Horst de Diass, and the North Littoral aquifers) currently supply nearly 50 percent of needs. Today, withdrawals are already 3 to 4 times higher than their recharge rate, causing saline intrusion in several areas. With these levels of overexploitation, they risk being definitively compromised not only for domestic use but also for irrigation. These aquifers are also increasingly polluted by sewage and septic tanks. The Thiaroye aquifer has already been abandoned by the National Senegalese Water Agency (SONES) due to massive pollution by untreated wastewater. As a side effect, this caused periodic groundwater overflows and nearly permanent flooding in parts of the Dakar suburbs. If sustainable management of these aquifers is not promptly implemented, low-cost water sources will disappear and Dakar will have to depend on water transfers and desalination in order to meet the needs of its inhabitants and its economy, which would greatly increase the cost of water. Section III evaluates these risks in detail and proposes solutions.
- Strong value-added agriculture in Niayes and Horst de Diass: For the same reasons, the future of agriculture irrigated by the Littoral Nord and Horst de Diass aquifers, representing more than 60 percent of the country's horticulture production and 80 percent of agricultural exports, and supplying the urban markets of Greater Dakar, is under threat. Tensions are already growing due to conflicts of use between agriculture, potable water supply, and an expanding mining activity.

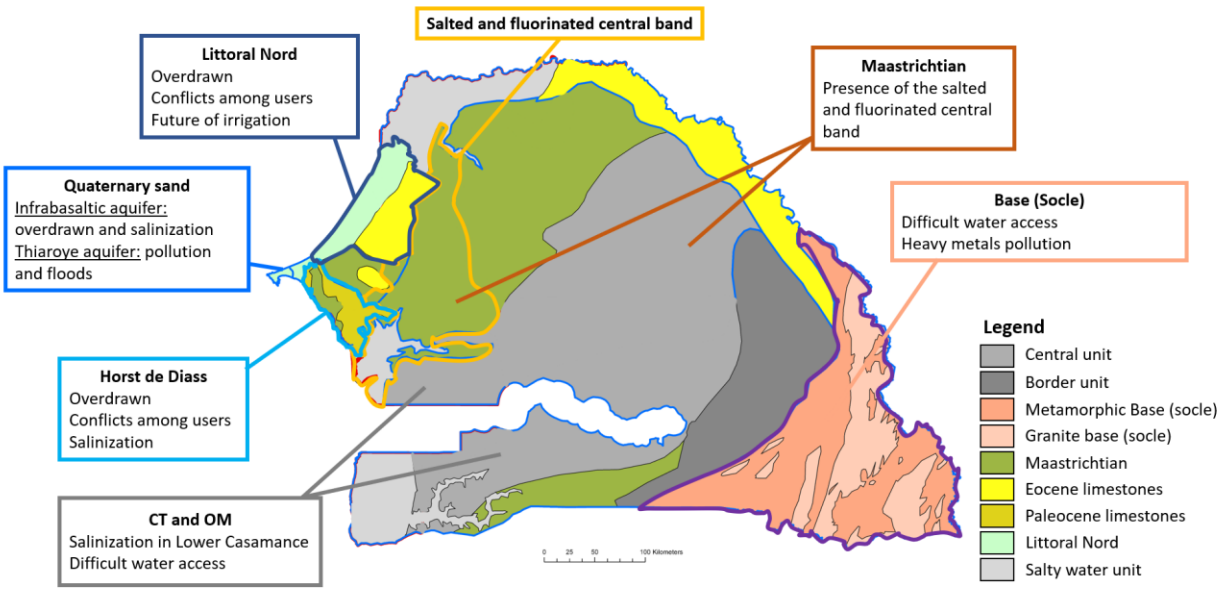
26. **Beyond the coastal area, in the Bassin Arachidier, geogenic contamination of water quality threatens the health of nearly 1 million people, particularly for children under 10, whose physical and intellectual development is sensitive to fluoride concentrations in drinking water.** The salty and fluorinated central strip stretches over 50,000 km^2 (see Map II.4). Despite the high levels of fluoride and chloride in groundwater rendering these unfit for drinking, they are used by most rural and urban communities, as it is the only water source (see paragraph 43). This results in a major risk for health safety.

27. Finally, **access to potable water is also difficult in the western part of Lower Casamance**, on the one hand due to saline invasion of both groundwater and surface water and the high level of iron and fluoride in certain areas. This is also the case in Eastern Senegal in the bedrock area covering one-third of the country but with very little population, its drastic reduction during particularly dry years, and the risk of heavy metal pollution from rapidly growing mining activities.

Map II.3: Overview of hydraulic potential of groundwater



Map II.4: Overview of challenges relative to groundwater



28. **Given these difficulties, the use of control structures, transfers, and non-conventional**

sources will likely need to increase. In particular, the desalination of brackish water and seawater and the reuse of wastewater are being considered. The development of new transfers, also being considered, requires significant investments. Water resources are also vulnerable in terms of security as recent accidents have shown how destruction or voluntary pollution of strategic structures (transfer channels) or reserves (Lac de Guiers) can impact the Dakar metropolitan area and its more than 4 million inhabitants.

29. **Improvements in use efficiency and pollution control, which have been neglected until now, are also to be seriously considered.** This would imply a change of paradigm, including placing greater importance on waste and loss reduction as well as sustainable surface water and groundwater resources management from both quantitative and qualitative points of view.

Current trends will continue and increase risks related to water security

30. **The observed trends will continue in the future and will accentuate the problems and risks related to water security** in terms of meeting needs, sanitary and environmental risks related to water quality, risks of extreme events such as droughts and flooding, and risks of conflict among users of overexploited aquifer and in transboundary river basins during dry years.

31. **Demographic growth and urbanization present major challenges.** The strong demographic growth rate of 2.5 percent per year and urbanization as well as migration for security and climate-related reasons[14] will lead to both a rapid increase in water needs and growing pressure on water resources, especially in coastal areas. *Without proper planning that explicitly considers water resources, the extension of urban areas toward the new industrial poles may accentuate the issues of flooding, pollution, and the reduction of local aquifers' recharge.* As we discussed in paragraph 23, today, failure to take water resources into account in land use planning and urban development is disrupting natural processes, sometimes with serious consequences. The extension of urban areas into natural riverbeds leads to violent flooding and at the same time reduces local aquifer recharge, as a result of ground impermeability (see paragraph 51).

32. **Climatic change will most likely accentuate the variability of surface water and the salination of coastal areas and reduce aquifer recharge.** Paradoxically, the climatic risks associated with droughts are rarely mentioned in national policies even though Senegal is a Sahelian country and forecasts indicate that it will be one of the countries whose water resources will be particularly vulnerable as early as 2025. In the Senegal River basin, a number of simulations indicate that climate change will bring a reduction of average flows by the year 2035 as well as displacement of the flood peak, which may once for all compromise artificial flooding and all the exosystemic services it provides (aquifer recharge, flood recession cultures, pasture lands, biodiversity). In addition, sea level rises will result in an accentuation of surface and groundwater salination in coastal areas,[15] flood risks in the deltas, and coastal erosion.[16] Given current knowledge, studies on the impact of climatic change on groundwater remain limited, though it is estimated that rising temperatures (and lower rainfall) mays reduce upper water table recharge.[17]

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[14] World Bank 2018. Systematic Country Diagnostic: Senegal. Dakar.

[15] OMVS. Climate Change Synthesis Report. p. 21.

[16] Brown, S., Kebede, A.S., and Nicholls, R.J. (2011). *Sea-Level Rise and Impacts in Africa, 2000 to 2100*. University of Southampton.

[17] Representative Concentration Pathway (RCP) includes are four trajectory scenarios of radiative forcing to the 2300 horizon. These scenarios were developed by the Intergovernmental Panel on Climate Change (IPCC) for its fifth report, AR5 (IPCC Fifth Assessment Report). An RCP scenario is used to model the future climate. In the AR5, based on four different assumptions about the amount of greenhouse gases that will be emitted in the coming years (period 2000-2100), each PCR scenario gives a variant of the climate that is considered likely to result from the emission level chosen as a working hypothesis. The four scenarios are named according to the range of radiative forcing thus obtained for the year 2100: the RCP2.6 scenario corresponds to a radiative forcing of +2.6 W/m^2, the RCP4.5 scenario to +4.5 W/m^2, and the same for the RCP6 and RCP8.53 scenarios. The higher this value, the more energy the earth-atmosphere system gains and warms up.

33. **Meeting the objectives of the Emerging Senegal Plan (PSE) implies a significant increase in water demand, which in its turn implies growing challenges to ensure water security.** The vision of the PSE is to mobilize "abundant and good quality water for all, everywhere, and for all uses in a healthy sustainable living environment, for an emerging Senegal." The PSE targets:

- Rice self-sufficiency, the development of horticulture for export, and a reduction in the trade balance deficit for irrigated cultures (millet, rice, corn), which should result in a significant expansion of irrigated surface areas (from 171,000 to 253,000 ha).
- Universal access to drinking water, in particular the realization of transfers and desalination in order to supply Dakar and its suburbs as well as areas subject to a public health risk (such as the Bassin Arachidier).
- Industrial development. This concerns mostly mining development, including iron, phosphates, phosphoric acid, gold, and zircon and the realization of three integrated industrial platforms. The Plan's ambitious objectives for industrial development imply risks of increased pollution in mining areas as well as an increase in water needs for the three integrated industrial platforms, the first of which is being constructed in Diamniadio in an area already under considerable water access' strain.
- Improvement in access to sanitation in urban and rural areas. These will affect 86 and 65 percent, respectively, of such areas by 2023 following implementation of the sub-sector reform, construction and reinforcement of waste treatment systems, depollution of wastewater in large cities, extension of rainwater drainage networks in urban centers, construction and rehabilitation of sewage networks in urban and peri-urban areas, and realization of collective excreta evacuation structures in rural areas.

34. **The Plan's implementation will be accompanied by a substantial rise in water demand, which could increase current withdrawals by 60 percent, or an additional 4 billion m^3 per year by 2035.**[18] Taking previous assessment into account, it is fundamental to strengthen the management of water resources in order to ensure the right balance between meeting human economic and ecological needs throughout the territory.

35. **The model for food self-sufficiency must be reevaluated.** Achieving self-sufficiency in rice implies significantly increasing irrigated surface areas. Yet such an investment will be in vain if it is not accompanied by change in agricultural practices related to the wet season since only 50 percent of irrigated land is cultivated during that period, and this is the only season when water is available in sufficient quantities to cultivate the totality of the irrigated surfaces. During the dry season, water availability in dry years is already insufficient for irrigating the average over 50,000 ha cultivated in the Senegal River basin (or 36 percent of irrigated land) given the low water efficiency of irrigation and current regulation of the Senegal River. In short, it would be helpful to analyze in depth the model designed to achieve the objective of food self-sufficiency, oriented towards irrigated agriculture and rice production, while the water resources that can be allocated to them will eventually be insufficient to develop the full potential of irrigable land. However, the current model seems to largely neglect the improvement of rainfed crop productivity, including by better rainwater harvesting, when this could constitute a strategic axis for diversification of risks and reinforcement of rural populations' resilience in areas with low irrigation potential. The risk of water-related conflicts, though it is managed at the international level by the OMVG and the OMVS, must not be neglected at the local level: an investment oriented mainly towards increasing irrigated agriculture, a large water consumer, risks creating tensions with thousands of rural families whose survival depends exclusively on rain-fed agriculture hard-hit by drought.

36. **Despite the economic and employment weight of horticulture, associated development**

[18] Annex 3 presents the methodology used in this estimation

objectives may not be achieved. Even if at the national level it seems that these additional needs could be met by the available water resources, this development will be difficult to achieve. In fact, more than 60 percent of horticulture production depends today on the aquifers of the Littoral Nord and of the Horst de Diass, already overexploited and affected by salinity intrusion. Moreover, the urbanization of agricultural land reduces both the aquifer recharge and the land available for agriculture. It is thus difficult to imagine that horticulture production will be able to increase in these areas as maintaining the current levels by increasing the productivity of land and water is already a major challenge.

37. **Universal access to drinking water will require the development of new sources.** Due to strong demographic growth (24.2 million in 2035) and migration to urban areas, it is estimated that by 2035, drinking water needs will reach 442 million m³/year. Urban areas will show a marked increase from 166 Mm³ in 2020 to 318 Mm³ in 2035 (+91 percent), particularly in the Dakar area. As regards rural hydraulic systems, in 2035, the areas currently supplied by the Maastrichtian and Continental Terminal/Oligo Miocene (CT/OM) aquifers will see the greatest increase in water needs (around 30 Mm³/year more than today). Although these volumes are small compared to these two systems' available potential, which could easily support additional needs, the remaining sustainably exploitable resource with satisfactory drinking water quality is located far away – mainly to the east of the salty central strip in the Maastrichtian (58 and 75 mm³/year) and the CT/OM system north of the Saloum River and east of the Lower Casamance coastal area. However, it may be possible to transfer these volumes. Increasing knowledge of the groundwater resource is also expected to allow to identify alternative locations for sustainable groundwater abstraction.

38. The high-risk areas for potable water security in 2035 are the following:

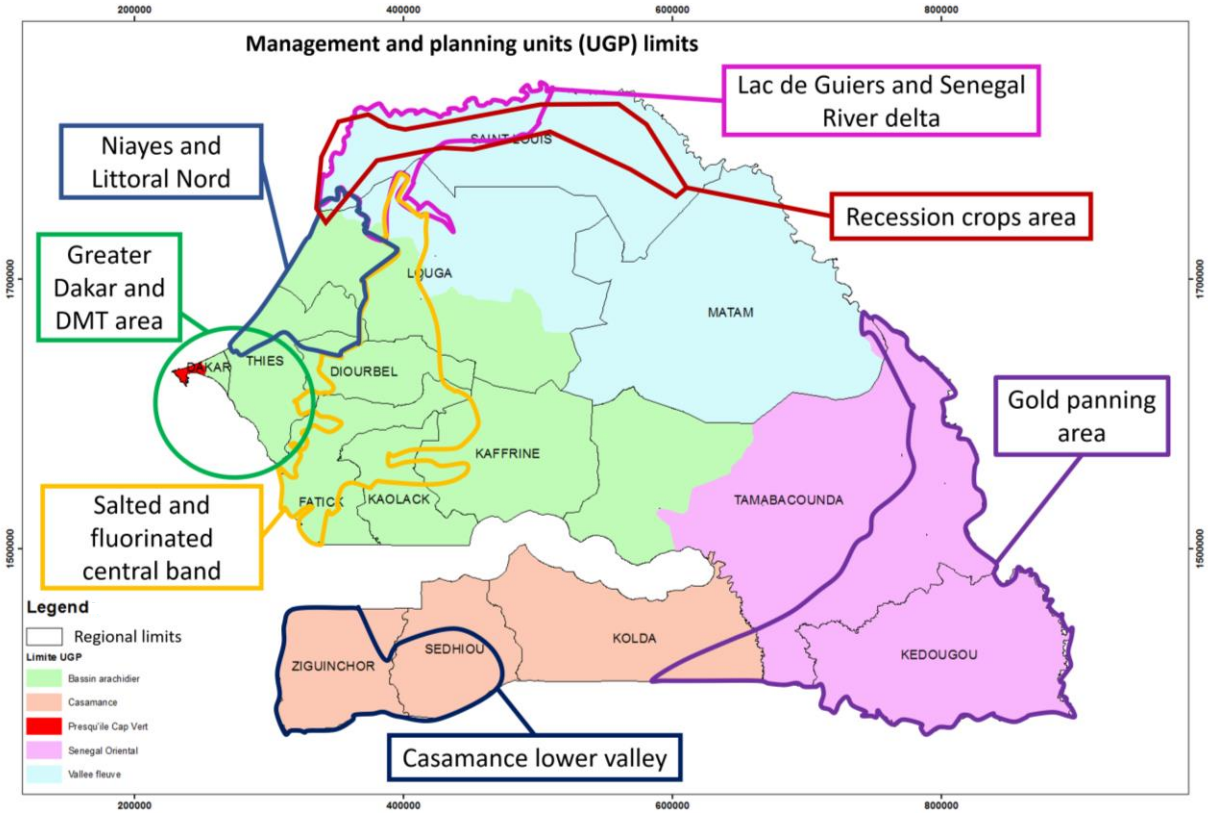
- Urban centers in the Greater Dakar region, where demand growth will be strongest and where there have already been insufficient locally-available resources for many years, will have to continue exploring various options while ensuring that priority is given to the following: (i) reducing the withdrawals on local aquifers to a level compatible with their sustainable management so as not to permanently lose this low-cost resource; (ii) improving water use efficiency as much as possible; (iii) using an optimized combination of treated wastewater recycling for uses with no-health-risks; and (iv) salinization and additional transfers from Lac de Guiers (Senegal River). We should also note the need to maintain a diverse range of resources so as to reduce transfer-related security risks.
- People who are supplied with water from Lac de Guiers and the Senegal River, which are highly vulnerable to agricultural runoff and domestic wastewater pollution, will require that this strategic resource be protected.
- Areas already experiencing drinking water supply problems in the Bassin Arachidier, particularly north of the Saloum River (fluoride and chloride) and in the Lower Casamance region (salinity), where it will be difficult to meet future needs. Two solutions are possible in these areas: extensive water treatment, or transfers from nearby areas in order to replace or dilute the locally available water and thus to meet quality standards. Choosing between these options will depend on the context. Unfortunately, both options are expensive in investment as well as in operation and maintenance. In addition, the transfer option poses a higher security risk in the event of intentional or accidental pipeline breaks. Attention should also be paid to reducing possible losses and wastage.
- The Littoral Nord and the Horst de Diass area, which present ever-gloomier prospects for drinking water depletion in rural areas unless aquifer exploitation is stabilized by reducing non-priority uses and all wastage, possibly combined with transfers from the Senegal River and wastewater recycling.

II.1.2. Hotspots

39. **Eight hotspots or high-priority areas for water resources management have been identified based on their socioeconomic importance and the water security-related risks they face.** These are Lac de Guiers and the Senegal River Delta, the Niayes and the Littoral Nord, the Horst de Diass, the central

salty and fluorinated band, the flood recession area, the Lower Casamance Valley, the gold mining area, and Greater Dakar, which are identified on the map below (Map II.5).

Map II.5: Map of the identified hotspots overlain with the existing planning units of the DGPRE



Note: The Horst de Diass is included in the Greater Dakar area

40. **Concentrating a large part of the Senegalese population and economic activity, the Greater Dakar area is a critical hotspot for water security.** It is home to the capital of Senegal and includes fast-developing urban communities in its vicinity, including Thiès and Mbour. It represents 32 percent of the national population and 55 percent of the country's economic activity. Water demand in the area is growing fast and has long exceeded local availability. The development of new sources to meet these needs, mostly through transfers from Lac de Guiers up to now and the over-pumping of local aquifers, has resulted in the ever-rising cost of water and investments losses as some boreholes needed to be abandoned. The heavy urbanization of this area is a source of over-pumping of the local groundwater and of its contamination from untreated wastewater, while over-pumping leads to saltwater intrusion. This area also suffers from heavy flooding, partly due to the lack of urban planning and the flooding of intermittent stream beds. The overflow of Thiaroye groundwater, which has been abandoned because of contamination, also risks contributing to these ongoing floods. The area's heavy reliance on transfers from Lac de Guiers (close to 40 percent) poses a security risk as this infrastructure carries water over long distances and is vulnerable to (intentional or accidental) pipeline breaks. Lastly, it should be noted that there is a lack of withdrawals monitoring and control in this area, except for the urban sector, which affects the water resources decision-making and planning. Section III presents these challenges in greater detail.

41. **The Horst de Diass provides one third of Greater Dakar's water supply and centralizes key activities for the nation's economic development.** Located on the eastern edge of the Cap Vert Peninsula, it is also part of Greater Dakar and as such, also examined in detail in Section III. This area extends from the Municipality of Sébikotane to the northern Fatick region. This is an important area for economic

development due to the presence of the airport, the creation of special economic zones (Diamniadio) and associated infrastructure, and the presence of the mining and cement industries. This rapid large-scale development is problematic because land use planning does not take local water resource availability into account. Based on the analysis of available data on water resources (groundwater and surface water) for Senegal, the Greater Dakar area clearly faces a situation of aggravated water stress, with renewable water availability between 20 and 40 m^3/year/inhabitant. Furthermore, the withdrawals assessed in the area are around 268,000 m^3/day, while the natural recharge capacities are estimated at only 83,000 m^3/day. The western part presents a significant Maastrichtian outcropping and recharge zone that is vulnerable to urbanization, especially pollution from domestic and industrial wastewater and soil sealing that limits recharge. Agribusiness development also carries groundwater contamination risks. The Maastrichtian is both overexploited and threatened by saltwater intrusion, two trends intensified by any increase in withdrawals. This in turn leads to excessively low waters levels in the seasonal coastal rivers, which are no longer sustained by the overexploited aquifers and to the loss of the vegetative cover due to gullying, soil erosion, and heavy sedimentation in the Sébikotane sector due to coastal flooding. The multitude of coexisting players operating in this area also present a high risk for conflict over land tenure as well as uses of water resources. Just as in Greater Dakar, withdrawals are poorly monitored other than for drinking water supply (DWS).

42. **The Niayes and Littoral Nord area is central to national horticulture production and the mining industry.** It runs along the ocean-facing coast north of the Cap Vert Peninsula from Kayar to Saint-Louis. The Niayes area benefits from a microclimate that is favorable to horticulture, and therefore 60 percent of national production is grown there, as it is the vast majority of exports. Industrial poultry farming and small ruminant breeding are also practiced in the area and growing. The mining sector is also booming in the area, particularly for phosphates and zircon as well as for sand extraction for construction materials. Extractive industries in particular are having a serious impact on groundwater quality and quantity along the Littoral Nord, when the aquifers in this area represent nearly 20 percent to the drinking water supply for Dakar and its surroundings. Overall, system-wide withdrawals from the Littoral Nord region (estimated at 92 Mm^3) far exceed (2.5 times) the renewal potential, leading to the drying up of many traditional wells and gradual saltwater intrusion, especially in the northern part, with a risk of complete salination of the resources. Due to intense economic activities and urbanization, the aquifer is also highly vulnerable to agricultural, industrial, and domestic pollution. This overexploitation and pollution are particularly threatening the future of horticulture, which generally uses shallow wells. Conflicts are already arising between users over the availability of water resources. The area also faces inadequate planning and occupation practices. Climate change, including rising sea levels and decreasing rainfall, is likely to exacerbate these trends.

43. **The salted and fluorinated central band suffers from poor water quality and relies on rainfed agriculture to produce key export crops, namely groundnuts.** crosses Western Senegal from the coast bordering Gambia to the Lac de Guiers delta. It includes major cities such as Touba, Diourbel, Kaolack, and Fatick and is characterized by excessively salty and fluorinated groundwater that impacts the drinking water source for around one million people, causing epidemiological problems. This is an area where rain-fed agriculture is very important because water quality and scarce surface water resources is a barrier to developing irrigation and livestock breeding. However, rain-fed agriculture is particularly affected by climate change and unreliable rainfall. The area lacks sustainable surface water and also includes the Bassin Arachidier, an important area for export-oriented groundnut production, and faces serious drinking water access problems. There is also a lack of monitoring and control over water withdrawals.

44. **The Lac de Guiers and Senegal River deltas are strategic water resources for water supply, agriculture and the environment, and already face significant risks.** They are located in the north-western part of the country, covering the western portion of the Saint-Louis region and a northern portion of the Louga region. Lac de Guiers is the largest strategic body of fresh water in Senegal and provides 40 percent of Dakar's drinking water. It also supplies the other large cities along the Keur Momar Sarr-Dakar axis as well as many villages. The city of Saint-Louis is supplied with fresh water by the Bango reserve, a

body of water fed by tributaries from the Senegal River delta. The area is home to major agro-industrial facilities, numerous irrigated village plots, a protected area, and several RAMSAR sites, where non-compliance with protective measures is widespread. Today, certain uses are threatened by the lake's water quality due to the increase in agricultural pollution from the runoff of fertilizer and phytosanitary products as well as domestic pollution from drainage discharges that give rise to eutrophication over 30 percent of the area. Gradual clogging of hydraulic axes due to sedimentation and invasive plants and of water bodies creates shortages due to lack of access to the water. Water-borne diseases such as malaria and bilharzia persist. The multiplicity of uses leads to competition and in some cases to conflicts between users, especially since withdrawals, except in the urban sector, are neither adequately monitored nor controlled.

45. **The Lower Casamance Valley will be a focus of future socio-economic development but currently faces serious water quality issues.** It covers the western part of the Casamance River Valley and shows considerable as-yet unrealized potential. The area is home to major cities there with strong tourism potential such as Ziguinchor, Bignona, Oussouye, and Cap Skirring despite having one of the country's lowest rates of access to drinking water. The area faces a serious problem with access to water for drinking and irrigation because all the aquifers (Maastrichtian, Oligo-Miocene, and Continental Terminal) are salty and in some areas fluoride levels exceed drinking water standards. It also has strong barely exploited potential in terms of fishing, agriculture, biodiversity, fruit and forest production, and zircon mining. However, excessive salt is causing loss of arable and forest land, thus impacting fish fauna and leading to the population losing income and becoming impoverished, destruction of mangroves, and increased surface area of the salt flats. Human as well as natural vegetation coverage loss and deforestation-related erosion are causing gullies and silted rivers in agricultural lowlands. Lastly, this is a politically sensitive area where the Government will be called upon to promote socioeconomic development for the benefit of the local population and where withdrawals are not closely monitored.

46. **The gold panning area hosts several important activities that threaten the water resources they rely on.** It is located in southeastern Senegal in the bedrock between Bakel and Pakour. This location sees significant industrial and artisanal gold, iron, and marble mining activity. There are also agricultural and livestock activities along with the expansion of irrigated farming marked by the presence of the Senegal River Delta Land Use and Operation Corporation (*Société d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal*, SAED), Agricultural and Industrial Development Corporation (*Société de Développement Agricole et Industriel*, SODAGRI), and Senegalese Textile Fiber Development Corporation (*Société de Développement des Fibres Textiles du Sénégal*, SODEFITEX) corporations. It is also home to forestry and tourist activities such as the Niokolo Koba National Park. Surface and groundwater are polluted by mining activity and pose risks to the human, domestic livestock, and wildlife populations. There is a significant risk of strong erosion due to loss of vegetative coverage. Groundwater extraction is limited to relatively low yielding boreholes tapping the fractured bedrock, and the aquifer, mostly of local extension and limited in depth, presents significant seasonal variability. In general, this area lacks information and control over water resources.

47. **The flood recession agricultural area is a multi-purpose area bordering the banks of the Senegal River from Saint-Louis to Bakel, where fishing, agriculture, and livestock activities take place.** This area provides ideal conditions for the reproduction and development of fish and is home to significant forest formations. Flood recession farming activities are increasing the agro-ecological potential of the Senegal River floodplain despite the significant floodplain loss that took place during the construction of the Manantali dam (due to the control of river flows). Poor water quality, which is declining due to water uses, is affecting yields on flood recession lands because the soil is less silty, and the obstruction of the marsh creeks from silting affects their flooding and land emergence conditions. This represents a basic means of subsistence for a significant segment of the country's population, although information on the socioeconomic significance of today's flooding is lacking. This is also an aquifer recharge area during the flooding period. Hydroelectric production is prioritized in dry years pursuant to the OMVS Charter, which could lead to the artificial flood's decline or even disappearance due to a significant decrease in flow rates. Lastly, a reduction in rainfall is projected, which could further impact these activities.

48. Preliminary recommendations for the improvement of water security in the hotspots are presented in Annex 4. Each of the hotspots will need to be the subject of a more in-depth analysis under the corresponding Water Development and Management Master Plan (*Schéma Directeur d'Aménagement et de Gestion de l'Eau*, SDAGE) and Water Management Plan (*Plan de Gestion de l'Eau*, PGE), in collaboration with the corresponding Management and Planning Committees. To resolve the problems faced by the hotspots identified in this section, it will be necessary not only to make investments and improve information, but also to undertake organizational and legal reforms, as covered in Section II.2, while at the same time taking into account the specific issues relating to each hotspot.

II.1.3 Cost of Status Quo in Terms of Water Resources Management

49. This section provides an overview of the growing socioeconomic costs of water stress, climate variability, and the pollution of water resources in Senegal. These are largely associated with currently inefficient water resources management, which is centered on an increase in supply and neglects the preservation of quality, improvements in usage efficiency, and the importance of water as a key variable in land use planning. The methodology for estimating the costs associated with water pollution and flooding is described in Annex 5.

50. **The water pollution costs associated with untreated domestic wastewater discharges are on the order of US$796 million (CFAF 464.5 billion), or 3.8 percent of annual GDP**,[19] taking into consideration their impact on the environment and on health in terms of both mortality and morbidity. This is a conservative estimate that does not take into account the costs associated with agricultural and industrial pollution (including mining) and with parasitic water-borne diseases such as malaria and bilharzia, which have both increased as a result of the construction of hydraulic infrastructures, particularly on the Senegal River, nor the health and environmental costs related to excess salt or fluoride. It also does not consider the impact of pollution-related costs on agricultural production, particularly from salinity. While conservative, this estimate far exceeds the order of magnitude for middle-income countries, where exposure to and use of heavily-polluted water typically results in GDP losses of around 2.5 percent.[20] In 2017 for example, diarrhea led to 40,000 deaths in children under 5.[21]

51. **Health impacts account for 90 percent of the cost of water-borne pollution that can be measured to date**.[22] Although the public health risks are well known, the slow pace of remediation contrasts with the magnitude of their impact on the population. The discharge of drainage water containing pesticides and heavy metals and minerals into Lac de Guiers is at the origin of the eutrophication of this reservoir, the use of water with high concentrations of salts and fluorine in the groundnut basin for human consumption, and pollution from urban landfills of shallow aquifers used for market gardening (especially Mbeubeuss).

52. **The 2017 flooding costs associated with infrastructure and habitat damage and with premature deaths have been estimated at US$1.034 billion (CFAF 603.4 billion), or 6.3 percent of GDP**.[23] It should be noted that this is bound to be an underestimate of the costs since it does not take into account the impact on economic activities. Although flood-related costs vary significantly from year to year, the frequency and magnitude of the flooding have clearly increased since at least the late 1990s due to more intense rainfall, soil sealing, and building in flood zones. By increasing the frequency and intensity

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[19] Croitoru, Lelia; Miranda, Juan José; Sarraf, Maria. 2019. *The Cost of Coastal Zone Degradation in West Africa : Benin, Côte d'Ivoire, Senegal and Togo*. World Bank, Washington, DC. © World Bank.

[20] Desbureaux, Sebastien; Damania, Richard; Rodella, Aude-Sophie; Russ, Jason; Zaveri, Esha. 2019. *The Impact of Water Quality on GDP Growth : Evidence from Around the World.* World Bank, Washington, DC. © World Bank.

[21] Croitoru, Lelia; Miranda, Juan José; Sarraf, Maria. 2019. *The Cost of Coastal Zone Degradation in West Africa : Benin, Côte d'Ivoire, Senegal and Togo*. World Bank, Washington, DC. © World Bank.

[22] It is important to note that health costs are more easily quantified, creating a bias in analysis rather than a reflection of true cost.

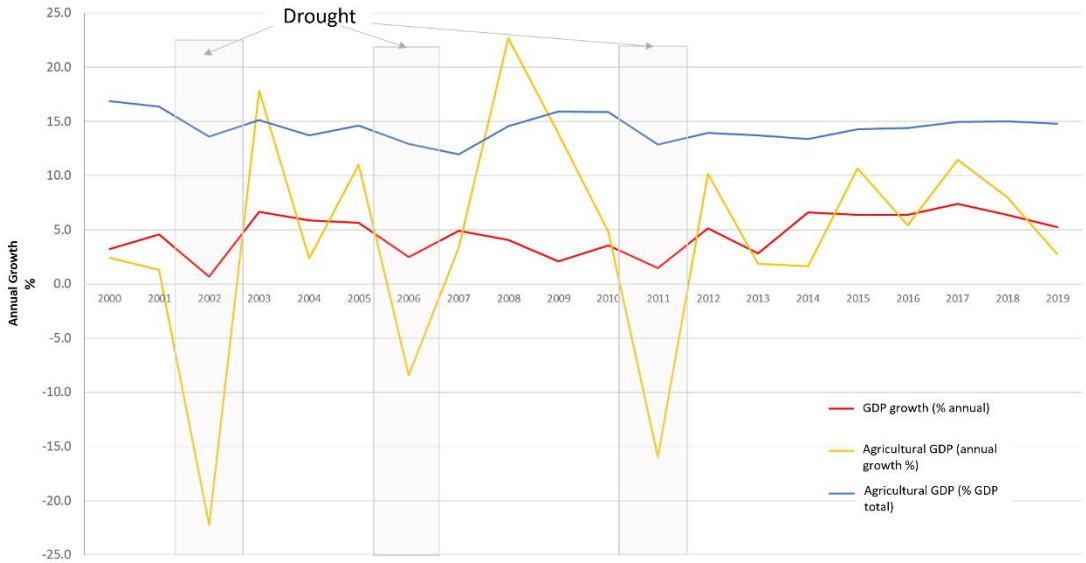
[23] Ibid.

of rains, climate change risks causing increasingly intense flooding, resulting in increased damage over time. For example, the floods of 2009 in the Dakar region caused CFAF 35 billion in damage and losses,[24] and those of 2012 in this same region damaged 11,400 homes and displaced more than 290,000 people.[25]

53. **The socioeconomic costs associated with the gradual increase in water stress and abnormally dry periods are also steadily rising as reflected in the gradual increase in the economic cost of water**. This is due to the cumulative effects of population growth, urbanization, and climate change. For example, Dakar and its suburbs, which account for 25 percent of the population and 55 percent of economic activity, have for several years faced rampant growth in their water needs, which have long exceeded local water availability. These needs have forced the Government to make costly investments, such as three transfers over more than 250 km from the Senegal River and a desalination plant while over-pumping the local aquifers at the risk of permanently losing a relatively inexpensive resource to salt intrusion. For example, the investments made by SONES between 1996 and 2015 reached nearly CFAF 280 billion (US$500 million). Projects in progress since 2015 represent nearly CFAF 430 billion (US$760 million). The economic impact from water stress in the Dakar region and from the status quo in terms of management dominated by the search for new water sources is reflected in a gradual increase in the economic cost of water, which has now reached a marginal cost in the order of US$7,200/m^3, or over CFAF 4 million/m^3.

54. **Though seldom highlighted in policy documents, droughts also represent a significant cost.** The cost of a year of drought as reflected by its impact on agricultural GDP are in the order of US$500 million, or 3 percent of GDP. Three drought episodes occurred over the past 20 years, causing a fall in GDP of between 11 and 26 percent compared to the ten-year average and a rise in the number of persons affected by food insecurity of between 300,000 and 800,000 depending on each case.

Figure II. 1 Impact of droughts on GDP and Agricultural GDP Growth (source: World Bank)



55. **In conclusion, the consequences of the inefficient water resources management in the status quo resulting from increased water stress, water pollution, and climate variability are generating ever-increasing socioeconomic costs.** It is crucial that water resources be deemed to be a non-renewable and degradable resource with significant economic value in order to ensure Senegal's water security and be

[24] Senegal: Urban Floods, Recovery Framework Case Study – August 2014, GFDRR.
[25] Rosalind J. Cornforth, "West African Monsoon 2012." *Weather*, 68: 256-263, 2013.

managed as such. The following section addresses this issue.

II.2 WATER RESOURCES MANAGEMENT IN CONSIDERATION OF THE CHALLENGES IDENTIFIED

56. **As shown in Section II.1, water security challenges have increased despite the efforts made,** and this trend is likely to continue in the years to come, posing very real risks to Senegal's socioeconomic development and to the achievement of the PSE's (*Plan Senegal Emergent*) objectives. Therefore, it would be appropriate, 40 years after the adoption of the Water Code and nearly 20 years after the establishment of the institutional framework for water resources management, to assess their performance and propose a series of recommendations to meet present and future challenges related to water resources management.

57. The first section evaluates the performance of resource management functions as defined in the legal framework and highlights the need to strengthen the Directorate of Water Resources Planning and Management (DGPRE), the main body in charge of water resources management in Senegal. Section 2 shows the need to raise the profile of water resources management and water security at the political level to obtain support at the highest level, in order to positively influence the content of the socio-economic policies of the country. Section 3 analyzes the legal framework, i.e. the rules, principles and processes that equip the entities in charge of water resources management with the instruments needed to perform their functions. Section 4 looks into organizational constraints.

II.2 .1. Evaluation of Water Resources Management

58. The Directorate General of Water Resources Planning (DGPRE), under the supervision of the Ministry of Water and Sanitation (MEA), is the main body in charge of water resources management in Senegal. Its functions consist in water resources planning; water abstractions and discharges management; surface and groundwater monitoring and knowledge development, in terms of quantity, quality and uses; and water information system management and water police. DGPRE takes part in the intersectoral coordination process at the national level by ensuring the secretariat of the Water Technical Committee (CTE) of the Higher Water Council (CSE), preparing meetings and ensuring follow-up of its decisions. It is also in charge of supervising, on behalf of the Minister, the performance contracts of the Lakes and Waterways Office (OLAC). Since 2010, OLAC has been responsible for the management of surface water not subject to international transboundary agreements and the development of infrastructure to mobilize them.

59. *There remain significant gaps in the implementation of the Water Resource Management functions as defined in the legal and regulatory framework,* and this despite considerable progress made over the past few years, particularly in deepening of groundwater knowledge, the formulation of the National Integrated Water Resource Management Plan (PAGIRE), the definition of an operational mechanism dividing the country into planning and management units, the setting up of the Water Police, the issuance of groundwater abstraction authorizations and the improved collection of the abstraction tax (called *taxe d'exhaure*). Table II.1. below, rates the degree of implementation of water resources management functions as defined in the legal framework, most of which are the responsibility of DGPRE.

Tableau II.1: Degree of implementation of water resources management functions

Function type	Specific functions and instruments defined in the legal framework	Grade	Justification
Intersectoral coordination at the national level	CTE Secretariat	1	The CSE has not met since 2001.
Coordination	Division of the territory	4	The management and planning units (*Unité de Gestion et*

of actors in priority river basins	into management and planning units		*Planification*, UGP and sub-UGP) are defined.
	Creation of management committees at UGP and sub-UGP level	2	Stakeholder committees have not yet been created. They are not provided for in the current legal framework and the provisions of the draft code are insufficient to ensure their proper functioning. The DGPRE is not sufficiently present in the field to provide them with lasting support. The current contract for the preparation of the five UGP master plans (SDAGE) provides for their implementation.
Planning	Planning at the national level	3	Several planning documents exist at the national level, including the Strategic Plan for the Mobilization of Water Resources and PAGIRE. They aim to establish national reference frameworks that identify the potential and limits of resource development. However, none of these plans are mentioned in the PSE, nor in the national sector plans, unlike drinking water and sanitation or agriculture plans, for example. Moreover, their degree of implementation is very low.
	Planning at the management unit level	2	The five master plans (SDAGE) of the five UGPs are in progress. 11 plans (out of 28) have been prepared at the sub-UGP level, but their quality needs to be improved. A third level of WRM plans at municipal level is not necessary, sub-UGP plans should be the mandatory framework for municipal development plans.
Administration of water rights		2.5	Ongoing function for groundwater permits; nothing for surface water.
Groundwater management	The zoning of aquifers at risk triggers reinforced management measures, including the prohibition of new drilling, etc.	2	Significant progress has been made in understanding groundwater and, to a lesser extent, in granting withdrawal permits and collecting the water use tax, but the tools specific to this management (listed opposite) have not been used. The overexploitation and pollution of the aquifers supplying Dakar and those of the Northern Littoral could not be stopped. The recommendations of the DGPRE are not respected. The decision-making levels to which the DGPRE does not have direct access have a poor understanding of the associated risks.
Water quality management	Emission permits; Ambient quality and emission standards	1	Not implemented.
Water knowledge and information	Knowledge of water resources and water information system (collection, treatment, dissemination)	2.5	Fairly good knowledge and monitoring of groundwater supplying Dakar in quantitative and qualitative terms; fairly good knowledge of surface waters in quantitative terms in the large transboundary basins, and poor knowledge elsewhere. Monitoring of withdrawals to be improved; data exchange protocols not operational, information system under development without public access.
Water Police	Water Police	3	Newly implemented function. The significant efforts of the past two years must continue.
Water saving	“User pays” and “polluter pays” principle	3	Substantial increase in collection on groundwater withdrawals. Not applied to surface water withdrawals and discharges.

Source: own elaboration based on the judgment of the experts who took part in this study (rating 1: not carried out to 5 perfectly carried out).

Strengthening the resources of the DGPRE is a necessary but not sufficient condition for improving the management of water resources

60. *The major gaps in the implementation of water resources management functions result in part from the limited resources available to the DGPRE, especially its field presence and human and financial resources.*

- The functions of the DGPRE require significant presence in the field. DGPRE should have "*brigades*" representing it in the country's 14 regions, instead of the current number of 6. The missions of the brigades must be redefined so that they take on all the local functions; their level of competence should be raised, and they should be equipped with appropriate logistical means. Currently, some brigades have only one agent and only two brigades have a car!
- DGPRE's staffing should be doubled to almost *100 agents and the agents should have a stronger technical profile so that DGPRE can fulfill its mission.* At the national level, it should incorporate high-level expertise capable of developing a strategic vision in keeping with the challenges of water security. To attract and retain qualified personnel, DGPRE must be able to offer them stable contracts and attractive salaries.
- *Its investment and operating budget should be increased to be in line with its missions.* In 2019, it had an overall budget of FCFA 1.69 billion (2 percent of the MEA's overall budget), most of these resources being devoted to groundwater resources studies and monitoring.
- *The water abstraction tax could partly make up for the lack of resources, provided its base is broadened and it is paid back in full to DGPRE.* While the tax was initially designed to cover the costs related to water resources management, the share paid back to DGPRE has been decreasing since 2015 and stood at 15 percent only in 2018. In addition, a fairly small proportion of authorized abstractions are currently subject to the tax.

61. While strengthening DGPRE's financial and human resources is a prerequisite to efficient management of water resources, it is far from sufficient. Indeed, it is also necessary to raise the profile of water resources management at the political level, by fundamentally reforming the legal and organizational framework.

II.2.2. Raise the profile of water resources management and water security at the political level

62. While Senegal has a wide range of national policies and programs that define a clear path for the country's socio-economic development, water resources and the risk to water security are mostly absent from those policies and programs. As a result, even though Senegal is a Sahelian country, water resources and the risk to water security due to inadequate management of water resources have a very low profile at the national policy level.

63. It is worth noting, for example, that the Emerging Senegal Plan (PSE), the medium and long-term national socio-economic development plan, defines an ambitious national program but does not explicitly acknowledge the risks to water resources as possible constraint to development, despite Senegal's arid climate. The closest it gets to addressing the issue is with a reference to *"preserving the environment and ensuring sustainable management of natural resources,"* a standard statement found in the policies of all countries. IWRM is mentioned, but under the title *"Water supply and sanitation,"* even though the PSE proposes an ambitious development program based on a structural transformation of the economy that places strong emphasis on the agricultural and industrial sectors, that are the largest users of water resources. The PSE contains references to important sector policies and plans relevant to the water sector, including

the Millennium Program for Drinking Water and Sanitation (PEPAM), the National Sanitation Development Plan (PNDS) and the National Agricultural Investment Program (PNIASAN). The Senegalese Agriculture Growth Acceleration Program (PRACAS) is aligned with the PNIASAN and makes bold statements on the availability of water resources for agricultural development as does the National Food Security and Resilience Strategy (SNSAR) 2016-2020. However, none of these documents mentions the National Plan for Water Resources Management (PAGIRE) - probably because it was never formally adopted by the CSE, or the Strategic Plan for Water Resources Mobilization (PSMRE) that was intended to serve as national reference, identifying the potential and limits for the development of water resources.

64. Water security is threatened by a widely shared vision of national development, centered on unconditional mobilization of water resources to achieve national objectives set without considering the availability and sustainability of the resource. On the one hand, compliance with the limits imposed to ensure sustainable management of water resources must be integrated into the rules of good governance and as an absolute priority in the overarching political vision that drives national development and guides all sectoral policies. Today, the only official policy document regarding water resources is the Ministry of Water and Sanitation's Water and Sanitation Sector Development Policy Letter (LPDSEA) for the period 2016-2025. This document restates the vision included in the PSE with regards to the sector's challenges, namely, to mobilize "*abundant quality water, for all, everywhere and for all uses, in an improved sustainable living environment, to foster Senegal's emergence*". The formulation of this vision is important because it strongly conditions the vision of "*water security*": the idea of "*abundance*" is far from reflecting the reality of many regions in Senegal, and the concept of "*sustainability*" is limited to sanitation. The overall sectoral development objective set in the LPDSEA ("*to contribute to the achievement of the sustainable development goal aimed at ensuring universal access to drinking water and sanitation by 2030 while ensuring integrated water resources management*") is hardly more precise.

65. In any case, the LPDSEA, as its name suggests, is a purely sectoral document, focusing on the water and sanitation sector rather than on water resources management. Water resources and water resources management are by definition a cross-cutting issue. In addition, the LPDSEA notes that the lack of an intersectoral mechanism for IWRM that promotes coordination among the different ministries is one of the main threats to Water Security".

66. The first very real challenge is therefore to urgently raise the profile of water resources management and water security at the policy level. This calls for the preparation of a national water resources management policy that should be approved at the highest level of Government. It is also a clear manifestation of the weak legal and institutional framework for water resources management, as discussed in the following sections.

II.2.3. Improve the legal framework for water resources management

67. The current Water Code became effective in 1981 but 40 years later, its implementation remains very limited. Senegal has undertaken to update the Code, but the existing draft Code must be improved to allow efficient management of water resources. This section offers a set of recommendations to this end. These recommendations are built on two premises: first, the way the law is drafted directly affects the likelihood of effective implementation; second, the more critical an issue is for water resources management, the more important it is to address it in primary legislation, i.e., in a law or code, rather than in lower-level legislation.

68. The general recommendations for improving the draft Code are as follows:

- **Refocus its scope on water resources.** The international trend is to design increasingly targeted water laws, instead of "omnibus" laws or codes that address all aspects of water. Given the serious threats to water resources in Senegal, there is a strong case to refocus the substantial scope of the draft Code on water resources, or water in its natural environment. This law would address the withdrawal of water from the natural cycle and its possible reintroduction into the cycle in the form

of wastewater. However, once water is taken out of the natural cycle, it would be regulated in reference to detailed legislation that is specific to the using sector. These specific laws already exist as regards to water supply and sanitation. If there is a need for a law specific for the irrigation sector due to the growing importance of irrigation in Senegal, this could take the form of a stand-alone law or perhaps an amendment to Law 2004-16 on the agro-sylvo-pastoral sector.

- **Extend and clarify the scope of the Code in relation to water resources management.** It is suggested to define in the draft Code what is meant by "water resources", to expand the Code's scope to all the functions relating to water resources management, beyond the administration of water in the public domain, and to make IWRM one of the Code's objectives and one of the State's responsibilities.
- **Acknowledge that water resources management is a *process* and define the *principles* guiding it**, as well as the links between its different elements, such as data collection and analysis, planning, administration of withdrawals and discharges, the water police, etc.

69. The following recommendations pertain to the two key IWRM instruments:

- **Provide for a national water resources strategy as the central instrument for intersectoral coordination.** The challenges identified in Chapter 2 are largely the combined result of uncoordinated national sector policies, strategies and programs having a direct or indirect impact on water resources. The core instrument of the IWRM model to address this issue is a national water resources policy/strategy that guides and coordinates policies around a common long-term vision of the resources and its management. It typically comes with a multi-ministerial coordination entity that is in charge of preparing the strategy. This coordination entity is discussed below (paragraph 82). To increase the likelihood of achieving results, the strategy must have a solid legal basis, and therefore it is recommended that the Code: (i) provides for its approval at a high level, typically at the Presidency level; (ii) legally links the strategy to the other decision-making processes provided for in the Code and (iii) requires that sectoral policies directly or indirectly related to water take this strategy into account.
- **Strengthen the provisions related to water resources planning since it is a central instrument for the coordination of actors at the management units level.** Planning is a central instrument for IWRM and acknowledges the fact that water management cannot be static. Through planning, the other water resources management instruments provided for in the legal framework are applied in a coordinated manner. Along with the planning instrument, the legal framework typically provides for the setting-up of a multisectoral coordination mechanism at the planning unit level to ensure adequate stakeholders participation in the planning process and later monitoring of the plan's implementation. Such an entity is provided for in the draft Code. To increase the likelihood that they are implemented, plans must have a *solid legal basis*, which implies that the Code, and not a lower-level legislation, should specify: (i) the plan's purpose and minimum scope, and how it is to be developed and approved; (ii) its alignment with the national water resources strategy and transboundary basin plans and international agreements; (iii) the role and legal consequences of these plans as regard to authorizing activities that have an impact on water resources; and (iv) their role as a guiding framework for sectoral and local development plans (the first plans developed at the level of sub-UGP cannot fulfill this role). The current Code and the proposed draft water Code have serious weaknesses in this topic.
- **Mandate the establishment of linkages between the water resources management plans.** IWRM usually considers the hydrographic basin or aquifer as the basic geographic unit for resource planning. Indeed, it is at this level that linkages between the different uses of water and between polluters and uses occur, and that trade-offs are made. However, while the draft Code and the draft implementing decree divide the country into five UGPs that overall match the contours of the internal hydrographic basins in the country, this is not the case for the 28 sub-UGPs that are made

up of the territory of four or five municipalities grouped together. The sub-UGPs are a Senegalese innovation whose purpose is to mobilize local authorities in managing water resources. However, this approach implies that planning at their scale, i.e., sub-UGPs, must consider the upstream and downstream impacts of any intervention in territories of sub-UGPs sharing the same aquifer or watershed. This requirement must be clearly stated in the Water Code. It should be noted that the first plans developed at the level of sub-UGP did not take these interactions into consideration.

70. A another set of recommendations pertains to the conventional WRM instruments whose implementation is guided by the two key IWRM instruments mentioned above, namely the national water resources strategy and the water resources management plans:

- **Consolidate water use rights regimes in the draft Water Code** by: (i) extending the free regime to all small uses; (ii) specifying that the rights are granted for a limited period; (iii) adopting a more flexible approach with regard to the prioritization of uses; (iv) extending the criteria for granting rights based on possible zoning, management plans, and environmental requirements; (v) clarifying the relationship between transboundary and national regimes; (vi) providing for the mandatory registration of water use rights in an official registry accessible to the public.

  It should be noted that there is currently a large number of uses without authorization, whose percentage is unknown but presumed to be high: less than five percent of boreholes whose operating flow is known had an authorization included in the DGPRE database. Those authorization are mainly for agricultural and industrial boreholes, very few for water supply systems. Surface water users do not have authorization, except for the Dakar drinking water supply from the Lac de Guiers. Control by the water police of illegal uses and of compliance with the requirements of water rights are still very limited due to lack of resources or information. This situation may affect water security for all users, including those who have a water right.

- **Improve groundwater management** by: complementing the planned regulatory measures (user rights; zoning), by (i) granting specific authority to local entities (user groups) to agree with DGPRE on the relevant rules for management of aquifers and participating in the control of abstractions and (ii) regulating the profession of drillers.

  The management of groundwater resources is crucial in Senegal. It is the main water resource in a large part of the country, and the majority of domestic and industrial uses as well as a small but growing share of agricultural uses are dependent on it. This resource is already subject to three major and often linked threats that affect its sustainability in the coastal areas: overexploitation, saline intrusion and pollution.

  International experience has shown that an approach to sustainable management of groundwater that relies solely on regulatory measures is unlikely to prevent groundwater overexploitation or pollution. Prohibition of new withdrawals or control of withdrawals are very difficult to implement by the public authority alone. The international trend is to complement these regulatory measures by establishing local entities and granting them specific authority so that they jointly agree with governmental entities on relevant rules for aquifer management (in particular through the planning exercise at the aquifer level) and, subsequently, participate in the control/enforcement of rules. These local entities are generally a group made up of aquifer users (legal and illegal). These local entities must be rapidly put in place where aquifers are already or are about to be overexploited, such as in the Littoral Nord and the Horst de Diass.

- **Initiate the management of water resources quality.** Because water quality is an increasingly important issue for water security in Senegal and that water quality and quantity cannot be dissociated, but also in line with international good practices, it is recommended that the Water Code be made the main law for water resource quality management and that the Environmental Code be amended accordingly. The Water Code should include the following instruments: (i) discharge authorization regime; (ii) resource emission and quality standards; (iii) obligation for polluters to

remedy the harmful effects of the pollution they caused; (iv) water quality protection zones to strengthen discharge conditions and introduce specific measures for non-point source pollution, for example through the establishment of land use rules, the promotion of good agricultural practices or the prohibition of certain polluting activities.

It should be noted that these instruments are currently included both in the current Water and Environment Codes, which causes paralysis and confusion and ultimately the non-implementation of the instruments by the two institutions in charge. Thus, to date, water resources pollution prevention and control are ensured - in a very ineffective way - through the administration of classified facilities (*établissements classés*) and environmental impact studies. Those instruments only partially address the issue of water resources quality because, among other reasons, they apply only to a limited number of polluters and do not pay special attention to water quality.

- **Specify that the revenue from the water abstraction tax must be used for water resources management.** Acknowledging that water resource is an economic good, the international practice consists in including in the water law provisions for a fee or tax associated with use water resources and for the revenue collected from this tax to be used for the management of water resources. It is recommended that the Water Code follows this practice.
- **Strengthen provisions relating to the information system.** Access to quality information is a prerequisite to effective decision-making in water resources management. It is strongly recommended to give an important place to this topic in the draft Code. An entire Chapter/Title could be developed specifying the following: (i) creation of a statutory base for the Integrated Water Information System within the Ministry of Water and Sanitation with the aim of facilitating the collection, processing, analysis, exchange and integration of data and information; (ii) obligation for the relevant public institutions to provide information within their competence to feed the information system; (iii) free access to data (including data in the water use rights registry); and (iv) obligation for holders of authorizations and licenses to provide the Ministry in charge of water resources management with information on water uses.

71. **Ensure consistency between the national and international legal frameworks concerning the management of transboundary water resources.** Senegal's water security is dependent on the joint and good management of transboundary waters as these represent 88 percent of its resources. Senegal is aware of this issue as demonstrated by its cooperation with countries in the Senegal basin for more than 50 years, and with countries in the Gambia basin since 1978. The international agreements ratified assign a set of obligations and duties and impose certain rules on State parties. *It is strongly recommended that the Code make reference to the treaties ratified by Senegal in the context of transboundary water management*, and that the draft Code be harmonized with them, in particular as regard to the withdrawal authorization; linkages between national and transboundary planning tools; the obligation to notify any State party of projects likely to have significant impacts on water resources; and the linkages national and transboundary between information systems.

II.2.4. Reform the organizational framework for water resources management

72. This section identifies the organizational constraints that contribute to inefficient management of water resources and to the difficulties that DGPRE encounters in fulfilling its functions. The constraints are associated with DGPRE's inadequate status, the scattering and overlap of the water resources management functions among various public organizations, both international and national - which weakens DGPRE's authority, and finally the lack of coordination mechanisms that are needed given the multidisciplinary and multi-objective nature of water resources management.

73. The Integrated Water Resources Management National Plan (PAGIRE) updated in 2019 acknowledges the need to put in place "*a water governance architecture that is simplified but coherent in*

order to avoid overlapping functions, and that is inclusive by taking into account all competence levels in order to make it more accountable and more efficient". On its end, the latest MEA sector policy letter notes that "*the absence of an intersectoral mechanism for the sustainable promotion of IWRM that fosters mutualization and convergences between different ministries"* is one of the main threats to the good water resources management.

Strengthen DGPRE's positioning

74. **Raise DGPRE's status.** DGPRE has a fairly low hierarchical rank and autonomy level in the public administration, both in financial and decision-making terms, when considering its functions and international practice in countries where the stakes related to water resources management are high as in Senegal. Its authority may sometimes be limited in the face of pressures aimed at influencing decisions with high social, economic and environmental stakes: its status does not allow it to impose those measures required to ensure good management of water resources, including within the MEA in some cases. Due to its status, it has difficulty ensuring coordination with the many public administration entities whose functions directly or indirectly affect water resources management and that have diverse and varied agendas, priorities and ranks, and are spread across several ministries.

75. **Bring together in a single institution water resources quality and quantity management.** As part of the analysis of the legal framework, the overlap in functions between the Ministry of the Environment and the MEA as regard to water quality management has been already discussed and a recommendation was made to bring together in a same institution the management of quality and quantity of water resources, two aspects that are closely linked (see paragraph 70).

76. **Keep the management of surface and groundwater within a single institution.** Within the MEA itself, special attention should be paid to the relationship between the Lake and Waterway Office (OLAC) and DGPRE. While the initial idea to establish an organization in charge of the management of Lac de Guiers (OLAG) was completely justified due to its nature and strategic character, the logic underpinning its conversion into an organization in charge of surface water management in the basins, in duplication of the role of the DGPRE, is difficult to understand.

Table II.2: Overlap in functions between DGPRE and OLAC as regards surface water

	DGPRE Surface and groundwater	**OLAC Surface water only**
Water resources planning	X	X
Administration of water use rights	X	
Administration of discharge permits	X	
Definition of ambient and emission quality standards water quality control	X	
Information on water	X	X
Water Police	X	X
Economic instruments ("user pays" and "polluter pays" principles)	X	
Development of multisectoral hydraulic infrastructure (studies, works, operation)		X
Management of aquatic invasive plants		X

Source: Water Code and Law 2017-17 establishing OLAC

77. On the one hand, transferring the duplicated functions from the DGPRE to OLAC in the long term would result in separating the management of surface and groundwater while these two resources are closely linked and must be managed together. On the other hand, the power imbalance between DGPRE and OLAC resulting from their respective status makes it difficult for DGPRE (on behalf of the Minister)

to ensure control over OLAC's performance-based contract though it is essential that its actions are aligned with the strategy prepared by DGPRE, especially as regards to planning, data collection, etc. Finally, given that it is entrusted with the function to manage water resources as well as function to develop infrastructure to exploit this resource, OLAC may find itself in a situation of conflict of interests, which is a risk for the sustainable management of water resources.

78. According to the 2018-2030 PAGIRE budget, OLAC would absorb the vast majority of financial resources dedicated to the water resources "management". The fact that DGPRE has validated a substantial investment (more than FCFA 27 billion, or 62 percent of the PAGIRE budget) in OLAC while this organization actually hijacks its activity and its prerogatives is a sign of a deteriorating institutional capacity.

79. Taking into account the analysis above, **the options to strengthen the organizational structure of water resources management** are presented below. Apart from the "status quo", all assume a reform of the legal framework along the lines presented in section II.2.3.

- **Status Quo:** no reform of the organizational framework or Water Code.

- **Option 1:** The DGPRE remains under the supervision of the MEA and its operational capacities are strengthened. The revision of the Water Code, as described above, would strengthen the legal authority of the Minister of the MEA and the DGPRE, but also its operational capacities with, in particular, a semi-autonomous financing mechanism strengthened for the management of water resources. OLAC becomes OLAG again with the mission to manage the Lac de Guiers, including the lake management infrastructure, in close collaboration with the sub-CGPE (sous-*Comité de Gestion et de Planification de l'Eau*, sub-Water Management and Planning Committee) created for the participatory management of the lake. OLAG's Board of Directors includes representatives of the lake's sub-CGPE colleges. OLAG collects fees for water withdrawals from lake users, including Dakar, and possibly those related to discharges into the lake.

- **Option 2:** The DGPRE is transformed into an agency under the supervision of the MEA. It is still responsible for defining and monitoring the National Water Resources Policy. The Water Code would give the Agency the relevant powers and assign it the revenue from the abstraction fee. OLAC becomes OLAG again (same as option 1).

- **Option 3:** OLAC is dissolved and its functions are integrated into the DGPRE, which is transformed into an Agency under the supervision of the MEA. The Water Code would grant the Agency the relevant powers.

- **Option 4:** High authority under the Presidency of the Republic or part of the President's administration. This approach would require primary legislation, the new Water Code for example, which would provide for its establishment and functions, the details of its internal structure and actual creation to be defined later, based on a presidential decree.

80. Table II.3 presents the pros and cons of these options. The choice of option will have to be the subject of in-depth reflection within the Government, once the commitment has been made to strengthen the status of the DGPRE to ensure water security in Senegal.

Table II.3: Institutional reform options

Options	Pros	Cons
Status quo. No organizational or legal change.	No real advantages except taking the path of least resistance.	No noticeable improvement in water resources management, current problems intensify.
Option 1. Strengthened DGPRE, OLAC becomes OLAG again.	The revision of the Water Code would strengthen the funding of DGPRE, the position of the MEA Minister and DGPRE as regard to WRM and their relations with other Ministries and non-governmental actors, supported by a transparent and participatory approach. Alignment of policy development with implementation, keeping DGWRP under MWS and with the Minister as champion. The current conflict of competence between DGPRE and OLAC disappears. A renewed OLAG is in better position to manage the Lac de Guiers in partnership with local authorities/other water users who have a shared incentive to maintain the quality of the lake water.	DGPRE's relative strength would remain dependent on MEA's support; DGPRE would remain within the Ministry's structure, including with regard to the civil servants salary scales. To be successful, this approach would require strong political support from MEA's leadership.
Option 2. DGPRE becomes an Agency, OLAC becomes OLAG again.	The agency would be much more independent regarding WRM decision-making and funding. Its staff would have more attractive salaries. It would have a direct link with the development of the WRM policy, as it still reports to MEA. The current conflict of competence between DGPRE and OLAC disappears. A renewed OLAG is in better position to manage Lac de Guiers (same as option 1).	As it still reports to MEA, it may not reach the desired higher level of authority, especially over other powerful sectors such as agriculture, town planning or mining. The creation of new authorities/agencies may go against the current government policy.
Option 3. Agency integrating DGPRE and OLAC functions.	The current conflict of competence between DGPRE and OLAC disappears. The agency would be much more independent regarding WRM decision-making and funding. Its staff would have more attractive salaries. It would have a direct link with the development of the WRM policy, as it still reports to MEA.	As it still reports to MEA, it may not reach the desired higher level of authority, especially over other powerful sectors such as agriculture, town planning or mining. Putting together in a same agency the contracting authority and WRM could lead to neglect of WRM or could generate conflicts of interest. Without a specific body to manage Lac de Guiers that explicitly provides for the involvement of stakeholders at the highest level and that includes a clear mechanism for the payment of

		environmental services, the quality of the lake's water may decrease the overall management of the lake may weaken.
Option 4. High authority under the Presidency of the Republic or part of the presidential administration.	High degree of authority due to its position within the presidential administration that would lift it above inter-ministerial pressure in terms of water resources management, without sectoral political interference.	Without a minister to speak for it, it might lack a champion and be subject to the President's conflicting priorities. The authority would not be able to lead the development of the national policy, which would remain the responsibility of MEA (in which case the functional links might be difficult to achieve), or would be assigned to a minister/vice-minister of the presidential administration who would need to have their own office/mini-ministry. The scope of WRM, which is based on data collection, modeling, planning, creation of institutional links and participatory decision-making processes, goes beyond mere sectoral "regulation". Lack of a specific organization for the management of Lac de Guiers (same as option 3).

Develop coordination and consultation mechanisms

81. The management of water resources is multidisciplinary in nature. It must reconcile different objectives, which sometimes requires trade-offs. It requires the intervention of many actors, both public and private, with distinct functions and priorities. Due to this complexity, clear and agile coordination mechanisms are necessary, firstly at the national level in order to coordinate the formulation and implementation of sectoral policies/strategies related to water resources management, and then, locally, at the level of key hydrographic/hydrogeological basins where water resources issues require coordination between public and private actors whose activities influence and/or depend on water resources. The latest MWS sector policy letter notes that "*the absence of an intersectoral mechanism for the sustainable promotion of IWRM that fosters pooling and implementation convergences between different ministries"* is one of the main threats to the good water resources management.

82. **At the national level, reactivate the Higher Water Council (CSE),** considering Senegal's past experience and international experience, so that it has the means to ensure effective intersectoral coordination. To this end, the Water Code should: (i) place the CSE in the Secretariat General of the Presidency that would chair it; (ii) assign the CSE real decision-making or arbitration functions, such as the approval of the National Water Resources Strategy, obliging it to regularly convene meetings and allowing the Minister in charge of IWRM to convene it; (iii) reduce the number of its members to a more operational size and limit its composition to people of similar status, with decision-making authority, such as ministers or secretaries general. The draft Code should be amended to this end as the current Water Code does not provide for the CSE. The provisions concerning the CTE as provided for in the draft Water Code are in line with international practice.

83. **At the local level, rationalize the number of committees to be created by prioritizing**

hotspots. The draft Code provides for the creation of a Water Management and Planning Committee (*Comité de Gestion et de Planification de l'Eau*, CGPE) at the level of the five UGPs and a sub-committee (sub-CGPE) in the 28 sub-UGPs. As a result, the structures to be created, taken as a whole, appear to be cumbersome and costly, especially given that the draft decree also provides for the creation of a Municipal Water Committee (*Comité Communal de l'Eau*, CCE) in each commune. It is therefore recommended to rationalize the number of sub-UGPs and to prioritize their establishment in hotspots and not to set up CCEs, but rather to sensitize existing municipal authorities on the SDAGEs and PGEs that should serve as an orientation framework (see paragraph 69).

84. **At the local level, strengthen the legal basis of CGPEs and sub-CGPEs.** Very little information is available in the draft Code and its implementing decree on CGPEs and sub-CGPEs. They only state that these committees are consultation platforms among the different categories of actors to develop and implement plans, strategies, programs and projects at the level of the UGPs and sub-UGPs respectively. International experience shows that when subnational entities that do not closely match administrative boundaries are created, whether with or without legal personality, for them to work well, it is necessary to define in primary legislation their basic elements such as their nature , their legal status, their membership and obligations, how they are selected, whether they are compensated, who provides the secretariat and technical support, whether they can hire staff, their rights and duties and - perhaps most importantly, how they are funded.

III. Water security in the Dakar-Mbour-Thiès Triangle

III.1. Circular economy: the Lens for Water Security in the DMT triangle

85. **Facing a water deficit since 2011, the DMT triangle illustrates the nation's struggle with water security and the solutions a circular economy approach can bring to address it.** Water resources are crucial to the drinking water supply (DWS) and the maintenance of economic activity in the DMT triangle, where water consumption is extremely high and growing at an average rate of 4 percent per year over the last decade. For the water sector, circular economy promotes refocusing urban centers as users within a broader WRM perspective and closing the resource cycle by looking for efficiencies. Its key principles consist in delivering resilient water-related services, designing out waste and pollution and regenerating natural systems.[26]Because of the different sectors that all use water and the impact on the water resources in the DMT triangle, the development of a strategy to ensure water security in the region calls for the integration of water and urban systems taking into account the urban water management cycle from abstraction to reuse and covering the different sub-sectors beyond drinking water. With an approach that centers on people, the economy, and the environment and combining commitments from stakeholders in different sectors with a balance between services, resources, and risks, circular economy aligns with integrated urban water management and aims to improve water security in the urban environment. For urban water security, this will also require diversifying water sources to hedge against growing risks and harmonizing the approaches across water using sectors. For urban water security, this will also require diversifying water sources to hedge against growing risks and harmonizing across water using sectors.

86. **The Dakar-Mbour-Thiès triangle (DMT) includes Senegal's largest urban agglomerations as well as several other future urban development hubs.** Their dynamic development is underpinned by the key sectors of industry and mining, tourism, fishing, and urban agriculture. The urbanization rate in the area is the highest in the country, at 96 percent in the Dakar agglomeration, and 51 percent of the country's urban population live within the DMT area. According to the latest report by the Senegalese National Statistical and Demographic Agency (ANSD) on the economic and social situation in the Dakar region,[27] this area is Senegal's principal economic hub and contributes more than half of national GDP. Nearly 40 percent of Senegal's companies are based in the Dakar region, a total of 160,031 economic entities according to the 2016 General Census of Enterprises (*Recensement Général des Entreprises*, RGE), with 51.7 percent of the 844,268-strong labor force employed in the region. The latest report by ANSD on the economic and social situation in the Thiès region published in August 2018 indicates that this region has the greatest economic potential in Senegal after Dakar, a favorable economic position it enjoys mainly thanks to dynamism in the tourism, horticulture, industrial, and fishing sectors.

III.2. The Strategic Framework for Water Security lacks Harmonization to address Water Security Challenges

87. **An integrated water security strategy must be developed for the DMT area, bringing together representation from water-using and water-impacting sectors,** to remedy the disjointed planning and implementation of priorities and actions in these different sectors to date. The elaboration of such a strategy would build on the revival of the CSE, as recommended in Section II, and would benefit from the consolidation of an integrated group of stakeholders from relevant ministries, local authorities and water users through a water platform.

88. **The Strategic Framework for Water Security in Senegal is based on several strategic**

[26] World Bank, upcoming. Water in Circular Economy and Resilience (WICER) Position Paper.
[27] Published in March 2019.

documents developed for different sub-sectors sectors that lack coordination. These documents were not drawn up using a harmonized approach, nor are they consolidated in a standard document. The Letter of Development Policy for the Water and Sanitation Sector (LPDSEA 2016–2025) defines objectives at the national level for IWRM, drinking water, sanitation, and stormwater management, but fails to articulate joint sub-sectoral priorities or assess tradeoffs between these services to promote water security. It also clearly indicates that at the national level there is currently no "*intersectoral mechanism for the sustainable promotion of Integrated Water Resources Management (IWRM)*[28] *that encourages mutualization and convergence between different ministries."* The Integrated Water Resources Management Action Plan (PAGIRE), updated in 2019, is the national strategic framework for WRM and promotes IWRM with a view to establishing the conditions for sustainable development through the satisfaction of water requirements. For sanitation, the strategic framework for sanitation suffers from an overemphasis on sewerage services compared to on-site sanitation, disjointed approaches across the urban-rural spectrum, and lack of financing. Stormwater and flood management has delivered good results following a project approach guided by the Ten-Year Flood Management Program (PDGI, 2012–2022). While the PSE references the different sub-sectors (drinking water, sanitation, agriculture) and their plans, and could integrate the nation's vision towards a water secure future as part of an emerging Senegal, it includes no mention of the IWRM plans. Instead, it refers to mobilizing "abundant" water resources. The National sectoral plans also fail to mention IWRM, meaning that even where water security is relevant to the sector's development it is not linked to the management of the resource or integration across water-using sectors (see Section II.2.2). For example, the National Agricultural Investment Program (PNIASAN) and the Senegalese Agriculture Growth Acceleration Program (PRACAS) make bold claims about water availability for irrigation without reference to quantification of available resources or DGPRE studies. This lack of harmonization is reflected in the fact that there is no strategic approach outlined in any specific document or decree that sets out the priorities for achieving water security at the national or DMT level. Instead, these priorities are distributed among different sectoral policies (national and zone-specific). These shortcomings highlight the need to improve coordination and define a more integrated approach with a view to achieving water security objectives.

89. **The strategic framework applied within the DMT triangle also lacks intersectoral coordination and harmonization between the different sub-sectors in question.** Each sub-sector is led by a different entity: the National Senegalese Water Agency (SONES) for water, the National Sanitation Office of Senegal (ONAS) for sanitation and stormwater collection, the Municipal Development Agency (ADM) and the municipalities for stormwater management and planning, while the MAER is represented regionally through the Dakar Regional Direction for Rural Development and the Dakar region branch of the National Agency for Rural and Agricultural Consulting (ANCAR). Further, each entity sets its own operating objectives without consideration for the impacts of its activities on other services. For example, one of the water security objectives within the Greater Dakar area is to satisfy demand for drinking water in the short, medium, and long term for all categories of the population connected to the public drinking water network. This includes households, local authorities, industries, businesses, market gardeners, etc. This objective appears in the 2017-2035 drinking water supply master plan for the urban centers of Dakar, Thiès, and Petite Côte, which was adopted in October 2017 by the SONES. Measures must be established to ensure better communication between sectoral plans and an integrated vision for the DMT area for the

[28] IWRM is based on three fundamental principles: (i) the economic efficiency of water use considering the scarcity and exhaustibility of the resource, (ii) equity in everyone's access to water (quantity & quality) to maximize economic and social well-being, and (iii) the environmental and ecological sustainability of current uses of water resources to preserve the sustainability of vital ecosystems and guarantee the use of this resource by future generations. In this approach, water management at the watershed level is recognized as good practice in the efficient management of water resources.

development of water-using services and the mitigation of risks and impacts across sectors.

90. **In the DMT triangle, water resources are not considered in land use planning initiatives or urban development planning, which disrupts natural processes, sometimes with serious consequences.** The responsibility for land use planning is shared between multiple bodies: the National Land Use Planning Agency (ANAT) is concerned with planning, while the General Directorate of Urban Planning and Architecture of the Ministry of Urban Planning, Housing, and Public Hygiene and Local and Regional Authorities are in charge of urban development. However, there appears to be no systematic coordination between all these entities, whose activities affect the management and use of water in the DMT zone when it comes to the planning or development of new projects. Further, flooding is significantly impacted by disorganized urban development as the beds of intermittent rivers are occupied by informal settlements and permeable areas reduced through urbanization. As shown in section II.1.2, this has serious costs to people and the built environment.

91. **Stormwater management has improved through a project-approach to infrastructure development but could be better integrated with urban planning policy.** The launch of the Ten-Year Flood Control Program in 2012 led to a very significant increase in stormwater management infrastructure. A sanitation fund for stormwater management is being established after several analyses and consultations[29] as a financing line in the ONAS budget, through the amendment of the decree linked to the law that created ONAS and defined its organization.[30] Establishing a dedicated funding mechanism within the purview of ONAS is expected to capitalize on investments to date and support the harmonized development of stormwater and wastewater management.

92. **While the ongoing urban water sector reform[31] has shown great results, it fails to integrate with or influence other sectors.** The urban water sector in Senegal has been the subject of reforms since 1996, with a public-private partnership (PPP) in the form of a hybrid lease (affermage) contract in 66 urban centers. The affermage contract has been relatively successful in the urban environment, combining the recovery of operating costs and investment with affordable water rates for users and a network efficiency rate of around 81 percent. The DMT area represents nearly 80 percent of its revenue. Under the second generation of reforms, the contract was renewed after two decades of partnership with the Senegalese Water Corporation (SDE). An international call for tender resulted in the renewal of the contract for a term of 15 years with the operator SEN'EAU, a subsidiary of SUEZ Group, starting on January 1, 2020, with the Operator committing to increased investment. The contractual network efficiency objective was set at 85 percent in order to ensure control of water loss and establish a culture of water conservation and forward-looking management of demand, principles fully aligned with best practices in terms of water security in the urban environment. However, this stellar progress in the management of the water service and associated infrastructure and the application of international best practice has been isolated vis à vis other sub-sectors, except for the rural water sector where the urban lease contract framework has been adapted in the development of eight affermage perimeters.

93. Regulation of Senegal urban water sector has been established in the first sector reform (1996) by using the framework of "regulation by contracts" and the financial model of SONES to monitor and set up water tariffs. Over the two decades period tariff increases have been affordable for consumers and SONES was at equilibrium enabling full cost recovery including debt service. In the second generation of reform starting in 2020, beyond this achievement, the government is exploring the issue of regulation across all sub-sectors as the private operators are increasing both in urban and rural areas, including the fecal sludge

[29] At the initiative of the World Bank within the framework of PROGEP.

[30] The draft text is currently in the process of official validation by the competent technical committee.

[31] This reform is governed by two fundamental laws that regulate the development of the urban water sector in the context of a PPP: Law 95-10 of April 7, 1995, organizing the urban water service and authorizing the creation of SONES, and Law 2008-59 of 24 September, 2008, organizing the public drinking water and collective wastewater treatment services, commonly known as the SPEPA Law.

management subsector. The donors are supporting this initiative and there is an ongoing study on sector regulation funded by the French cooperation (AFD).

94. **Poor planning and lack of funding for sanitation services in the DMT triangle threatens water quality, and urban sanitation reform needs a clear roadmap.** Within the sanitation sub-sector, planning for on-site and sewerage sanitation services requires better alignment, despite being handled by the same entity (ONAS). The on-site sanitation strategy for the Greater Dakar area, included in the National Program of On-Site Sanitation Sustainable Development (PNDDAA), only extends to 2025 and will need to be completed. Local sanitation master plans (PDA) are developed at the city-level; in the DMT triangle the PDA are not aligned with current priorities and urban expansion and are often underfunded. This lack of funding creates delays in rolling out services, in turn requiring the studies to be revised years after their completion. The management of sewerage services in ONAS service area currently faces numerous constraints, such as aging infrastructure due to an insufficient renewal rate, low wastewater treatment capacity with, in some places, direct discharges of untreated wastewater, and frequent network clogging with solid waste due to customer behavior and the low rate of networks cleaning. In view of the major investment projects planned to expand assets, ONAS has failed to guarantee satisfactory operation of its infrastructure and there is now a consensus among Senegalese stakeholders for greater private sector involvement.[32]

95. **The development framework for the irrigation sector in Greater Dakar is currently not guided by any strategy.** The security of the future irrigation water supply in the zone is dependent on measures designed to improve the environment for the horticultural sector, especially in the Niayes area, by increasing the level of data and knowledge about water catchment infrastructures, water abstraction, equipment used, and irrigation practices. This will mostly involve making the water resources management plans operational in the sub-UGPs of the Littoral Nord and Somone regions (water policing, usage monitoring, recovery of dewatering royalty payments, etc.). Measures to be applied will be based on a two-pronged approach (analysis and experimentation) and on a real analysis of the impact of current horticultural practices on water resources in the two territories.

96. **To improve long-term irrigation planning and the consistency of irrigation water requirement ratios in the target zone**, a study should be undertaken to increase the level of knowledge about the size and spacing of farms, catchment points, crop calendars, and water requirement ratios. In addition, an updated database should be set up containing information about horticultural activities, the development of cultivated land, sources of water used, and the impact of farming practices on the quality of water resources, metering of water abstraction, irrigation methods used, and all other relevant information. This will help the relevant departments of the MEA and the Ministry of Agriculture and Rural Equipment (*Ministère de l'Agriculture et de l'Equipement Rural*, MAER) manage water resources in the region more effectively. To that end, programs in place to monitor agricultural and industrial water usage must be equipped with adequate resources and must cover the entire region.

97. **To realign the planning and development for the DMT triangle from the perspective of water security, it is essential that these sub-sectors be brought together in one integrated strategy for the area.** This strategy must be based on IUWM principles and must provide for coordination mechanisms as recommended in Section II. The conclusions of this report (Sections III.7 and IV) set out strategic orientations in this sense.

[32] The Government of Senegal has requested the Bank to hire an International Consultant to assist in developing a strategy and roadmap for sound urban sanitation reform. One of the options envisage is to delegate the management of sewerage systems in Greater Dakar to a private operator. This analytical work will be completed in 2021 and pave the way for the future reform of urban sanitation and contribute to its long-term financial sustainability.

III.3. WATER RESOURCES MANAGEMENT IN THE DMT TRIANGLE

III.3.1. Major challenges relating to water security and water resources management for 2035 and beyond

98. **The DMT triangle faces serious problems with regard to the quantity and quality of the water resources on which the zone is dependent.** Currently, the water supply for cities in the DMT triangle depends largely on the transfer of water from outside the area, with 60 percent of the water transferred coming from Lac de Guiers and boreholes along the North Littoral (Louga) region. However, water quality in Lac de Guiers is threatened by (among other things) agricultural and industrial activities along its shores. The strategy of developing new water catchment zones locally is no longer viable due to the fact that some aquifers have become highly polluted with nitrates, while in others, the piezometric water level has dropped significantly due to overexploitation, causing seawater intrusion in coastal areas. Moreover, growth of urban areas toward new industrial developments is accentuating the problems of flooding, pollution, and reduced recharge of local water tables. Groundwater pollution resulting from uncontrolled occupation of space and lack of wastewater treatment systems affect water security in the DMT triangle. Pending the completion of the KMS3 water transfer project, the emergency DWS has drawn heavily on already overexploited aquifers (abstraction from sub-basaltic sands tripled in 2018), threatening the level of the water table and accelerating seawater intrusion.

99. **The Lac de Guiers supply system, on which the DMT triangle will depend in the coming years for nearly 60 percent of its water consumption, is threatened with regard to both quality and security of access.** Lac de Guiers is one of the country's principal water resources and is part of the transboundary Senegal River Basin. In general, it is not considered advisable for a metropolis the size of the DMT triangle to depend on a single source for the majority of its water consumption. This dependence makes the area particularly vulnerable if the quantity of available water is reduced or its quality is severely compromised. There is also a security risk with regard to the water transportation infrastructure as the pipeline is vulnerable to terrorist attacks or extreme events that could damage it and prevent the DMT zone from accessing this source. Note also the risks associated with the transit capacity of water from the Senegal River via the Taouey Canal, the availability of water in the dry season for all uses, and the quality of the water due to the development of agro-industries and agglomerations around the lake. This development particularly affects water quality through the discharge of drainage water containing residues of fertilizers and phytosanitary products and the inadequate collection and treatment of waste produced by neighboring localities.

100. **The groundwater tables that supply the DMT zone are overexploited, and the wetland ecosystems are threatened.** The results of recent hydrogeological studies warn of:

- Overexploitation of the sub-basaltic sand aquifer in Dakar and subsequent risks of seawater intrusion, of the groundwater tables in the Pout aquifer leading to steep drops in piezometric levels in both the north and south sections of the aquifer (Pout Sud and Pout Kirene) and of the groundwater tables of the North Littoral (Quaternary sands and Eocene limestone), as well as the necessity to freeze the current level of abstraction from these groundwater tables.
- Increasing levels of seawater intrusion along the South Littoral that are progressively affecting the Maastrichtian sands groundwater table south of the Horst de Diass, the Mbour limestone aquifer (Mballing zone), and the Paleocene limestone aquifer in Sébikotane.
- Occupation of wetlands, which has led to a decline in the quality of the water resources available locally, especially in peri-urban zones with no sanitation. Uncontrolled dumping of waste (Mbeubeuss landfill in the Dakar region) and the infiltration of domestic untreated wastewater in the Dakar suburbs are responsible for diffuse nitrate pollution in the Thiaroye Quaternary sands groundwater table.

101. **There is also increasing competition in the area between the various requirements for use of**

the land and water resources. One example is urbanization encroaching on agriculture, leading to the intensification of irrigated agriculture on the remaining plots. However, there are also conflicts between the mining industries currently developing around the North Littoral in particular and the market gardeners because the extraction of phosphates and zircon are water-intensive processes that degrade the quality of the soil. Moreover, with market gardeners in the zone using increasing quantities of chemical fertilizer and phytosanitary treatment products, often without taking the necessary precautions, the situation requires increased monitoring to prevent irreversible degradation of groundwater tables, soils, and the environment in the area's market gardening centers.

102. **Urbanization accentuates competition for water resources in a reduced space, which poses challenges for water distribution, water quality, and stormwater management.** The rapid urbanization in the Greater Dakar region has led to often uncontrolled land use, and the proliferation of shantytowns and slums, frequently with no sanitation facilities, and unlawful occupation of wetlands and natural riverbeds. Soil sealing resulting from building and the occupation of wetlands are having a significant impact on the global water cycle (runoff and recharging of water tables), leading to increased flooding in the Dakar suburbs. In 2009, floods resulted in US$67 million (CFAF 39 billion) of damage in Dakar. Note also the recharging of the Thiaroye Quaternary sands aquifer after it was abandoned due to problems with quality, leading to flooding during the rainy season. The recurrent flooding observed in the Dakar suburbs mainly affects improperly subdivided areas that are often characterized by poor land use planning, with some neighborhoods settling in depressions in the Niayes zone and in backwater areas.

103. **The zone under study is in a situation of drinking water deficit that has continued since 2011, and water requirements for drinking water and irrigation exceed available resources.** The emergence of water shortages and the decline in water quality, especially in the cities of Dakar and Petite Côte in the absence of any forward planning, could threaten the water supply for the population and the economic outlook for the medium to long terms. The evaluation of needs relative to resources over the various time frames considered in this study is summarized in the table below.

Table III.1: Evaluation of needs vs. resources for the Greater Dakar area, 2020–2050

	Water requirements (m^3/d)		**Usable water resources (m^3/d)**		**Deficit/Surplus (m^3/d)**		**Aquifer protection plan (m^3/d)**	
	DWS[33]	Irrigation	DWS	Irrigation[34]	DWS	Irrigation	Sum	
2020 – 2025	759,400	503,000	748,800	30,000	-10,600	-445,000	(77,375)	▪ 2024 : -77,375 m^3/d on the Maastrichtian (Thiès, ALG system)
2025 – 2035	1,105,400	219,000	1,273,800	100,000	+168,400	-119,000	(202,875)	▪ 2030 : -30,000 m^3/d on the Infrabasaltic ▪ 2030 : -60,000 m^3/d on the Paleocene ▪ 2030 : -35,500 m^3/d

[33] The calculation hypotheses are presented in Annex 3.
[34] Irrigation facilities and infrastructure built by the Government.

								on the Maastrichtian (Petite cote)
2035 – 2050	2,406,100	219,000	1,273,800	130,000	-1,132,300	-89,000	(202,875)	Same

104. The general approach that should be considered for the mobilization of water resources to meet the requirements of populations and the economy in the DMT zone is to diversify sources and increasingly target renewable water resources, including non-conventional sources (desalination, reuse, aquifer recharge, etc.), and to work on controlling network losses.

III.3.2. Recommendations and solutions proposed for improved management of water resources

105. Water resources in the DMT are vulnerable. Given the complexity of the challenges faced in this hotspot, it is important to note that **solutions will not always be local but must be considered at the national level**, especially on the institutional and operational front (transfer of water between reservoirs, aquifer protection plan, protection of Lac de Guiers, etc.).

106. **Diversification of water resources and fit-for-purpose water allocation are essential to achieving a modern and integrated water resources management approach in the DMT triangle**. From 2026 onward, the current plan for mobilization of water resources in the Greater Dakar region will need to be strengthened further by bringing into play additional capacities as well as by the implementation of efficient maintenance programs and the renewal of existing production facilities. To meet increasing water supply needs in the Greater Dakar region for the various competing uses, several types of water resources are being considered as a priority: (i) the surface water resources of Lac de Guiers along with those that can be collected from the various hydrographic catchment areas in the zone; (ii) subterranean resources from the various aquifers within or outside the Greater Dakar area; (iii) rainwater harvested by an impluvium system; (iv) secondary or tertiary treated wastewater; (v) unmetered water (network losses); and (vi) seawater.

107. **Mobilizing future water resources for the DMT will need to follow key principles building on circular economy and integrated urban water management approaches.** In particular, the DMT faces a need to conserve groundwater resources and must consider the economic and financial limitations of relying on seawater desalination for large shares of the water portfolio. As such, the following strategy for mobilizing future water resources for the DMT triangle has outlined:

- Favor surface water resources, especially those from Lac de Guiers, while considering the fact that these are shared with the countries bordering the Senegal River;
- Prioritize the water needs of households and industries in the urban centers in the zone;
- Use the water source closest to the location of consumption as a priority;
- Reduce or even suspend abstraction from the most threatened groundwater tables (groundwater protection program) for a period to allow them to recharge;
- Take only as much as the renewable reserve from the Greater Dakar groundwater tables allow;
- Reserve at least 10 percent of renewable subterranean reserves at the local level to meet the needs of the Greater Dakar rural zones;
- Allocate tertiary treated wastewater to irrigation as a priority and secondary treated wastewater to the artificial recharge of groundwater tables and the maintenance and restoration of urban forests;

- Use seawater desalination in proportions that make it possible to maintain the financial equilibrium of the sector given the high production costs of this solution.

108. **Protecting the Lac de Guiers and improving the pipeline from the Taouey Canal are essential to ensuring water security in the DMT triangle. The** Lac de Guiers is one of the hotspots identified in Section II, which details the challenges relating to this zone (II.1.2) and recommends increasing the monitoring and management of the lake in order to improve its quality for DWS and other uses (II.3). The baseline water quality status established in 2019 by Senegal's Lakes and Watercourses Agency (OLAC) indicates the presence of around 30 pesticides, 10 heavy metals, and various bacteria such as E.coli and Salmonella, such that the water fails to meet drinking water standards. In addition to problems with the water quality, Section II.1.2 also mentions the gradual silting up of waterways and bodies of water within the Delta due to the combined effects of sedimentation and the proliferation of aquatic plants across 30 percent of the surface of the lake. This gradual silting up reduces water flow into the waterways and the supply capacity for irrigation and other uses, leading to shortages during peak periods.

109. **Conserving subterranean water tables calls for a groundwater protection program.** The objectives of the program are:

- To reduce abstraction over at least the next decade, targeting the most threatened aquifers (Infrabasaltic, Maastrichtian and Paleocene) until 2050, according to the schedule below:
- To establish an observatory to monitor piezometric domes and depressions to preserve and guarantee the resource: (i) dome on the North Littoral water table and the Mbour aquifer in the Louly Ngogom zone; (ii) piezometric depression zones south of the Sébikotane aquifer at the Pout limestone layer and the Quaternary sands in the Beer Thialane-Bayakh zone that lead to seawater intrusion.

Table III.2: Schedule for reducing abstraction from subterranean groundwater tables

Years	Proposed reduction of abstraction
2024	Maastrichtian protection plan (Thiès, ALG system): -77,375 m^3/d
2030	Sub-basaltic protection plan: -30,000 m^3/d Paleocene protection plan: -60,000 m^3/d Maastrichtian protection plan (Petite Côte): -35,500 m^3/d

110. **The restoration of the aquifers and aquatic ecosystems will involve the development of the recharge zones identified for the aquifers most threatened by seawater intrusion.** Managed Aquifer Recharge (MAR) involves the improvement of natural recharge conditions (slowing down surface runoff and increasing soil permeability) and the artificial introduction of additional water into the groundwater tables by means of infiltration devices and systems. Such solutions will alleviate the problems linked to the overexploitation of groundwater tables and combat the seawater intrusion that often goes along with a drop in groundwater levels in aquifers close to the coast or in contact with a body of brackish or salt water. Other benefits include the restoration or improvement in maintenance of wetland areas, prevention of freshwater loss by evaporation, and storage of water for future use. As regards the aquifers in the DMT triangle, this artificial recharge will be achieved by reusing wastewater and stormwater.

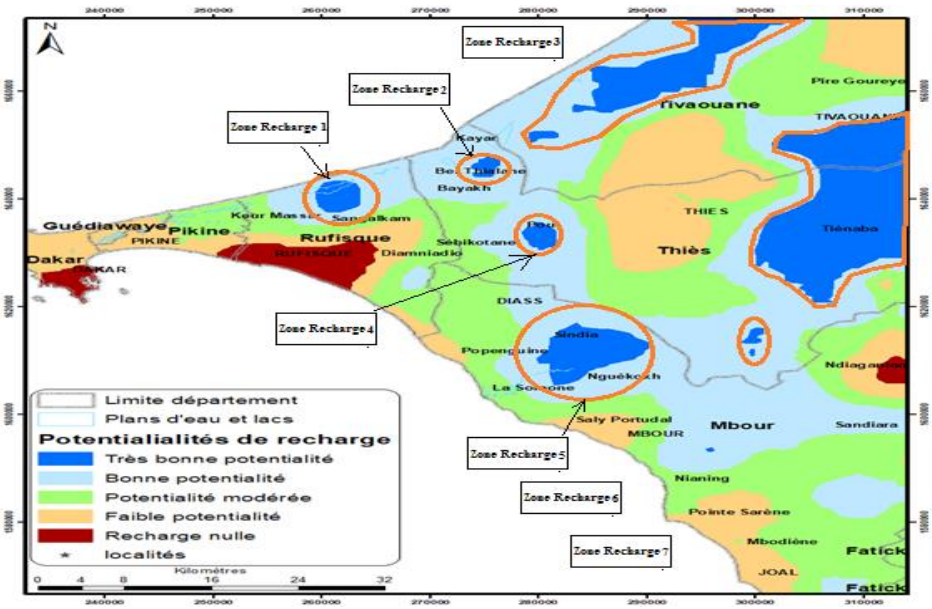
111. **Finally, to minimize the effects of pollution and overexploitation in vulnerable areas, the environmental elements of the urban ecosystems must be restored through the promotion of green cities and towns.** The application of strategies for promoting and protecting natural parks and wetlands (lakes and bodies of water) will enable the development of sites used for education and water conservation, the restoration of biodiversity, and reconnecting humans to nature. Such initiatives, which contribute to the recharge of the water tables, also increase the availability of drinking water and improve the humidity in the air as a result of evapotranspiration from nature parks and gallery forests around wetlands. The

restoration of nature in towns and cities improves the health of residents, makes the urban environment more attractive, improves the quality of life, and offers better opportunities for education and employment.

112. The strategy of recharging aquifers and ecosystems will be based on the use of stormwater and treated wastewater:

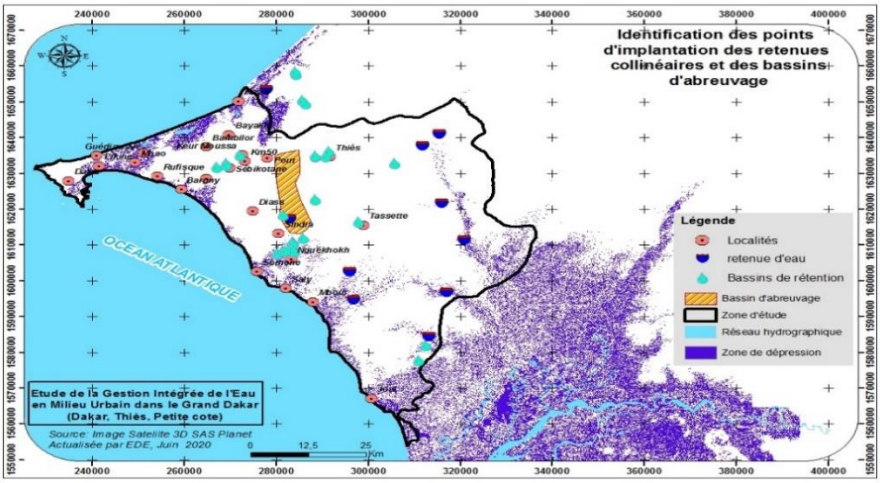
i. **Aquifer recharge using stormwater.** The map below shows potential areas for recharge and indicates that there are promising recharge zones located along a long stretch of the coastal strip of sands on the North Littoral from Lake Retba toward Beer-Thialane and to the north on the Mboro-Diogo-Lompoul route. Areas with very good potential can also be also found in the central part of the Horst de Diass system near Pout and in the south in the Bandia sector. There are also very promising zones located in the eastern part of the Horst system in the Thiénéba sector toward Diack and its surroundings. Note also the presence of zones with good recharge potential in sectors where the topography is favorable (low slope and altitude) and associated with advantageous edaphic conditions (permeable soil). These zones are located on the North Littoral sands water table and the Paleocene water table of the Pout aquifer and a small part of the Maastrichtian surface aquifer. There are areas with moderate potential in the mountainous areas of the Horst de Diass, the slopes of the Thiès plateau, the area south-east of Mbour, and the Pire-Thiénéba-Khombole sector.

Map III.1: Potential sites for aquifer recharge



- The geomorphological conditions in the Somone basin are favorable to recharge. However, the fact that the ground is sometimes variously permeable could limit the potential for water infiltration. Various options can be considered through a detailed feasibility study, including among others retaining levees on several sections of the watercourse or infiltration wells or ponds. With respect to results, the map below shows the proposed stormwater storage structures:

Map III.2: Facilities for intake and storage of runoff water



ii. **Recharge using treated wastewater.** There is also significant potential to use treated wastewater for aquifer recharge in the Greater Dakar region. The table below shows an evaluation of the volumes of water that could be used for recharge:

Table III.3: Volume of recharge using treated wastewater (m^3/d)

Zone	2025	2030	2035	2040	2045	2050
Dakar	4,600	16,560	40,950	71,715	89,644	115,620
Rufisque		4,500	8,750	15,000	18,750	40,000
Thiès				21,600	27,000	28,800
Mbour				1,944	2,430	2,592
Total	**4,600**	**21,060**	**49,700**	**110,259**	**137,824**	**186,212**

113. **The management of demand for water plays an essential part in achieving water security for Greater Dakar.** An integrated urban water management strategy cannot only focus on developing new sources of water and solutions based on supply. It must also aim to change the behavior of consumers in order to reduce demand and make water use more efficient. Demand-focused strategies include measures intended to manage water consumption more carefully, reduce waste, and maintain quality at an acceptable level. Water demand management strategies might focus on rationalization of water use, education, and pricing. Another general category of initiatives intended to resolve problems of water shortage involves the use of technologies and other strategies designed to increase supply. For example, in the affermage contract with SEN'EAU, provision is made for the installation of smart water meters allowing the remote management of water flows among large consumers of the administration (barracks, hospitals, high schools, universities, etc.) in order to limit nocturnal water losses and wastage. The development of water-saving or low-water sanitary devices is also another avenue to be explored (cf. water saving pilot project developed as part of the water sectoral project in the 2000s) to help change the domestic water demand curve. These actions on saving water are complementary to the actions mentioned in the lease contract where the operator SEN'EAU is tasked to reach a level of water network efficiency from 81 to 85 percent.

114. **The legal and institutional framework needs to be reinforced, both at the national level and in the DMT zone.** The initiative relating to water resources management at the national level makes specific recommendations for the improvement of the legal and organizational framework of water resources management in Senegal as well as for reinforcing the capacities of the Directorate General of Water Resources Planning, and Management (DGPRE). Note in particular the importance of finalizing the reform of the Water Code as described earlier in this report. Water security in the DMT triangle cannot be achieved

without the application of these strategic elements. Within the triangle itself, there is also a need for collaboration between users of the water resources and the institutions in charge of their planning and development. In this regard, this study recommends the development of a water management platform bringing together these stakeholders on a regular basis and establishing clear procedures for coordination around decisions linked to water resources for the zone. These various institutions should also be strengthened to allow them to manage their functions as part of an integrated approach to the management of urban water resources.

III.3.3. Development of infrastructure for sustainable management of water resources

115. The integrated consolidated investment program designed to ensure water security for the period 2025-2035 is based on the strategic approaches mentioned above and summarized in the table below:

Table III.4 Summary of strategic approaches for the Integrated Consolidated Investment Program to ensure water security for the period 2025-2035

2021–2025	2026–2035	2036–2050
Reinforce the water pipeline from the Taouey Canal and improve water conditions in Lac de Guiers		
Implement protective measures for the securing Lac de Guiers (Phase 1)	Implement protective measures for securing Lake (Phase 2)	Implement protective measures for securing Lac de Guiers (Phase 3)
Artificial recharge of aquifers using stormwater and wastewater (Phase 1)	Artificial recharge of aquifers (Phase 2)	Artificial recharge of aquifers (Phase 3)
Restoration and protection of aquatic ecosystems: Somone Lagoon, Pikine Niayes, Yene Lagoon, Lake Tamna, Lake Retba, Mbao backwaters, reservoirs (Phase 1)	Restoration and protection of aquatic ecosystems: Somone Lagoon, Pikine Niayes, Yene Lagoon, Lake Tamna, Lake Retba, Mbao backwaters, reservoirs (Phase 2)	Restoration and protection of aquatic ecosystems: Somone Lagoon, Pikine Niayes, Yene Lagoon, Lake Tamna, Lake Retba, Mbao backwaters, reservoirs (Phase 3)

III.4. SECURE ACCESS TO DRINKING WATER FOR DMT

III.4.1. Challenges of supplying water to the DMT zone for 2035 and beyond

116. **Demand for drinking water in the DMT triangle has grown dramatically.** Given this strong growth (financing of development projects every 10 years), a strategy aiming to control this demand in the short and medium terms must be developed in order to rationalize the financing and to expand the water supply system. Promoting management strategies for managing water supply demand in urban areas and encouraging water conservation are clearly the least costly methods for increasing access to this resource. When demand management policies are insufficient, adopting new technologies and other strategies to increase supply may prove useful, even if they are inevitably very expensive.

117. **In Greater Dakar, users are experiencing more frequent water shortages, especially during the dry period.** Economic and demographic growth has increased demand and forced the authorities to look for additional water sources to supply the population and maintain economic activities. Given this rising demand and despite the Government's investment efforts, satisfying Greater Dakar's water needs remains problematic. Moreover, the effects of climate change and its consequences on the available water resources are aggravating the situation. Although satisfying demand for water is a concern throughout the country, it is strongest in the Greater Dakar area, where urban expansion and the demographic growth rate are the highest in the country.

118. **Meeting demand for drinking water in the DMT triangle requires implementing a development project with a long-term vision.** Currently, the water supply for the cities of Greater Dakar largely depends on solutions involving the transfer of water from locations outside its own territory. Already, 60 percent of transfers come from Lac de Guiers and a substantial proportion from aquifers along the northern coast (Louga region). The strategy for developing new local water catchment areas is no longer viable since some of the groundwater is strongly affected by nitrate pollution while other sources are experiencing severe drops in their piezometric level due to over-exploitation, leading to saltwater intrusion in coastal regions.

119. **Greater Dakar's water consumption** represents on average 76 percent of the total volume of all of the cities in the leased perimeter of SONES. The overall share of water transfers to Greater Dakar is 63 percent. From 2015 to 2018, the Lac de Guiers contribution to this transfer of water increased from 40 to 45 percent. At that time, Greater Dakar was experiencing a deficit of approximately 95,000 m^3 per day before the Special Dakar Region Supply Improvement Program (PSDAK), which is financed by the Government, mobilized additional water resources.

120. **The KMS3 investment sequence**, which is currently underway, should increase the production capacity of Dakar's water supply by 200,000 m^3 per day by 2022. Furthermore, to diversify water resources and improve water supply reliability, the Government has turned to seawater desalination to supplement surface and groundwater exploitation. The Mamelles site in Dakar has been selected as the location for the first water desalination plant, which will produce 100,000 m^3 per day, to be delivered in two phases of 50,000 m^3 per day by 2026. Another site located on the Littoral Nord between Lake Rose and Kayar has been selected to house a desalination station producing 200,000 m^3 per day.

121. According to the forecasts of the SONES master plans, these investments will meet water supply demand in 2035, which is estimated at 1,105,416 m^3 per day. Beyond that, no water resource mobilization plan has been approved by the authorities to meet future demand for water. The production capacity needed to meet the DMT's water needs for 2050 is currently estimated at 1,675,000 m^3 per day. **The extremely vulnerable nature of water resources in Greater Dakar thus means that more concerted and integrated water management measures must be put in place.**

III.4.2. Meeting water needs in the DMT zone

Forecasting DMT water needs for 2035

122. To estimate water needs, specific consumptions were set for different uses (domestic: 100 liters/hour/day, etc.) and the following scenarios were identified:[35]

Table III.5. Scenarios for Estimated Water Needs

Consumption Centers	Pop. Growth rate	Unit consumption (l/d/pers)	Network Yield	Peak Coefficient
Dakar agglomeration	2.57%	100	79%	1.1
Thiès Metropolitan Area	3.10%	65	87%	1.2
Mbour and southern coastal cities	5.90%	75	85%	1.3

35 Cabinet EDE: "Rapport sur la stratégie de satisfaction des besoins eau et assainissement en milieu urbain dans le Grand Dakar" – September 2020.

123. For the purposes of this study, three demand growth scenarios were developed. The water demand forecast (production capacity needed to satisfy peak needs) for the different timeframes is as follows:

Table III.6: Water Demand Forecast Scenarios (m^3/day)

	2020	2025	2030	2035
High scenario (m^3/day)	**577,467**	**759,432**	**915,124**	**1,105,416**
Medium scenario (m^3/day)	549,841	658,886	796,048	963,311
Low scenario (m^3/day)	530,555	582,889	693,528	828,741

124. After consulting with stakeholders and based on recent experience, it was determined that the medium scenario, which until recently had been used to forecast demand, was often exceeded and thus insufficient in terms of security. **The high scenario** was thus used to determine water demand forecasts for the DMT zone, with the following breakdown:

Table III.7: Water Demand Forecast by Zone for 2035 (m^3/day)

	2020	2025	2030	2035
Dakar agglomeration	482,738	607,749	719,933	848,948
Thiès metropolitan area	56,622	76,234	88,891	103,776
Mbour and southern coastal cities	38,087	75,449	106,300	152,692
Total for Greater Dakar	**577,467**	**759,432**	**915,124**	**1,105,416**

Production capacity and available water resources

125. Today, two types of production are used to provide water to Greater Dakar's various consumption zones (Dakar agglomeration, Thiès, and Mbour and other communities along Petite Côte):

- Wells drawing groundwater within and outside the zone;
- Water treatment facilities for raw water from Lac de Guiers.

126. To meet water demand for 2025 and 2035, SONES has invested in development projects with the following investment sequences:

- Completion of a 200,000 m^3/day drinking water treatment plant at Lac de Guiers with a transfer line; this is the KMS3 project, to be delivered in two phases: 100,000 m^3/day in 2021 and 100,000 m^3/day in 2022 following commissioning of the pressure boost for MEKHE2;
- Completion of a seawater desalination plant in Mamelles for 100,000 m^3/day, to be delivered in two phases: 50,000 m^3/day in 2023 and 50,000 m^3/day after 2026;
- Completion of a new water catchment in Diogo drawing from the Maastrichtian aquifer (50,000 m^3/day);
- Construction of a new water catchment in the Kaba/Toubatoul area drawing from the Eocene limestone aquifer (25,000 m^3/day)
- Completion of a seawater desalination plant along the Littoral Nord near Kayar, providing 200,000 m^3/day and expandable to 400,000 m^3/day or KMS4 (275,000 m^3/day) by 2030.

127. In parallel, an aquifer protection plan is recommended, with a reduction in withdrawals from the various water tables according to the updated calendar below. Given the delays in commissioning the KMS3 and Mamelles desalination plant and in order to balance needs and resources in the study zone up to 2035, the groundwater protection program should be updated as follows:

- Deadlines for reducing withdrawals planned for 2020 and 2021 should be postponed to 2024;
- Deadlines for 2026 should also be postponed to 2030 (see Table III.8 below):

Table III.8: Reducing Water Withdrawals from Aquifers

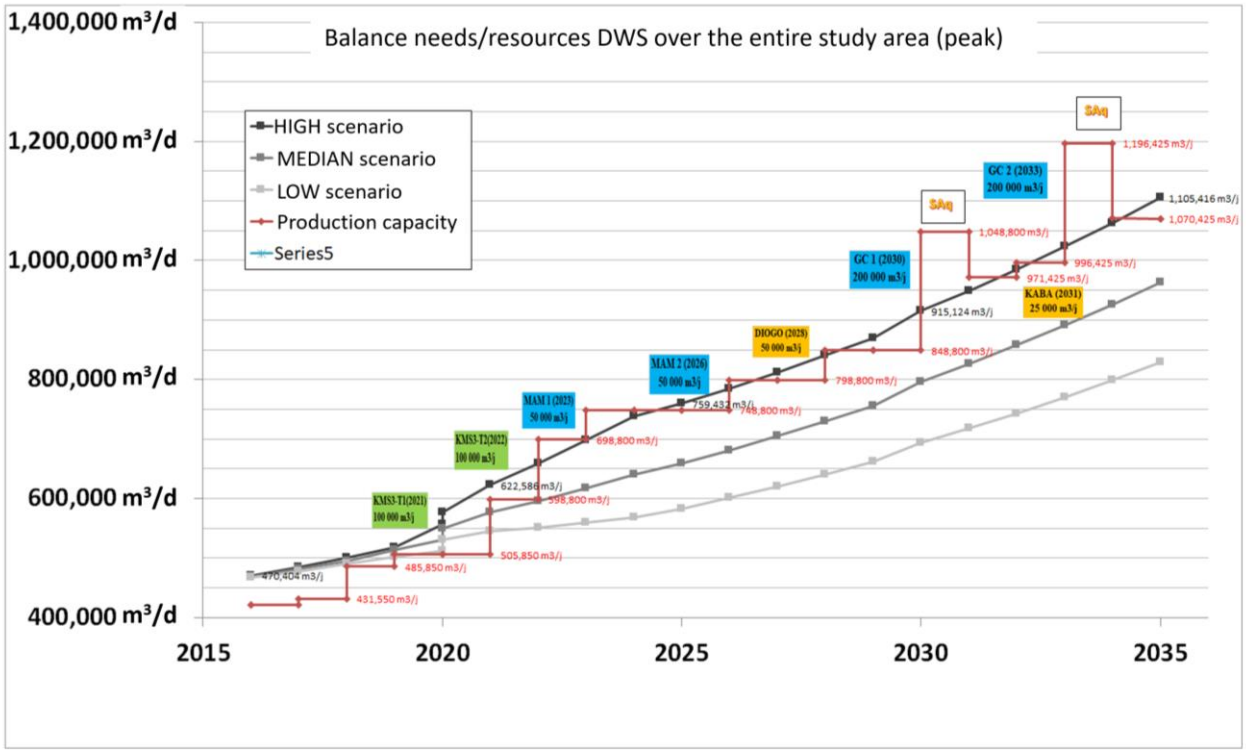
Year	Reducing Water Withdrawals from Aquifers
2024	Maastrichtian Protection Plan (Thiès, ALG system): -77,375 m^3/day
2030	Infra-Basaltic Protection Plan: -30,000 m^3/day Paleocene Protection Plan: -60,000 m^3/day Maastrichtian (Petite Côte) Protection Plan: -35,500 m^3/day

128. Reminder on meeting water demand for Greater Dakar for 2035:

Table III.9: Meet Water Demand for Greater Dakar – 2035

Water Needs/Production Capacity	2020	2025	2030	2035
Water needs, high scenario (m^3/day)	**577,467**	**759,432**	**915,124**	**1,105,416**
Well production capacity in 2020 (m^3/day)	318,500	318,500	318,500	318,500
Well withdrawal reduction plan (m^3/day)	0	-77,375	-125,500	0
Cumulative well withdrawal reductions (m^3/day)	0	-77,375	-202,875	-202,875
Lac de Guiers production plants (m^3/day)	185,000	385,000	385,000	385,000
Desalination plant production (m^3/day)	0	50,000	400,000	500,000
DIOGO water catchment production (m^3/day)	0	0	50,000	50,000
Kaba/Toubatoul water catchment production (m^3/day)	0	0	0	25,000
Total Production (m^3/day)	**498,800**	**671,425**	**845,925**	**1,070,925**
Surplus/Shortfall (m^3/day)	-78,667	-83,007	-69,199	-34,491
Additional Capacity Invest. (m^3/day)	**–**	**250,000**	**300,000**	**225,000**
New production capacities (m^3/day)	–	**KMS3: 100,000 (2021) KMS3: 100,000 (2022) M1: 50,000 in 2023**	**M2: 50,000 in 2026 Desal/GC1: 200,000 (2030) F. Diogo: 50,000 (2030)**	**Desal/GC2: 200,000 (2033) F. Kaba: 25,000 (2031)**

129. The graph below provides a schematic illustration of strategies for meeting water needs for peak periods in the Greater Dakar region from 2015 to 2035.



Forecasting Water Needs in DMT triangle for 2035–2050

130. The forecast for this need is based on data provided by Cabinet EDE for the Thiès and Mbour metropolitan areas; the growth rate for the Dakar agglomeration is declining.

Table III.10: Forecast for Water Needs by Zone – 2050

	2035	2040	2045	2050
Agglomération de Dakar	848,948	1,135,153	1,418,218	1,786,663
Métropole de Thiès	103,776	134,443	179,068	238,505
Mbour et la Petite Côte	152,692	280,729	327,025	380,956
Total Grand Dakar	**1,105,416**	**1,550,663**	**1,924,311**	**2,406,124**

Meeting DMT water needs for 2050

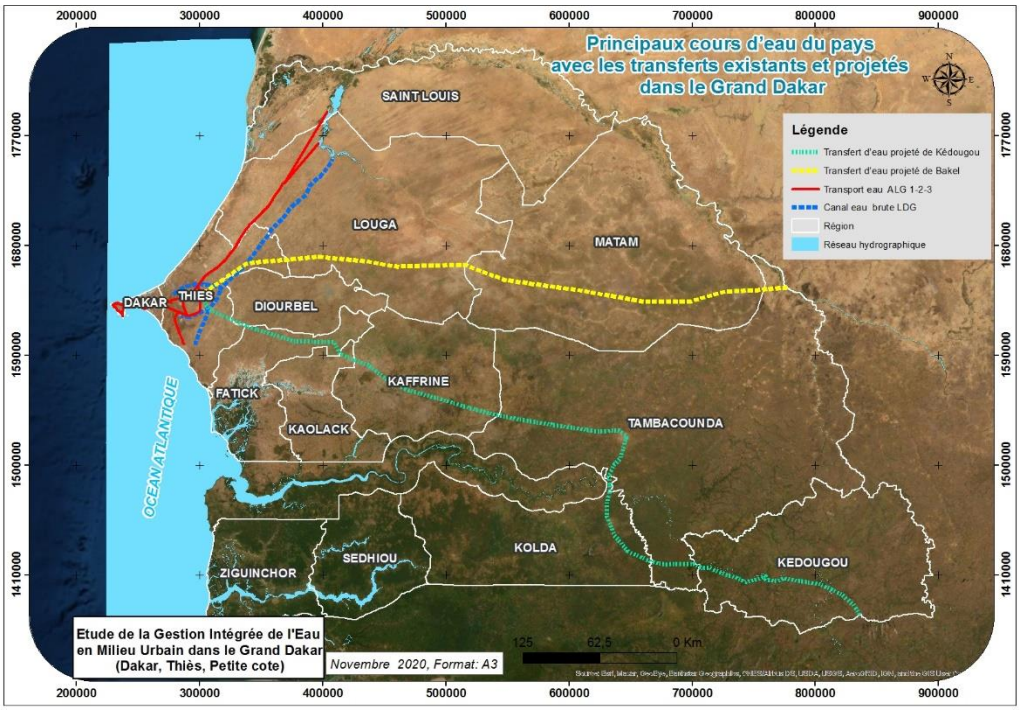
131. To preserve the residual capacity of the water tables being strained by high demand, the authorities have decided to meet the DMT triangle's water needs by mobilizing renewable water resources (shared rivers, desalination, etc.). Given the volumes of water involved for 2050 (approximately 20 m^3/second), SONES has considered four potential options for mobilizing water resources:

- Option 1: Transfer of gravity flow water supply by canal or pipeline from Lac de Guiers through the Bas Ferlo region
- Option 2: Transfer of gravity flow water supply from the Senegal River near Bakel
- Option 3: Transfer water through a gravity flow pipeline from the Gambia River in Kédougou region

132. Discussions with stakeholders revealed that a risk weighs on the water transfer to the DMT area from La dec Guiers, since the remainder of the quota allocated by the OMVS for Dakar drinking water supply (20 m^3/s) was transferred to the PREFERLO irrigation project. To secure the water supply of the DMT area by 2050, a request must be urgently submitted to the OMVS permanent water commission (*commission permanente des eaux*, CPE) for an allocation of additional water resources towards the long term solution.

133. All of these options are designed to meet drinking water and irrigation needs for 2050, with a target of water resources mobilized by desalination of at least 20 percent and ensure the preservation of aquifers. Water sanitation needs are essentially the same regardless of the proposed water supply system.

Map III.3: Routes for the three Options for Transfer of Surface Water



134. **Elements of multi-criteria analysis**: A multi-criteria analysis was used to examine these options. Before comparing the different proposed options, it is important to note the key objectives, which are to ensure:

- Water supply for the population
- Water supply for agriculture
- Financial accessibility for the population
- Financial accessibility for irrigation
- Sector's financial balance (cost recovery)
- Environmental protection and protection of over-exploited aquifers suffering from threats to water quality
- A circular economy, with the recycling of treated wastewater for specific water needs (agriculture, industry, replenishing, etc.)

135. In addition to these objectives, financial and institutional feasibility are also to be taken into consideration. The table below aims to show how each option responds to each of these requirements.

Table III.11: Evaluation Criteria for Proposed Options

	Option 1	Option 2	Option 3
Description of Investments	**Bas Ferlo-Thiès Canal/Pipeline[36]**	**Bakel-Thiès PRV Pipeline**	**Kédougou-Thiès PRV[37] Pipeline**
Volume available for population's needs	YES	YES	YES
Volume available for agricultural needs	YES In part	YES In part	YES In part
Amount of long-term investments (US$ million)	1,846	2,066	2,196
Total cost US$/m^3	0.078	0.108	0.122
Environmental protection	YES	YES	YES
Circular economy	YES	YES	YES
Accessibility of funding for investments	X	X	X
Supply on route	X	XX	XX
Degree of institutional complexity	XX	XX	XX

US$1 = CFAF 500. Note: "XX" indicates greater difficulty than single "X" in: (i) finding funding and (ii) encountering a more difficult institutional context (including dialogue with basin organizations such as the OMVS and OMVG).

136. The table reveals that the Kédougou and Bakel options are quite similar but involve institutional complexities in regard to the shared basin organizations (OMVS and OMVG) and related issues with supplying on route. Option 2 (canal or pipeline from the Bas Ferlo region) offers the most advantages as it is a gravity solution with less electricity costs, with water withdrawals below Lac de Guiers under increasing control. The distance from the water source to transfer is less than 200 km for option 1 compared to 600 or 700 km respectively for options 2 and 3. However, this solution (Option 2) needs further study, including technical, financial, institutional and environmental studies.

III.4.3. Developing DMT water infrastructures for 2035

137. The SONES investment program (2020–2026), which comprises KMS3 and Phase 1 of the Mamelles desalination facility, has already mobilized funding for the major infrastructures, with the exception of the second phase of the Mamelles desalination facility for 50,000 m^3/day.

138. The investment program intended to meet the water needs for the period 2030–2035 includes:

- Increasing water production: Lac de Guiers water plant (KMS4: 275,000 m^3/day) + Phase 1 of Grande Côte desalination facility (200,000 m^3/day) with associated structures (transfer pipelines, pressure booster, reservoirs, etc.);
- Strengthening water distribution structures (network rehabilitation and expansion, connections, leakage reduction program, water demand management, etc.);
- Defining a roadmap to prepare for a long-term solution (preliminary studies, perspective for mobilizing private funding, etc.).

139. For the sake of expediency, the Government could validly anticipate reflection on the long-term solution (Option 2) by launching technical, financial, and environmental studies immediately in order to be

[36] The cost of the canal was approximated from the prices of the contracts for the construction of PROGEP primary drainage canals.
[37] Cost of PRV approximated from its weight which is four times lighter than that of ductile iron. Investment amounts also include those relating to water treatment, storage, conveyance and distribution works, including the renewal and extension of networks, standpipes and connections.

able to program investments for 2030 in a timely manner.

Indicative Cost of Water Supply Investment Program for the Period 2030–2035

Table III.12: Option A – KMS4 and Grande Côte Desalination Phase 1

	Unit	Quantity	Cost (US$ million)	Funding
Grande Côte desalination Phase 1	m^3/day	200,000	247	To be mobilized
Grande Côte desalination Phase 2	m^3/day	200,000	247	
Reservoirs (installment 3: 2030-2035)	Km^3	–	30	
Rehabilitation of distribution networks	Km	500	60	
Expansion of distribution networks	Km	2,600	136	
Household (social) connections	u	171,000	25	
Institutional support/water security studies	Fixed price	–	10	
Total investments – Option A		**–**	**755**	

Table III.13: Option B – Transfer of Water from Bas Ferlo

	Unit	Quantity	Cost (US$ million)	Funding
Transfer of raw water from Bas Ferlo (200 km)	m^3/day	1,800,000	562	To be mobilized
Reservoirs (installment 3: 2030-2035)	Km^3	–	30	
Thiès water treatment plant (Phase 1)	m^3/day	600,000	220	
Rehabilitation of distribution networks	Km	500	60	
Expansion of distribution networks	Km	2,600	136	
Household (social) connections	u	171,000	25	
Institutional support/water security studies	Fixed Price	–	10	
Total investments – Option B		**–**	**1,033**	

140. Implementing the 2035 investment program for the high scenario shows that with Option A, there is a production deficit of roughly 34,500 m^3/day (see Table III-9), while Option B shows a surplus of 91,000 m^3/day. In this light, the advantage of considering implementing a long-term solution as of 2030 is clear, especially Option B (to be determined whether canal or pipeline), which appears to be the most favorable according to the multi-criteria analysis.

III.5. SANITATION IN DMT PRESENTS CHALLENGES AND MAJOR OPPORTUNITIES

III.5.1. Major Challenges for Wastewater Sanitation Services for 2035 and Beyond

141. **The lack of adequate sanitation structures for households and insufficient wastewater treatment pose a threat to public health and the environment.** In Senegal, the low quality of water for domestic use, the lack of wastewater treatment, and the poor management of stagnant waters lead to a high prevalence of waterborne diseases, with serious consequences for human capital and economic development. For example, in 2017, diarrhea led to the death of nearly 40,000 children under 5 (see Section II.1).

142. **Although the main urban centers in Greater Dakar (Dakar, Rufisque, Thiès, Mbour, Saly) have collective sewage networks with a total of 122,258 connections, individual sanitation systems**

remain most widely used. Only a small portion of the population enjoys safely managed sewage services. Significant gaps in collective sanitation must be overcome with regards to wastewater evacuation, transfer, and treatment. In Dakar, which is home to a large majority of infrastructures, over half of the wastewater evacuation network is in poor condition. Originally designed as separate systems, it also transports rainwater, which causes numerous network overflows during winterizing, constituting a real sanitary risk. With regards to individual sanitation, although progress has been made in fecal sludge collection and treatment, manual emptying is still common, and existing depository facilities are unable to treat all of the sludge and are operating in overload conditions. In addition to design, the installation and operation of individual systems are not subject to any oversight. In short, in terms of individual sanitation, public services are essentially non-existent, and when it comes to collective sanitation, service quality remains insufficient.

143. **Conditions for disposing treated wastewater into the environment must comply with Senegal's current standards, namely those provided in the Environment Code and Standard NS 05-061.** However, since the regulations are not being followed, the receiving environments are being polluted. Greater Dakar's high-water consumption leads to significant wastewater discharges, and without adequate treatment, these discharges will pollute the receiving environments. While 445,555 m^3 are consumed daily, the total capacity of Greater Dakar's wastewater treatment facilities is **35,531 m^3/day**. This means that only 25 percent of the wastewater collected (**126,000 m^3/day**) is treated. The rest pollutes the environment since it is released into the sea or seeps into the water table untreated. Moreover, the majority of independent sanitation systems were not installed according to technical standards and thus pollute groundwater. Industrial effluents are another significant source of pollution. The example of Hann Bay illustrates the impact the discharge of untreated industrial wastewater into the sea can have. Nitrate pollution of the Thiaroye water table clearly shows the impact inadequate wastewater systems have on groundwater resources, thus threatening their use and leading to major economic consequences. By 2035, this volume will increase dramatically, hence the paramount importance of wastewater sanitation.

144. **The quality of the treated wastewater still does not allow for its reuse for agricultural purposes. The volumes receiving tertiary treatment are estimated at 9,500 m^3/day, and only 1,800 m^3/day are reused.** In 2020, the volumes of treated wastewater in Greater Dakar are estimated at 35,531 m^3/day, which means that the majority of treated wastewater is released into the sea or receiving environments. However, their reuse in agriculture could help significantly reduce withdrawals from Greater Dakar's overexploited groundwater. Moreover, reusing treated wastewater could be a way for the agricultural sector to adapt to climate change. However, major potential users of this treated wastewater have not been identified, which makes the reuse even more difficult.

145. **Furthermore, funding for the sanitation sub-sector remains insufficient even though Senegal has shown political commitment to sanitation development.** Government budget allocations remain substantially below funding needs, which delays the completion of planned investments that still largely rely on external funding. Sanitation fees do not cover the operating costs of ONAS, which receives government subsidies. Thus, not only must the Government fund the necessary infrastructures, it must also establish funding mechanisms for their sustainable management.

III.5.2. Recommendations and Proposed Solutions for Wastewater Sanitation Services

146. The Emerging Senegal Plan (PSE) targets universal access to safely managed wastewater sanitation services. This will involve increasing access to improved structures while ensuring excreta containment as well as collection, transfer, and treatment of sludge and wastewater in complete safety. This will ensure proper household and urban sanitation and thus improve general sanitary conditions and avoid environmental pollution.

147. Promoting wastewater recycling in a circular economic perspective could be achieved through agricultural reuse or aquifer replenishing. In both cases, the water must be treated to allow its reuse without

posing any sanitary risk or having major environmental consequences. This reuse would constitute an alternative water source that could help reduce the effects of climate change. For agricultural use, there would need to be agricultural lands nearby, and the financial viability of this reuse would need to be assured.

148. Regarding the institutional and regulatory framework, the roles and responsibilities of those involved in providing sustainable sanitation services must be clarified. The legislative and regulatory framework must be updated (SPEPA law, Sanitation Code, establishment of a non-collective sanitation public service) and standards defined so as to create an environment conducive to the provision of safely managed sanitation services, especially for individual sanitation systems.

149. On a financial level, funding mechanisms must be established to ensure, plan, and carry out the necessary investments to expand access to safe services and ensure sustainable supply of these services. In particular, for collective sanitation, the urban sanitation reform must be implemented to delegate the operation of sanitation infrastructures to private companies in order to improve management performance.

150. Finally, a communication campaign should be implemented to inform households of the risks incurred by an improper sanitation system but also of current regulations to incite them to install individual sanitation systems or connect their homes to the collective network. Both social and commercial marketing methods could be used with the help of the private sector specialized in installing individual sanitation systems. In this regard, communication plans must be defined for the various target audiences.

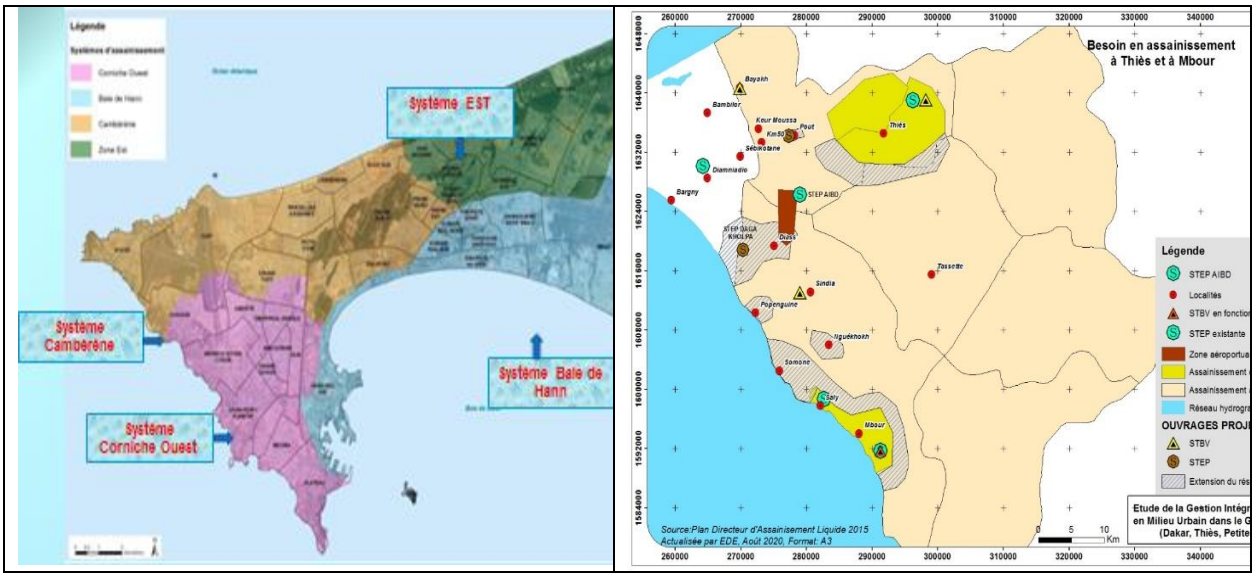
Proposed Solutions for Greater Dakar

151. So that all households have safely managed sanitation systems, collective and individual sanitation systems must be connected. Several Sanitation Master Plans (*plans directeurs d'assainissement*, PDA) with extended horizons have been exceeded will have to be updated (Bargny, Rufisque, etc.), sanitation options will have to be defined based on the PDA, and rigorous studies conducted to guarantee the sustainability and efficiency of the systems to be installed.

152. Collective sanitation will be consolidated in the cities already serviced (Dakar, Guédiawaye, Pikine, Rufisque, Mbour, Thiès, Saly). This will involve increasing supply by rehabilitating, densifying, and expanding current networks and increasing wastewater treatment capacities. In Dakar, network rehabilitation will impact the Corniche Ouest System, the Cambérene System, and central Rufisque. Network expansion will affect the Cambérene System and Hann Bay. In the Thiès area, network expansion will impact the Thiès System and the Petite Côte System. The construction of new collective networks and water treatment plants in other urban centers will be considered as part of the implementation of their PDA. For Dakar, this will concern the East System priority phase, North Rufisque, Bargny, and Sendon while for Thiès, it will concern the Petite Côte System. Increasing the treatment capacities and performances of Water Treatment Plants (STEP) will be achieved with a cumulative additional treatment capacity of 318,000 m^3/day in 2050.

153. Similarly, individual sanitation will be developed in compliance with the provisions of the PDA. It will be based on a technical package of infrastructures adapted to the local context to preserve groundwater and ensure excreta and wastewater management. Existing non-compliant structures will have to be rehabilitated or reinstalled where possible. Sludge management options are an integral part of the PDA. Sludge evacuation must be controlled, and the frequency of evacuations and system maintenance adhered to. As regards adequate sludge evacuation, capacity-building will be required for the Senegalese Association of Sanitation Stakeholders (AAAS) and evacuation and transport personnel. With regards to wastewater treatment, sludge treatment plants must be rehabilitated, and new plants built, with nine (9) sludge treatment plants to be built for a capacity of 24,000 m^3/day.

Map III.4: Sanitation System in Dakar and Thiès regions



154. To reach the reuse objective:

- Wastewater and sludge must be treated to allow for their reuse without posing sanitary risks for users or the environment;
- The Niayes area, which is threatened by urbanization, must be reserved for agricultural use;
- The concept of reuse must be acceptable both politically and socially;
- Transfer infrastructures to reuse areas must be installed;
- The institutional, regulatory, and organizational framework for wastewater reuse must be clearly defined to ensure investment sustainability.

III.5.3. Development of Sanitation Infrastructures

155. Infrastructure development will be refined via the Dakar and Rufisque PDA update studies by integrating Bargny. For Dakar, the new Ouakam-Ngor-Almadies-Yoff sub-system must be studied, while for Thiès, studies for the final design for the priority phase must be carried out. In regard to Saly, all technical studies (preliminary design, front-end engineering design, and tender documents) must be carried out.

156. Infrastructure development will therefore involve:

- Rehabilitating and securing Dakar's networks: network renewal in the Corniche Ouest and Cambérene system, strengthening the structuring network, and rehabilitation of the Hann Fann collection system.

- Installation and expansion of the wastewater collection network: (i) Dakar: Corniche Ouest interceptor and treatment plant; new Ouakam-Ngor-Almadies-Yoff sub-system with autonomous network; and works for the priority phase of the East System; (ii) Rufisque: expansion of the Rufisque network and construction of network at Bargny and Sendu taking into account the future mineral port and construction of a treatment plant north of the city in compliance with the recommendations of the Dakar Urban Master Plan (2035); (iii) Thiès: expansion and densification of the current sanitation network and construction of a sludge depository; iv) Mbour: new Petite Côte system.

- Strengthening of treatment capacities and performance with new STEP.

- Construction of individual sanitation structures, public lavatories, and new sludge treatment plants.

Table III.14: 2021–2050 Investment Program

Action	2020–2025	2025–2035	2035–2050
Institutional and regulatory technical studies	• Sanitation Master Plan (PDA) update • Completion of a front-end engineering design (APD) • Revision of the Sanitation Code • Revision of the SPEPA Law • Study to establish the public onsite sanitation service • Study on normalization of onsite sanitation solutions • Study on the legal and regulatory framework for reuse of treated wastewater		
Rehabilitation and securing of existing networks	234 km	100 km	
Expansion of the wastewater collection network	894 km	1,017 km	9,975 km
Connections to the sewer network (40%)	64,470 connections	63,500 connections	65,000 connections
WWTP additional treatment capacities and performance	190,509 m^3/day	95,500 m^3/day	190,000 m^3/day
Development of sludge treatment plants (STP)	1040 m^3/day	1300 m^3/day	790 m^3/day
Standardized onsite systems and public lavatories (PL) package	8,000 onsite systems and 200 PLs	41,325 onsite systems and 400 PLs	100,000 onsite systems and 600 PLs

III.6. STORMWATER AND FLOOD MANAGEMENT IN DMT TRIANGLE

III.6.1. Major challenges in stormwater management to 2035 and beyond

157. **Flooding has become a persistent problem due to demographic pressures and urban expansion,** the latter often unplanned for most cities in the Dakar, Mbour, and Thiès Triangle (see paragraph 96 for a description of the challenges linked to current stormwater management). Rural exodus toward cities has resulted in the rapid development of peri-urban areas, where there are several wetlands on which construction is usually forbidden. The stormwater sewer system classified by ONAS has a total length of 223 km, with 49 pumping stations and 16 stormwater reservoirs for runoff water storage. The area is marked by informal settlements over an area of 4,480 hectares in Dakar and 2,055 hectares in Pikine and Guédiawaye.

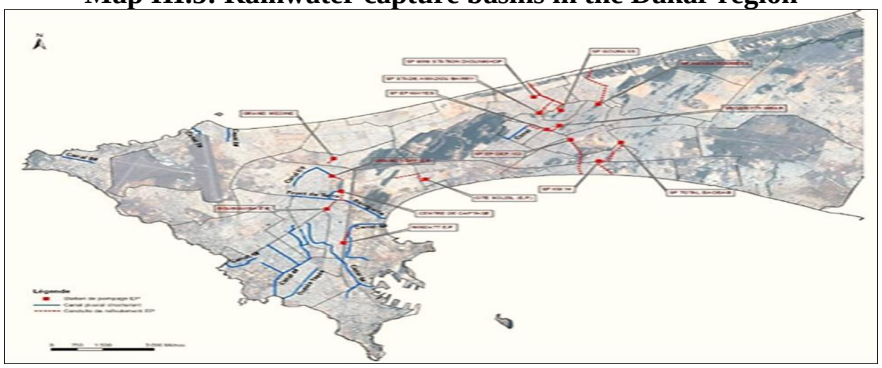
158. **Many runoff water capture systems have been created within the perimeter of Greater Dakar, mainly for agricultural use and livestock watering.** They range from water retention dikes to small hill dams, including retention ponds, groundwater accumulation and recharge facilities such as the Panthior dam not far from the village of Yenne Todd south of Sendou municipality as well as ponds, some of which are fed by runoff water collection. Most of these water storage facilities have been built across the valleys of the Somone (a forebay located near the RN1 highway at the exit to the Bandia reserve and the Thiéo, Kissane, and Bandia dams) or consist of the Bargny, Sébi-Ponty, and Sébikotane reservoirs (built by FiliFili), the Sébi-Dougar and Yenne Tod reservoirs, the valleys of Hanène, and Notto Diobasse in Notto municipality. Other small water retention works have been constructed by the DBRLA and BARVAFOR projects in Mont Rolland and the forest reserve of Thiès near Thiès None as well as in Fandène.

159. **Due to lack of monitoring and regular maintenance since they were built, first generation constructions (2000–2006) are no longer functional** as a result of the deterioration of dikes and small concrete works, and silting or filling of water retention basins. In the area between Bargny and Sébikotane, most of the catchment areas drained by water retention operations have gradually disappeared and been replaced by urban developments such as housing developments, the creation of the Diamniadio urban hub, and the Dakar-AIBD-Thiès toll road.

160. **Stormwater management in the city of Dakar varies according to area.** In the western section, approximately the area of Dakar Department except for its eastern limits, the rainwater drainage system rests on a framework of several open-air canals. This section is better equipped from the point of view of rainwater drainage, for two main reasons:

- First, this section saw the relatively gradual and planned establishment of a genuine urban fabric, which began in the southern tip at the start of the colonial era; infrastructure has therefore had time to develop;
- Second, its relatively regular and small-scale topography made it relatively easy to equip compared to the eastern section.

Map III.5: Rainwater capture basins in the Dakar region



161. In the eastern section, the problem is different. The landscape comprises mainly dead dunes and coastal beaches, with depressions of various sizes (the Niayes), some of which have water all year round because of the water table.

162. **There is no exhaustive inventory of the rainwater sewage system in the other urban centers in Greater Dakar.** A detailed review of Drainage Master Plans (PDA) leads to the following conclusions:

- **The city of Thiès** has an old sewage system designed in two parts, one comprising a perimeter network protecting the city from outside water, and the other to drain stormwater inside the city. However, work has not been completed. The current network is run-down and improperly sized and has many problems with silting, lack of maintenance, upkeep of channels, obstruction by domestic waste (people use the stormwater networks due to a lack of equipment for wastewater drainage), and some housing encroachment on the network.
- **The municipality of Saly** does not have a stormwater system. Stormwater is drained in certain places into a network designed exclusively for wastewater. This poses real problems in pumping stations and water treatment plants.
- **The stormwater drainage network in the city of Mbour** has the following structures:
    - A northern, gravity-operated, ocean-bound collector. The rectangular concrete channel has a combined total length of 2,432 meters and comprises a main branch and three (3) secondary branches;
    - A southern, gravity-operated, ocean-bound collector. The rectangular concrete channel has a combined total length of 6,304 meters and comprises a main branch and six (6) secondary branches;
    - A pumping station with an ocean-bound discharge line. The station is in good condition even though the network has some operational failings.

III.6.2. Recommendations and solutions for better stormwater management

163. The stormwater management strategy in the triangle is based on the following three (3) strategic axes:

Strategic Axis 1: Improve stormwater management by rehabilitating and extending stormwater drainage systems in the four (4) urban agglomerations.

164. The objective involves: (i) rehabilitating or replacing all the outdated and aging infrastructure and extending it; (ii) developing natural depressions such as stormwater retention basins in urban agglomerations in compliance with PDUs; and (iii) integrating the construction of new infrastructures (collector, water storage reservoir for industry, pumping station, runoff retention basin for recreational activities, etc.). This also involves rehabilitating and strengthening the protection of aquatic ecosystems to ensure that they remain sustainable and protect the environment.

Strategic Axis 2: Ensure closer coordination between actors working in the field

165. The MEA is the main sanitation actor in Senegal, working principally through the Directorate of Flood Prevention and Management (DPGI), the Sanitation Department, and ONAS. However, there has been a fragmentation of jurisdictions between the various ministries and local governments in terms of stormwater management. The Ministry responsible for urban planning, housing, and public hygiene, the Municipal Development Agency (ADM), the National Agency for Promoting Major Project Investment (APIX), and AGEROUTE all take part in creating stormwater drainage systems and related operations. In total, more than 12 actors have been identified in the planning, investment, and management of stormwater operations. The activities of actors across this strategic axis should be harmonized to avoid the overlapping

of jurisdictions and the dissipation of effort and financing.

Strategic Axis 3: Establish a sustainable financing mechanism for infrastructure and stormwater management

166. This will require establishing sustainable financing mechanisms for the stormwater sanitation sub-sector. For these financing mechanisms to be sustainable, they must be linked to the volume of infrastructure and level of service required. They must also keep fully transparent separate expenditure and resources accounts for both wastewater and stormwater sanitation.

III.6.3. Proposed solutions for sustainable stormwater management

167. The stormwater management investment plan stems from the first two strategic axes, i.e., rehabilitation and extension of current systems and coordination among actors. Table III.15 presents a summary of high-priority investments.

Table III.15

2021-2025	2026-2035	2036-2050
Rehabilitation of stormwater drainage systems (Dakar, Rufisque) – 100 km	Rehabilitation of stormwater drainage systems (Dakar, Rufisque) – 50 km	
Construction of new stormwater drainage systems in the DMT triangle (Phase 1): 200 km	Construction of new stormwater drainage systems in the DMT triangle (Phase 2): 150 km	Construction of new stormwater drainage systems (Phase 3): 100 km
Rehabilitation of natural depressions		
Rehabilitation of retention basins and construction of new basins		

168. **Implementing the investment plan will require institutional reform to strengthen governance in the stormwater management sector (Axis 2).** A key recommendation is that the Government of Senegal should clarify institutional responsibilities based on prior ONAS and ADM studies of stormwater management. The institutional analysis shows the positioning of several government, local government, and private actor organizations. The key actors involved in stormwater management in urban areas are:

- Ministry of Water and Sanitation (MEA)
- Senegalese National Sanitation Office (ONAS)
- Municipal Development Agency (ADM)
- Major Works Investment Promotion Agency (APIX)
- Road Management Agency (AGEROUTE)
- Municipalities.

169. Coordination between these actors is not effective enough to ensure consistency in investment, intervention, or sustainability of works. The second recommendation is that political decisions should formalize financing of the stormwater sanitation sector, for which current resources are still extremely limited with respect to the numerous technical, environmental, and socioeconomic constraints. The sustainability of stormwater management infrastructure will depend on how it is operated and maintained

since the drainage network will not operate correctly if channels are clogged.

170. Operations of works could profit from possible synergy with the operation of sanitation networks. However, stormwater management reform depends on a number of prerequisites:

- Greater clarification of the institutional framework among public actors and, especially, of the technical planning approach;
- Establishment of a sustainable financing mechanism linked to the volume of activity in terms of infrastructure and required level of service and fully transparent in terms of separating the accounts (expenditure and resources) of the sanitation of wastewater and stormwater;
- Urgently making an inventory of existing infrastructure and its rehabilitation (disconnecting wastewater from stormwater networks and vice versa) for improved management, thereby ensuring the durability of infrastructure.

III.7 IRRIGATION POTENTIAL IN THE DMT TRIANGLE

III.7.1 Major challenges in the irrigation sector in DMT to 2035 and beyond

171. **Competition with respect to development of the area and the use of water resources.** Horticulture in Greater Dakar is practiced on two types of land: dry and irrigated, and is one of the major economies in the area, accounting for 60 percent of national production and 80 percent of Senegal's fruit and vegetable exports. However, competition with respect to development of the area is a key factor when it comes to establishing and developing agriculture in Greater Dakar (see the *Niayes and North Littoral* hotspot, Section II.2 and Table II.3). The result is that urbanization is currently on the rise to the detriment of agriculture. Horticulturalists and pastoral operators are choosing to intensify production, increasing yield by surface unit, rather than working toward farming a larger area.

172. In the long term, drastic reduction in agricultural land seems probable, especially in the western part of Greater Dakar. In contrast, market gardening in the east on land in the municipalities of Tassette and Sindia seems more dynamic and robust than in the rest of the region. By 2050, a small increase in area under market gardening seems possible, but this will not be equal to the loss of agricultural land in the west.

173. The gradual disappearance of horticultural farms is linked to:

- Delays in adopting a legal and regulatory framework for the sector as recommended in the various development plans for the Niayes area initiated by the Government;
- Growing urbanization as a result of haphazard land use and the active presence of real estate developers;
- Installation of mining industries and the urban hubs of Diamniadio and Lake Retba in the area, threatening market gardening; and especially
- Lack of water in the territory. Note that the water tables of North Littoral and Horst de Diass, the main sources of water for horticulture in the area, are already severely undersupplied (Section II.1). One of this report's recommendations (Section II.3) is to establish more balanced management and development policies for land and water resources according to use and potential and with appropriate arbitration systems as needed.

174. Users of irrigation water include market gardening subscribers connected to the SONES drinking water public network and market gardening farms using independently and privately managed water (from production to distribution) at plot level. The latter are mainly private farmers, agribusiness, and pilot farms of the National Agricultural Insertion and Development Agency (ANIDA). Most market gardening farms linked to the SONES drinking water network are concentrated in four (4) distinct areas: Dakar/Rufisque, Sangalkam/Sébikotane, Keur Mousseu/Pout, and Mbour. Unfortunately, few data are available on horticultural activity outside the SONES network.

175. Irrigation water production infrastructure in SONES territory consisted initially of the Beer-Thialane catchment center north of Sébikotane. The pumping station in the Thiaroye boreholes was recently connected to the network at Point K, thus forming a network or embryonic irrigation network for the area's market gardeners only. This independent infrastructure will need to grow in the future to gradually include market gardeners connected to the public drinking water network. The transfer will require supporting measures (public awareness and investment) such as laying pipes parallel to the existing drinking water network and disconnecting or reconnecting to the new network.

176. Since water resources are increasingly scarce in the Greater Dakar area and expectations are that this will be one of the most significant handicaps to the area's development, greater efforts are needed to optimize the amount of freshwater used for horticulture; similarly, agricultural practices will have to be rationalized given that 85 percent of water pollution is attributed to them. Furthermore, market garden producers in the area are using growing quantities of chemical fertilizer and phytopharmaceutical products, usually without taking appropriate precautions. This situation requires greater monitoring to prevent irreversible damage to water tables, soils, and the environment in the area's market gardening hubs.

III.7.2. Satisfying demand for water for agriculture by 2035

177. To improve long-term irrigation planning and consistency within the requirement ratios for irrigation water in the intervention area, a study is necessary to improve knowledge on the spread and distribution of farms, catchment points, crop calendars, and water requirement ratios. It is also essential to establish an up-to-date database on horticultural activities, changes in irrigated areas, sources of water used and impact of farming practices on the quality of water resources, water usage metering, irrigation techniques practiced, and all other pertinent aspects. This will help the appropriate departments of the Ministry responsible for water to manage water resources in the region more effectively. In this regard, adequate resources will have to be provided to programs for monitoring agricultural and industrial usage of water and should be extended to the whole territory.

178. The key horticultural hubs in Greater Dakar are the following:

Table III.16: Spatial Distribution of Agricultural Hubs

Agricultural Hubs	**Sowable Areas (ha)**
Pikine Niayes	100
Filfili – Sébi – Ponty – Deni – Mbiriam – Keur Séga – Sococim – Bargny – Toll Road	2,000
Berr Thialane – Mbayakh – Diender – Notto Gouya Diama – Mbiridam – Pout – Keur Matar Guèye	1,400
Tassette (East Thiès)	10,540
Fandène – Notto (East Thiès)	5,000
Joal – Fadiouth	60
Kirène (East Thiès)	2,000
Pout – Keur Mousseu (East Thiès)	500
Total	**21,600**

179. **Irrigation water demands.** A decision was taken to base calculations of irrigation water requirements on actual data as much as possible based on reference documents and national agency statistics, specifically the Department of Horticulture of the Ministry of Agriculture and Rural Development (MAER), the Senegalese Agricultural Research Institute (ISRA/BAME), and the Macro-Economic Research Institute (BAME), and the Niayes Land Use and Economic Development Program (PADEN) rather than to correct them based on national averages. To make ratios of irrigation water requirements *in situ* as accurate as possible, the specific consumption for an onion crop in the Niayes area has been studied

based on the two main types of irrigation and on irrigation practices reported in the area. The two types of irrigation used are powered and manual, and irrigation parameters are shown in the table below.

Table III.17: Irrigation parameters in the Niayes area

Type of Irrigation	Number of Times Watered	Application Dose	Water Used
Motor pump	16 to 20	55 m^3/ha	9,000 m^3/ha
Manual	24 to30	28 m^3/ha	7,800 m^3/ha
Average	16 to 28	50 m^3/ha	8,500 m^3/ha

Source: PADEN activity reports

180. To make best use of the large volumes of water that have to be mobilized for horticulture in the area and significantly save on water use, manual watering will gradually be replaced by motorized watering. More water-economical irrigation techniques (spray and drip irrigation, installing irrigation management systems by measuring agricultural and soil parameters, etc.) will also be encouraged through various incentives to horticultural producers. Such improvements could reduce plot consumption by half (or 3,700 m^3/d per hectare per season). The volumes of water used economically per season are therefore assessed on this basis. Projections of demand for agricultural water in the Greater Dakar perimeter are as follows:

Table III.18: Projection of Agricultural Water Demand

PLANTED AREA (ha)/HORTICULTURAL WATER REQUIREMENT							
	Undeveloped Irrigation Practices			Improved Irrigation Techniques			
	2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Sowable areas (ha)	21,600	21,600	21,600	21,600	21,600	21,600	21,600
Water requirements (m^3/d)	503,014	503,014	503,014	218,960	218,960	218,960	218,960
Measures to be taken	Capacity-building period			Mobilization of additional dedicated water resources by transferring raw water and reusing it			

181. The strategy for supplying irrigation water to the Niayes area is based on the use of the following alternative water resources:

- *Mobilizing/Reactivating the water catchment areas of Beer-Thialane and Thiaroye:* As far as irrigation water is concerned, mobilizing alternative water resources for horticulture in the Niayes of Dakar and Thiès as part of the PDMAS project has strengthened the water supply for future agricultural users by constructing a pumping station with a production capacity of approximately 28,000 m^3/d from the catchment areas of Thiaroye and Beer-Thialane drawn from the 16 existing boreholes.
- *Reusing treated wastewater for irrigation:* There is real potential for reusing treated wastewater from 14 wastewater treatment plants; this could be a factor in the short, medium, and long terms and provide 132,000 m^3/d of treated water for irrigation in the tertiary sector.
- *Recycling stormwater for irrigation:* There is also potential for reusing runoff waters captured through small hillside reservoirs and retention basins. In total, 10 sites have been identified in Greater Dakar for constructing retention reservoirs for runoff waters. This seasonal water can be used profitably for irrigation.

- *Transferring raw water from Lac de Guiers:* This option could be implemented in the long term once the potential of local water resources has been exhausted.

III.7.3. Developing irrigation infrastructure in the DMT triangle to 2035

182. Demand for irrigation water in the Greater Dakar perimeter was assessed at approximately 503,000 m^3/d in 2020 for an easily irrigable potential of 21,600 hectares. These water requirements have been calculated with reference to current irrigation practices, which are water inefficient and far above the renewable potential of underground water resources in the area (186,000 m^3/d – or 68 Mm^3/year, distributed as follows: between 25 and 38 Mm^3/year in North Littoral and 30 Mm^3/year in the Niayes area [67.9 Mm^3/year], see Section II.1), an area that is already overexploited, all uses combined. Planning documents for the horticulture sector show that using more efficient irrigation techniques (drip irrigation, etc.), strengthening the capacities of market gardeners in sustainable farming methods, and using modern technology could change this trend in demand for agricultural water. The possibility of using alternative water sources must be encouraged given that several initiatives could be developed and strengthened further in the area (retention basins, hillside reservoirs, reusing treated wastewater, managed public irrigation infrastructure, etc.) to reduce pressure on water resources, which are increasingly more costly to mobilize. The table below shows requirements in agricultural water and the potential for reusing alternative water sources, which is estimated at 30,000 m^3/d in 2020. This potential does not include retention basins or hillside reservoirs in the area, which could store 1 Mm^3/year of water with an identified potential of 5 Mm^3/year.

Table III.19: Demand for Agricultural Water and Reuse Capacity of STEP water in Greater Dakar

No.	Agricultural Hubs	Cultivable Areas (ha)	Actual Consumption (m^3/ha/year)	Water Requirements (m^3/d)	Irrigation Infrastructures	Existing Capacity STEP (m^3/d)	Reuse Capacity (2020) (m^3/d)	Reuse Capacity (2030) (m^3/d)
1	Pikine Niayes	100	8,500	2,300	STEP Cambérène	19,200	960	1,840
2	Filfili – Sébi – Ponty – Deni B. Ndao, Niaga, Sangalkam, Sococim, Bargny Toll Road	2,000	8,500	46,600	Thiaroye Pt K STEP Tivaouane P. STEP Rufisque STEP Diamniadio Private	14,000 2,525 2,855 2,500	14,000 126 143 125	14,000 126 571 500
3	Beer-Thialane, Mbayakh, Diender, Mbirdiam, Keur Séga, Notto Gouya Diama,	1,400	8,500	32,600	Beer-Thialane Private	14,000	14,000	14,000
4	Pout – Keur Mousseu	500	8,500	11,600	Beer-Thialane Private			

5	Fandène, Notto Diobass	5,000	8,500	116,600	STEP Thiès Private	3,000	150	150
6	Kirène	2,000	8,500	46,600	STEP AIBD Private			
7	Tassette	10,540	8,500	245,500	STEP Saly/Mbour Private	2,620	131	2,161
8	Joal – Fadiouth	60	8,500	1,400	STEP Joal	2,000	100	400
Total		**21,600**	**8,500**	**503,200**		**62,700**	**29,735**	**33,748**

183. The investment program meant to satisfy irrigation requirements in Greater Dakar over the 2020–2035 period is structured around three (3) axes:

- **Short term (2022–2025):** Program to support the modernization of irrigation by: (i) strengthening the capacities of market gardeners in water-efficient farming practices, irrigation techniques, and use and maintenance of equipment; (ii) rehabilitating and expanding current irrigation infrastructures (water transfer from Thiaroye, Beer-Thialane, retention basins and hillside reservoirs, etc.), reframing work management methods; and (iii) carrying out feasibility studies for reusing purified wastewater and runoff water capture for agriculture use.
- **Medium term (2025–2035):** Implementing high-priority investments by mobilizing alternative sources of water (treated wastewater and stormwater) for the area's irrigation needs, including establishing an institutional, organizational, and regulatory framework for managing these new works.
- **Long term (2035–2050):** Carrying out studies and implementing raw water transfer to satisfy agricultural needs not already covered.

III.8. SUMMARY OF STRATEGIC ORIENTATIONS

184. The first strategic orientations that can be drawn from this analytical study of the DMT zones are the following:

Water resources management

- Implement a program for resting groundwater extraction starting in 2022 for the Pout compartment (South Pout and Pout Kirène), the northern littoral (Quaternary sands and Eocene limestones), the Maastrichtian sandbars to the south of the Horst de Diass aquifer, the Mbour limestone compartment, and Dakar's coastal strip of the infra-basaltic sandbars.
- Strengthen the transit of the Taouey canal for Lac de Guiers water supply and its protection against pollution.
- Prepare a request for an allocation of an additional 30m^3/s from the OMVS Permanent Water Commission for potable water supply to Greater Dakar.
- Establish an aquifer recharge program from treated wastewater and runoff water catpure.
- Rehabilitate wetlands and topographic depressions, in particular in the Niayes area and in the Somone valley.

Drinking water

- Reach SDG 6.1 by 2030 and ensure hookup access for 100 percent of the population and industries of the DMT triangle to quality and safely managed drinking water services.
- Ensure a safe water supply hookup for all schools, health centers, and public places.
- Ensure long-term water security through a mix of groundwater, water desalination, and renewable surface water.
- Update studies with a view to selecting the best water transfer option of 30 m^3/s between Lac de Guiers and the DMT area to complement the new desalination plant in the lac Rose area.
- Strengthen the public-private partnership (PPP) and study the possibility of realizing the transfer of water from Lac de Guiers and the desalination plant through a combination of private and public financing.
- Establish a long-term water demand management strategy through the establishment of dissuasive pricing, combating physical and commercial water loss, raising the population's awareness, and establishing a program for reducing administrative and household water consumption.
- Implement preventive measures with water service operators in order to face future health crises.
- Strengthen drinking water supply in the Mbour area by using the Lac de Guiers network.
- Encourage SONES and SEN'EAU to adopt new technologies in sector management in particular through the generalization of intelligent meters and mobile payment methods.
- Strengthen the sector's adaptation to climate change by adopting new construction standards for water structures.

Wastewater treatment

- Reach SDG 6.2 by 2030 and ensure access of 80 percent of the DMT triangle's population to adequate sanitation and hygiene services and end outdoor defecation, paying particular attention to the needs of women, girls, and vulnerable persons.
- Increase the wastewater and excreta treatment rate from 15 percent in 2020 to 50 percent in 2035.
- Increase the rate of reuse of treated wastewater for agriculture and aquifer recharge purposes from 5 percent in 2020 to 30 percent in 2035.
- Elaborate and implement a proactive program for the systematic reuse of wastewater and excreta.
- Get the private sector more involved in sector management.
- Ensure sustainable financing of the wastewater treatment sub-sector in urban areas.
- Ensure correct wastewater treatment for all schools, health centers and public places.
- Implement preventive measures with water treatment service operators in order to face future health crises.
- Strengthen the role of the National Sanitation Office (ONAS) as an asset management company and confine the operational management of wastewater and excreta to the private sector.

- Encourage ONAS to adopt new technologies and strengthen its resilience and capacity for adapting to climate change.

Rainwater treatment

- Proceed with the rehabilitation and extension of rainwater drainage systems in the four urban agglomerations.
- Ensure better coordination of actor intervention.
- Establish a sustainable financing mechanism for infrastructures and rainwater management.

Water for agricultural purposes

- Reactivate the Beer Thialane and Thiaroye catchment fields and reinforce the associated irrigation system for a production capacity of 28,000 m^3/d to meet the farmers' water needs in the area.
- Establish the principles of a circular economy through the development of programs for the reuse of treated rainwater and wastewater for agriculture.
- Establish a legal and regulatory framework securing the cultivation of agricultural land in the Niayes area.
- Set up an umbrella structure in charge of agricultural development in the Niayes area.
- Establish a program for equipping market gardeners with water-saving materials.

Water platform

- Establish a multi-sector and multi-actor collaboration platform in order to strengthen water governance in greater Dakar, aimed at re-establishing and maintaining balance between the use of water resources, the preservation, and the protection of these resources.
- Identify future multi-sector projects that may serve as justification for launching the water platform in the DMT area and bring it to life in order to establish its sustainability as a pilot experiment to be scaled up throughout the country, in particular in hotspots.
- The current steering committee (COPIL) of the study where all sectors related to water are represented and discussing the water security approach, will serve as a springboard for the construction of the future water platform, pending the installation of the bodies mentioned in the water law (code) under preparation; namely the National Water Council (CSE), the Technical Water Committee (CTE), and regional and local water platforms that will be set up at the end of the validation process of the Water Development and Management Master Plan (SDAGE) at basin level, and the Water Management Plans (PGE) at local level. The COPIL will be maintained and served as a forum for dialogue between stakeholders and actors for the formulation of a future project in the DMT area. It will benefit from the support and technical assistance dedicated to water platforms by the WRG 2030.

III.9. GOVERNMENTAL DMT TRIANGLE WATER SECURITY INVESTMENT PROGRAM FOR 2035

185. Following an exhaustive review of the problems identified in the DMT area in terms of water resources management and services associated with water, it is important that the next Governmental Investment Program in the area address these issues in a holistic and integrated manner in order to take into account the water cycle and to work toward buffering climate deterioration and laying down the foundations of a long process of re-establishing natural ecosystems in the area. This investment program will be developed around the following axes: (i) protection, preservation, and development of water resources in order to satisfy water needs in the area on a short-, medium-, and long-term basis; (ii) design and implementation a robust solution for satisfying water needs for all uses in a safe and sustainable manner; (iii) experiment with water conservation techniques in order to control water demand and effectively combat water loss and waste; (iv) development of efficient water treatment services within a circular economy, environmental protection, and the development of water sanitation and wastewater by-products; (v) implementation of a construction program for rainwater drainage infrastructures, and especially protective structures against flooding that will allow the ecological function of natural watercourses to be restored; and (vi) capacity building of actors in the irrigation sector, promotion of water-saving irrigation techniques, development of existing public irrigation infrastructure in the area and setup of an institutional, regulatory and contractual framework appropriate to entrust the management of these structures to the private sector.

186. In pragmatic terms, the investment program should aim to satisfy short-term needs identified in the area and prepare the long-term vision through bold actions in order to establish water security in the DMT area. The options considered were retained following discussions by sub-sector with the ministerial agencies and institutions. The proposed global investment program is broken down by sub-sector, as follows.

III.9.1. Developing infrastructures for sustainable water resources management

187. The integrated consolidated investment program to ensure water security for the 2025–2035 period is based on the above-mentioned strategic orientations and summarized in the table below:

Table III.20: Integrated consolidated investment program

Activities	**Projected costs (US$)**		
	2020–2025 Phase 1	**2025–2035 Phase 2**	**2035–2050 Phase 3**
Strengthening the legislative and institutional framework	–	–	–
Strengthening hydraulic transit from Taouey and improving Lac de Guiers hydraulicity	38,520,000		
Artificial aquifer recharge	1,545,000	9,225,000	9,225,000
(i) Recharge by rainwater	*750,000*	*6,750,000*	*6,750,000*
(ii) Recharge by treated wastewater	*795,000*	*2,475,000*	*2,475,000*

Put in place protective measures for securing Lac de Guiers (structural works, quality monitoring, security measures)	6,000,000	12,000,000	12,000,000
Restore and protect aquatic ecosystems: Somone Lagoon, Niayes areas in Pikine, Lake Tamna, Lake Rose, the Mbao Backwaters, and water retention reservoirs (Phase 1)	10,000,000	22,000,000	22,000,000
TOTAL	**56,065,000**	**43,225,000**	**43,225,000**

US$1 = CFAF 500

III.9.2. Developing drinking water infrastructures for the DMT triangle by 2035

188. To satisfy DMT water needs, the implementation of the investment program by 2035 for the high scenario shows that with Option 1 (variant A), a production deficit of 34,500 m^3/d is noted compared with a surplus of 91,000 m^3/d for Option 1 (variant B), hence the need to consider as early as 2030 the implementation of the long-term solution, in particular Option 1 (whether channels or pipelines to be determined) that seems most advantageous according to the multi-criteria analyses.

Table III.21: Option 2 – Water transfer from the Bas Ferlo Valley

	Unit	Quantity	Cost (US$ million)	Financing
Raw water transfer from the Bas Ferlo Valley	m^3/d	1,800,000	562	To be researched
Reservoirs	m^3	–	30	
Thiès water treatment plant (phase 1)	m^3/d	600,000	220	
Rehabilitation of distribution networks	Km	500	60	
Extension of distribution networks	Km	2,600	136	
Household water connections	U	171,000	25	
Institutional support/Water security studies	Flat fee	–	10	
Total investments – Option 1 (variant B)		**–**	**1,043**	

III.9.3. Developing DMT wastewater treatment infrastructures by 2035

189. The investment program for wastewater treatment in the DMT perimeter will be oriented toward four (4) main axes:

- Consolidation of collective wastewater treatment in cities already equipped (Dakar, Guédiawaye, Pkine, Rufisque, Mbour, Thiès, Joal);
- Development of independent wastewater treatment sectors in non-equipped areas, in particular peri-urban areas, and development of wastewater treatment by-products;
- Increasing wastewater treatment capacities with a view to improved environmental protection, in particular aquatic ecosystems;
- Recycling secondary and tertiary treated wastewater for aquifer recharge needs and provision of alternative water resources for irrigation needs.

190. This investment program is summarized in the table below:

Table III.22: 2021–2050 Investment Program

	Projected costs (US$))		
Actions	**2020–2025**	**2025–2035**	**2035–2050**
Technical, institutional and regulatory studies / Financing mechanisms - Revision of the SPEPA law - Revision of the sanitation code - Studies for the standardization of autonomous sanitation works - Study of the implementation of the public service of autonomous sanitation - Study of the reform of urban sanitation - Study of the legislative and regulatory framework for the reuse of treated wastewater - Update of the investment program	680 000		
Access to safely managed sanitation services: - PDA, APD/DAO studies, etc. - Renewal and extension of networks - Rehabilitation and extension of STEP/STBV - Construction of sewer connections - Construction of public toilets	433 800 000	299 800 000	404 400 000
Promotion of wastewater reuse - Technical and financial studies of the reuse of treated wastewater - Technical studies of aquifer recharge systems - Construction of structures for the reuse of treated wastewater - - Construction of groundwater recharge works	12 243 000	10 070 000	9 683 000
TOTAL	**446 723 000**	**309 870 000**	**414 083 000**

1 US$ = 500 CFAF

III.9.4. Developing infrastructures for sustainable stormwater management in DMT

191. The investment program for stormwater management stems from the first two strategic axes being retained, namely rehabilitation and extension of existing systems.

Table III.23: 2021–2050 Stormwater Investment Program

2021–2025	2026–2035	2036–2050	Costs (M US$)
Rehabilitation of rainwater drainage systems (Dakar, Rufisque)	Rehabilitation of rainwater drainage systems (Dakar, Rufisque)		92
Realization of new rainwater drainage systems in DMT triangle (Phase 1)	Realization of new rainwater drainage systems (Phase 2)	Realization of new rainwater drainage systems (Phase 3)	231.6

Rehabilitation of natural topical depressions			46.4
Rehabilitation of catchment basins and construction of new basins			74
Investments total			**444**

III.9.5. Developing irrigation infrastructures in DMT by the year 2035

Table III.24: Indicative price of Agricultural Water Investment Program for 2022–2025

Main activities	**Cost (US$ million)**	**Financing**
Promoting irrigation practices and water-saving technologies and strengthening irrigator capacity	3	To be researched
Improving knowledge of uses, users, catchment structures, and withdrawal control	4	
Extending Thiaroye-Beer Thialane transfer system and promoting delegated management of agriculture water services	20	
Rehabilitating catchment basins and hillside retention reservoirs	10	
Conducting feasibility studies for reuse of purified wastewater and catchment of run-off water for agricultural use	3	
Providing project management and institutional support, strengthening capacities, and providing institutional and organizational framework for the irrigation sector	10	
Total investments	**50**	

Priority integrated program for water security in the DMT zone: US$1,530 million

192. The global investment program for ensuring water security by 2050 in the greater Dakar area has been broken down into three (3) phases: Phase 1 (2020–2025); Phase 2 (2025–2035); and Phase 3 (2035–2050). Each sub-program is articulated around the following activities: (i) providing institutional support and strengthening the institutional and regulatory framework for the sub-sector; (ii) rehabilitating and improving the efficiency of service provision; (iii) strengthening and extending infrastructures; and (iv) developing innovative techniques and strengthening actors' capacities.

193. The cost estimate was made in reference to similar national-level investment programs or in other regions of the world. It is understood that the development of retained solutions must be subject to in-depth studies at the technical, financial, environmental, social, institutional, and legal levels. The table below breaks down investments by sub-sector. Priority actions included in the program have been identified on the basis of occurrence of risks (durability or availability of water resources, water shortages, pollution, etc.) and of contributions to water service and environmental protection sustainability. The breakdown into phases allows for absorption capacities of the sector of financing to be taken into account while trying to maintain interventional coherence.

Table III.25: Integrated Governmental Water Security Program for Greater Dakar and identified priority actions

No.	ACTIVITIES	Projected costs (US$ million)					REMARKS
		Phase 1	Phase 2	Phase 3	Program	Program	
		2020–2025	2025–2035	2035–2050	TOTAL	Priority	
I	**WATER RESOURCES MANAGEMENT**						
1	Strengthening legislative and institutional framework	3.00			3.00	3.00	Overhaul of Water Code and strengthening DGPRE
2	Strengthening hydraulic transit from Taouey	38.52			38.52	38.52	Strengthening Lac de Guiers supply via Taouey River
3	Artificial aquifer recharge	1.55	9.23	9.23	20.00	10.77	Aquifer recharge through recycling purified water and rainwater storage
4	Protecting and securing Lac de Guiers	6.00	12.00	12.00	30.00	18.00	Structural works, quality control, security measures
5	Restoration and safeguard of aquatic ecosystems (lagoons, lakes, backwater)	10.00	22.00	22.00	54.00	10.00	Restoration of DMT wet zones
	TOTAL WATER RESOURCES MANAGEMENT	**59.07**	**43.23**	**43.23**	**145.52**	**80.29**	
II	**PROVISION OF DRINKING WATER (Option 1)**						
1	Raw water transfer from Bas Ferlo Valley		300.00	262.00	562.00	300.00	Transfer of gravity-fed water by channels or pipes
2	Storage reservoirs		20.00	10.00	30.00	30.00	
3	Thiès water plant		100.00	120.00	220.00	100.00	
4	Rehabilitation and extension of distribution networks and hookups		50.00	161.00	221.00	60.00	
5	Institutional support and water security studies	5.00	5.00		10.00	10.00	Technical, financial, environmental and social studies

	TOTAL PDW GREATER DAKAR	**5.00**	**495.00**	**553.00**	**1,043.00**	**500.00**	
III	**WASTEWATER TREATMENT**						
1	Rehabilitating and securing existing networks	100.00	50.00	64.00	214.00	100.00	Rehabilitation of large water collectors: Hann-Fann, Main, etc.
2	Sewage treatment plants (STEP)	90.00	55.00	102.00	247.00	90.00	
3	Sewage sludge treatment plants (STBV)	50.00	50.00	50.00	150.00	100.00	
4	Extension of collection network and hookups to sewer system	100.00	50.00	100.00	250.00	100.00	Development of access by collective network
5	Development of independent wastewater treatment sectors	100.00	100.00	100.00	300.00	100.00	Development of access and independent wastewater treatment sectors
6	Technical, financial, institutional, and regulatory studies	5.00	5.00		10.00	10.00	Technical, financial, environmental and social studies
	TOTAL WASTEWATER TREATMENT	**445.00**	**310.00**	**416.00**	**1,171.00**	**500.00**	
IV	**RAINWATER DRAINAGE**						
1	Rehabilitation of rainwater drainage systems (Dakar, Rufisque)	50.00	40.00		90.00	90.00	Overhaul Water Code and strengthening DGPRE
2	Realization of new rainwater drainage systems	100.00	90.00	40.00	230.00	190.00	Extension of rainwater drainage network
3	Rehabilitation of natural topical depressions	20.00	20.00	4.00	44.00	40.00	Revitalization of wet zones

4	Rehabilitation of catchment basins and construction of new basins	25.00	50.00		75.00	75.00	Construction of storm basins and rainwater catchment basins
5	Institutional support for the reform of rainwater drainage system management	5.00			5.00	5.00	Strengthening of rainwater drainage management
	TOTAL PUBLIC FACILITIES DRAINAGE	**200.00**	**200.00**	**44.00**	**444.00**	**400.00**	
V	**IRRIGATION WATER**						
1	Strengthening irrigator capacity and promoting water-saving practices and technologies	1.50	1.50		3.00	3.00	Promoting water-saving techniques for irrigation water
2	Improving knowledge of uses, users, catchment, and withdrawal control	2.00	2.00		4.00	4.00	
3	Extension of the water transfer system from Thiaroye–Beer Thialane and promoting delegated management of agricultural water services	10.00	10.00		20.00	20.00	Development of public irrigation system
4	Rehabilitating catchment basins and hillside retention reservoirs	5.00	5.00		10.00	10.00	
5	Feasibility studies for reuse of wastewater and catchment of run-off water for agricultural use	1.50	1.50		3.00	3.00	Technical, financial, environmental and social studies
6	Strengthening capacities and institutional and organizational	5.00	5.00		10.00	10.00	Strengthening institutional and organizational framework of irrigation sector

	framework of irrigation sector						
	TOTAL IRRIGATION	**20.00**	**25.00**	**0.00**	**50.00**	**50.00**	

	PRIORITY GOVERNMENTAL PROGRAM (Phases 1 & 2)	**734.07**	**1,063.23**	**1,056.23**	**2,853.52**	**1,530.29**	

III.10. ECONOMIC ANALYSIS

III.10.1. Economic situation of the DMT area

194. The Dakar-Mbour-Thiès triangle is home to Senegal's largest conurbations and several other future urban growth hubs whose development is driven by the key sectors of industry, mining, tourism, fisheries, and urban agriculture. The urbanization rate is the highest in the country, the triangle being home to 51 percent of Senegal's urban population while covering only 2.1 percent of the territory. The 2019 ANSD report on the economic and social situation in the Dakar region indicated that it is Senegal's leading economic hub, contributing over 50 percent of national GDP. The Dakar region accounts for 39.5 percent of firms in Senegal, or 160,031 economic units according to the 2016 General Census of Enterprises (*Recensement Général des Entreprises*, RGE). According to the same source, it concentrates 51.7 percent of the 844,268 employed workers. According to the August 2018 ANSD report on the economic and social situation in the Thiès region, it has the second-greatest economic potential behind Dakar itself. It occupies this elevated economic position thanks primarily to the dynamism of its horticulture, tourism, industry, and fisheries sectors.

195. **With regard to agriculture,** the Niayes area produces two-thirds of the country's fruit and vegetables, thanks in particular to the fertility of its soils. Of the 837 production sites identified throughout the Niayes strip from Dakar to Saint-Louis, about half are located within the triangle in the municipalities of Bambilor, Keur Moussa, and Diender Guedj. In general, horticulture occupies an important place in the Senegalese economy thanks to the value generated by its exports. It plays an important role in food security, poverty reduction, the creation of productive and sustainable jobs, and the balance of payments. The objective is to contribute to Senegal's economic growth by improving the productivity and competitiveness of its horticulture via a value chain approach. The Thiès-Mbour axis forms the second-largest agricultural hub in the DMT triangle after the Niayes strip. This axis has considerable land use and hydrogeological potential.

196. **With regard to fisheries,** the cities of Mbour, Kayar, and Rufisque make the DMT triangle Senegal's leading artisanal fishing hub. The Thiès region provides 55 percent of the country's fisheries catch, ranking it first, ahead of Dakar in third place. In 2019, nationwide artisanal fishing landed 451,963 tons, ahead of industrial fishing with 114,729 tons. Their respective market values were CFAF 182 billion and 81 billion. The DMT triangle accounts for a very large share of fisheries activity in Senegal. Together, Thiès' dual coastline (north and south) and the coast of Dakar form a region characterized by important fishing and related processing activities (Dakar had 94 processing plants in 2018).

197. **Tourism** is highly developed in the triangle thanks to conducive conditions provided by attractive beaches, the proximity of the urban agglomeration of Dakar, the mild climate, and appropriate infrastructure. The triangle is the country's leading tourism area, with 70.6 percent of accommodation capacity in 2018. Mbour department is the second-largest tourism hub, with 23.4 percent of accommodation capacity. Tourism-related offerings are primarily concentrated between Saly Portudal, Nianning, Somone,

and Toubab Dialaw. Mbour's relative importance will increase with the new developments planned by SAPCO along Petite Côte in Pointe Sarène, Mbodiène, and Joal. To revive the tourism sector, which has been hit hard by the COVID-19 pandemic, the tourism ministerial department concerned has developed a new tourism and air transport development strategy for the period 2020–2025. The ambition is to raise the level of revenue from CFAF 710 billion to CFAF 1 trillion between 2018 and 2025 and the number of visitors to approximately 1,500,000.

198. **Mining is highly developed.** The triangle's subsoil is rich in minerals such as attapulgite, phosphate, limestone, basalt, sandstone, and sand. This area is also the country's leading mining hub and one of Senegal's most dynamic regions in terms of the production and exploitation of mines and quarries, as evidenced by the presence of large mining companies such as the Senegalese Chemical Corporation (ICS), which mines phosphate, Cimenteries du Sahel, SOCOCIM, and Dangote. These cement makers produce more than the country's needs. According to the ANDS report, the region had 28 quarries in 2015 compared with 71 in 2014. Most of these quarries mine limestone.

199. **With regard to infrastructure,** this area is home to the Blaise Diagne International Airport (AIBD), the Integrated Special Economic Zone (ZESI), the urban areas of Diamniadio, Diass, and Lake Rose, the Diamniadio industrial park, and Dakar's second university, among others. From this viewpoint, urban planners and utilities managers (water and sanitation, housing, etc.) play a vital role in sustaining growth and improving and diversifying service offerings, particularly for drinking water, agricultural water, flood management, and sanitation. In this context, the water security strategy for the sustainability of water resources and related services in Greater Dakar takes on particular significance thanks to its specific character, its national role, the spatial distribution of its population, and the characteristics of its economic fabric.

200. To conclude the review of its main economic sectors, the DMT area is the subject of a spatial development plan that is central to Senegal's future: it is a highly strategic area, receiving major anchor projects already under way or planned. Water security is vital to the success of this development plan.

III.10.2. Analysis of costs, benefits, and externalities of proposed investments

201. The proposed options are designed to meet demand for drinking water to 2050 while safeguarding aquifers, including by generating freshwater via the desalination of seawater (300,000 m^3/day). While Option 1, which is based on increasing the number of KMS plants, is formulated to meet demand for drinking water, the three other options provide a flow rate of 1,675,000 m^3/day from 2035, allowing surplus water to be released for irrigation. Only one plan is proposed for sanitation.

Drinking water supply and irrigation

202. An overview of the four options proposed to supply drinking water to the DTM area is provided in Table III.11. Option 1 is reserved exclusively for drinking water supply.

203. The table suggests that Option 2 (Bas Ferlo/Thiès transfer) has the lowest cost while Option 1 (increasing the number of KMS stations) has the highest (7.7 times the cost of Option 2). In terms of capital costs, Option 2 requires a larger investment than Option 3 but has much higher local content than the other options. Options 3 and 4 have the weakness of having to transfer water across areas of the Bassin Arachidier where there are unmet needs, both in terms of quantity and quality.

204. In addition to its much lower cost, Option 2 offers possibilities for irrigation, whose economic impact should be taken into account by first establishing a baseline for irrigated cultivation in the area.

Irrigation baseline in the DMT area

205. The 21,600 hectares of easily irrigable land in the Greater Dakar area is divided into different clusters: Pikine (100 ha), Rufisque (2,000 ha), Thiès (17,440 ha), and Mbour (2,060 ha). The 2016 survey

of market production in the Niayes area indicated that in 2015–2016, the portion of Niayes covered by greater Dakar represented approximately 25.2 percent of the total planted area in the Niayes region and 23.8 percent of the region's market production. The economic analysis of irrigated cultivation projected in the Greater Dakar region out to 2035 will draw on the findings of this survey, with the assumptions set out below forming the basis for the long-term prospects for irrigated cultivation in the area.

206. The 12,240 hectares planted with the four dominant crops are expected to yield 313 200 tons, equating to a market value of CFAF 57.34 billion and value added of CFAF 42.2 billion. Adding other production to the mix would give an overall value added of CFAF 47 billion during the cooler off-season.

207. Across 12 months, both seasons combined are expected to generate CFAF 70.5 billion in value added. For comparison, Senegal's GDP is forecast to be CFAF 15,085.9 billion in 2020 following CFAF 13,942.7 billion in 2019. Value added by the Agriculture and Related Activities sector in 2018 was estimated at CFAF 1,217.1 billion. From 2018 to 2035, an annual growth rate of 4 percent would double this value, raising it to CFAF 2,435 billion, implying that the direct value added induced by irrigation would represent 3 percent of value added by the agriculture sector.

Wastewater disposal and treatment

208. The sanitation subsector is characterized by a lack of adequate infrastructure for households and inadequate wastewater treatment. In the main urban centers of Greater Dakar (Dakar, Rufisque, Thiès, Mbour, Saly, Joal), public sanitation networks total some 122,258 connections, but onsite sewage facilities remain predominant (80 percent). While 445,555 m^3 of drinking water is consumed daily, the total treatment capacity of greater Dakar's sewage treatment plants is 35,531 m^3/day, accounting for 28 percent of wastewater collected (126,000 m^3/day). Of this volume, only 9,500 m^3/day undergoes tertiary treatment and 800 m^3/day is reused. There is potential to reuse treated wastewater, the main constraint being funding the infrastructure to treat and supply purified water to agricultural areas. Steps are being taken in this direction, as illustrated by the case of Dakar, where experiments are being trialed.

209. At the Camberène water treatment plant, a sewage sludge treatment plant receives wastewater collected from onsite sewage systems. Collection is generally carried out by trucks of 10 to 14 m^3 at a rate of CFAF 25,000–35,000 depending on the distance between the collection site and the water treatment plant. The sewage sludge treatment plant receives the trucks' contents at a rate of CFAF 3,000 per load.

210. The two water and sewage sludge treatment plants result in the existence of two business lines: treated water, and sludge. Stabilized sludge is sold as fertilizer at CFAF 500/kg. Tertiary treated water, meanwhile, is either sold directly upon exiting the water treatment plant at a rate of 200 CFAF/m^3 or sold to market gardeners through an existing network at CFAF 50/m^3. ONAS has a general policy of delegating the management of water treatment plants to the private sector.

III.10.3. Stakeholder impact analysis

211. Depending on the consistency and configuration of investments envisaged to safeguard water security in Greater Dakar, the following impact analysis is structured around three components: drinking water supply, wastewater disposal and treatment, and irrigation.

Expected impacts of drinking water supply component

212. The main expected impact is the control of water prices for the benefit of stakeholders; low water costs help to consolidate SONES' financial position, reduce demand for government support, and lower water bills for consumers.[38] Reduced costs will allow the tariff policy to provide a balanced distribution of

[38] A tariff simulation with the costs of the canal transfer option will be necessary to provide an accurate indication of the consequences for SONES, the Government, and households. Option 2 is likely to have the impact of lowering SONES' royalty price.

costs between SONES, the Government, and consumers.

213. Controlling water loss will help reduce distribution costs and have a positive impact on tariffs for both households and SONES. For example, in Greater Dakar in 2018, 435,849 m^3/day were produced while consumption was estimated at approximately 325,227 m^3/day, leading to an overall loss of 25 percent or 108,960 m^3/day. Reducing these losses to 15 percent would result in savings of 43,584 m^3/day and therefore an annual value of CFAF 2,1 billion for SONES' 2020 royalty price of CFAF 133.9/m^3. While controlling losses may seem symbolic, it benefits SONES, consumers, and the Government, the latter facing less consumer demand for subsidies.

214. Some 80,000 households are expected to benefit from extensions and connections, resulting in better-quality water supply, improved wellbeing, time savings compared with other water supply methods, and possibly also financial gain.

Impacts of wastewater disposal and treatment component

215. The expected benefits include improved environmental conditions and safeguards (reduced pollution of groundwater and receiving environments), improved access and expanded range of sanitation services, and added value to sanitation by-products (treated water, sewage sludge, and biogas) via various uses: irrigation, garden watering, recharge of aquifers, fertilizers, etc. Altogether, the impacts of the wastewater disposal and treatment component are difficult to quantify but of major importance for public health and the environment.

Impacts of irrigation component

216. The main impact is the high value added of the horticultural sector in the country's economy, with the creation of jobs and improvement to the trade balance.

217. **Altogether, the proposed investments combined** contribute to water security in the Greater Dakar region, with the major impacts of supporting economic growth, poverty reduction, and improving the wellbeing of populations along with environmental preservation.

IV. Conclusions

Risks related to water security in Senegal

218. **Water security is threatened by a widely shared vision of national development centered on the unconditional mobilization of resources for the achievement of land use planning objectives defined with no thought for their sustainability.** Although Senegal has a wide range of high-level policies and programs that define a clear path for the country's sustainable development, water resources and the issue of water security receive little or no mention in these policies or programs. The Emerging Senegal Plan (PSE), the reference for medium and long-term economic and social policy, defines an ambitious national development program but does not explicitly recognize risks to water resources as a possible constraint on development despite Senegal having such an arid climate. On the contrary, it refers to other significant sectoral policies and plans, making bold assumptions with regard to the availability of water resources but mentioning neither the Integrated Water Resources Management Action Plan (PAGIRE) nor the Strategic Water Resources Mobilization Plan (PSMRE), which should form a national frame of reference, identifying the potential opportunities and limits relating to the development of water resources.

219. **While as water was widely available, subject to periodic droughts and shortages, like many other countries, Senegal could continue to largely ignore its water resources and the need for efficient management.** However, the status quo is clearly not sustainable as the challenges related to water security have only increased, posing real and growing risks to the country's socioeconomic development and the achievement of the objectives of the Emerging Senegal Plan (PSE).

220. **As long as water security is not guaranteed, the Government finds itself with no option but to implement emergency measures will remain the unsustainable norm.** Yet these come too late in response to the unaddressed suffering of people no longer able to meet their basic needs or whose lives are in danger. A lack of time to assess the impacts of interventions too often leads to hasty action, giving rise to irreparable mistakes capable of causing considerable ecological and social disaster.

221. **The costs of poor water security management are financial, environmental, and social.** They have been estimated at over 10 percent of GDP annually and include: (i) considerable agricultural losses in periods of drought; (ii) the risk of irreversible saltwater intrusion into coastal aquifers that supply water to a large share of the country's population and economic activity; (iii) tens of billions of CFA francs poured into flood management; (iv) destruction of the Langue de Barbarie natural reserve due to a breach in the Saint-Louis lagoon; (v) violence over arrangements for access drinking water in rural areas; (vi) development of industrial agriculture around Lac de Guiers and the upstream mining industries around the Falémé, posing the risk of contamination to (among others) the Greater Dakar water supply; (vii) the deterioration in the living conditions of the populations in the zircon mining area; and (viii) the impact on the lives of millions of accidents occurring in the transfer works that supply Dakar.

222. **Most worrying is the social conflict arising from a deterioration in people's rights to safe drinking water and adequate food, which in Senegal is closely linked to crop water security.** In 2000, for example, officials in the service in charge of water resources management were reluctant to publish the findings of an assessment of the extent of the public health risk associated with the use of fluorinated boreholes,[39] and it took ten long years for this issue to be addressed in a calm and integrated manner as part of the sectoral development strategy.

223. **Water resources management is a pillar of water security and faces major challenges in Senegal**, as identified and presented in Chapter II.1. Over the past 20 years, water resources management has improved considerably under the influence of the DGPRE through knowledge deepening and sharing, design of spaces for consultation on conditions of use, initiation of a process to revise the regulatory framework, launch of the water police, and the granting of withdrawal authorizations. However, this process

[39] Close to 500,000 people are affected, among them mainly children under the age of 10.

must continue and its effectiveness be strengthened as current resources management is not commensurate with present and future challenges, including the protection of the at-risk areas (hotspots) to safeguard their contribution to the country's socioeconomic development.

224. **Today, the situation has reached the point where the Ministry of Water cannot deal with it alone; it requires the intervention of the Government as a whole.** Many of the stakeholders and decision-makers interviewed as part of this study have a clear understanding that water security is a major issue for national development, but none of them can define it or identify a framework within which it could be addressed. Responsibilities are therefore not defined.

225. In the context of Senegal, the risks identified are perceived in highly variable ways:

- The risk of flooding is a frequent topic: it includes (among other things) issues relating to civil security (damage to persons and property), ecology (impacts on ecosystems of the opening of the Saint-Louis breach), urban planning (obstruction of flow paths), and industrial development (disruption of flood forecasting systems caused by the dredging of the Falémé river).
- Paradoxically, the climate or drought risk is seldom raised despite Senegal's Sahelian climate and forecasts indicating that water resources will be particularly vulnerable by 2025. The food self-sufficiency model is oriented toward irrigated agriculture and rice production, while the resources that can be allocated will ultimately be insufficient to develop the full land use potential. Improvements in the productivity of rainfed crops could offer a strategic path to diversify risks and strengthen the resilience of rural populations where irrigation potential is low.
- The public health risk is well known, but the slow pace at which it is being addressed contrasts with the magnitude of its impact on populations. These include: (i) release into Lac de Guiers of drainage waters containing pesticides and heavy metals and minerals, causing eutrophication of this reservoir; (ii) exploitation for human consumption of water with high concentrations of salts and fluorine in the Bassin Arachidier; and (iii) pollution of shallow groundwater used for market gardening.
- Groundwater resources are at risk of irreversible degradation as they continue to be in high demand in areas where the risk of saltwater intrusion is very high and threaten living conditions in the Cap Vert peninsula.
- The security risk is mounting rapidly as a result of ever-greater dependence on long-distance transfers to supply drinking water.
- The risk of water-related conflicts, while contained internationally by OMVG and OMVS, should not be overlooked at the local level as investment is overwhelmingly oriented toward irrigated agriculture, which could risk creating growing tensions with thousands of rural families whose survival depends exclusively on rainfed agriculture severely impacted by drought.

The national development vision should take sustainable and equitable water resources management into account

- The letter of policy development for the water and sanitation sector (LPDSEA) for the period 2016–2025 recalls the vision given by the Emerging Senegal Plan of the challenge facing the sector, namely to mobilize "abundant, quality water for all, everywhere, and for all uses, in a healthy and sustainable environment for an emerging Senegal."
- The formulation of this vision is important because it expresses the vision policymakers have of water security. Yet the idea of abundance is far from reality in many parts of Senegal, and the notion of sustainability is eclipsed.

- However, the LDPSEA does address the issue of water security, albeit without using the term. First, it identifies as threats "the absence of a sustainable intersectoral mechanism to promote IWRM that encourages pooling and collaboration between different ministries." Second, it cites among challenges the urgent need to find a lasting solution to the problem of water quality, the consideration of various sources of resource pollution, and the management of tensions generated by conflicts over use.
- Four years later, these threats and challenges not only appear difficult to control but continue to grow. The emergence of a sector-based rather than a policy approach to resource management has given rise to competing demands between water, environmental, and agricultural institutions, fueled by high financial stakes. Water security is therefore threatened by a national development vision centered on the unconditional mobilization of resources to achieve predefined land use objectives without taking into account their sustainability.
- Because people's lives are at stake, the challenge is to integrate constraints relating to sustainable and equitable management of water resources in the national development vision and to respect the limits they impose on their mobilization within good governance rules.

Summary of recommendations relating to water resources management

- Water security is threatened by a widely shared national development vision centered on the unconditional mobilization of resources to achieve predefined land use objectives without taking into account their sustainability. The definition of governance rules and the overall political vision driving national development and guiding sectoral policies must integrally account for and comply with the limits imposed by the sustainable management of water resources.
- The management of the hotspots defined in Chapter II.1, where major risks have been identified for water security, must be considered a strategic priority at the highest level for sustainable national development. Recommendations specific to each hotspot are identified in annex IV
- The implementation of these recommendations requires a strengthening of the organizational and legal frameworks for WRM, the key features of which ae presented below:
    - The status of the organization responsible for WRM (DGPRE) should be raised in order to increase its level of authority in the face of pressures to influence decisions with high social, economic, and environmental content while bringing together the functions of managing the quality and quantity of surface and groundwater resources, which are closely linked. The main options for reform, along with their advantages and disadvantages, are presented in Table II.3. The choice of option requires an in-depth discussion within the Government, which the World Bank could potentially support.
    - The competencies of the DGPRE must change as the remuneration and logistical and financial means currently available to it are insufficient to ensure capitalization and stability.
    - The management of the quantitative and qualitative aspects of the resource, which are intricately linked to and consistent with the principles of IWRM should be centralized within the Ministry of Water and Sanitation (MEA).
    - The DGPRE's intervention framework should be optimized, giving it a presence in all regions, a smaller number of management and planning sub-units, and a smaller number and reframing of the content of planning documents.
    - With respect to financing the DGPRE, withdrawal authorizations should be offered to all users and the revenues generated by resource use or discharge fees must be fully earmarked for the management of the resource.

- OLAC should revert to OLAG to ensure the sustainable management of Lac de Guiers, including the lake management infrastructure, in close collaboration with the water management and planning sub-committee, which will be established for participatory management of the lake.
- The Water High Council (CSE) should be reactivated, taking into account the lessons from the past and international experience to ensure effective intersectoral coordination around WRM. The new Water Code should attach it to the General Secretariat of the Presidency, assigning it real decision-making or arbitration functions, forcing it to meet regularly, and limiting the number of its members to an operational size and its composition to persons of similar status. It should be supported by a technical water committee chaired by the organization responsible for WRM.
- The Water Code should be revised to refocus on water resources management and no longer be limited to the management of the public water domain. Strengthening intersectoral coordination will require giving legal significance to the water resources management strategy in relation to sectoral development strategies and to water resources management plans in relation to local development planning. Water rights management and transparency should be strengthened. The Water Code should be the reference text for water quality management, from which the provisions of the Environment Code and other regulations are derived. Finally, all public institutions should be required to provide the necessary information under their jurisdiction for the water information system.

Summary of recommendations relating to Greater Dakar and the DMT triangle

- An integrated water security vision in greater Dakar is vital to meeting the multiple needs for drinking water, irrigation, and wastewater and stormwater treatment out to 2050. This calls for long-term planning of the mobilization of water resources for multiple uses. Beyond 2030, the integrated approach will mobilize surface water resources to meet future water demand generated by rapid population growth in the capital region, the development of a new economic and industrial hub near the AIBD airport and the Diamniadio region, and demand for water for agriculture in the coastal region of Niayes;
- To ensure long-term water security in the DMT area, it will be necessary to better protect Lac de Guiers from pollution, strengthen the transfer of water supply from the lake, and obtain the necessary allocations from the OMVS Permanent Waters Committee to transfer raw water to the Dakar region;
- The implementation of a voluntary program to recharge groundwater from 2022 will make it possible to safeguard infra-basaltic groundwater of Dakar, the Pout Sud and Pout Kirène compartment, the northern coastline, the Maastrichtian to the south of the horst of Diass, and the Mbour limestone compartment threatened by saline intrusion;
- The application of circular economy principles in the DMT triangle will increase the population's access to wastewater treatment systems and resolve recurring flood problems in the suburbs of Dakar through the creation of a program to recharge groundwater and restore wetlands and natural depressions from treated wastewater, rainwater, dam water, and retention basins;
- Urgent precautionary measures should be taken to preserve the Niayes agricultural area by effectively controlling land use, prohibiting the installation of precarious establishments in depressions of the Niayes area and reservoir beds, and strictly controlling the sprawl of real estate projects in this area.

Annex I – Detailed methodological note on the estimation of renewable water resources available in Senegal and water demand

The experts who worked on this report used existing sources identified in the thematic reports drawn up during the preparation of this study. During this assessment, in cases where data does not exist or is not available, the experts made estimates based on their judgments, experiences and knowledge of the country. It should be noted that no new data were collected as part of this study.

The following tables show all the sources used and the corresponding calculations. When the experts in charge of the study have made an expert judgment, they will be referred to in the following table as "the experts".

Water source	**Estimation**	**Information source**
Annually renewable surface water (Table 2.1)		
Senegal River Basin, including Lac de Guiers and Falémé (337,000 km^2, of which 60,000 km^2 in Senegal)	Water available on average: 15 000 - 17 600 Mm^3/yr, *to share between Mali, Mauritania and Senegal* Withdrawals in Senegal : 2 198 Mm^3/yr (2126 Mm^3/yr for ag. Use and 72 Mm^3/yr for water supply)	Water available on average: 17,600 Mm^3/year represents the average over the last 20 years (2000-2018), 15,000 Mm^3/year the average over the last 50 years (1970-2018), measured at the Bakel station and **to share between Mali, Mauritania and Senegal** (Guinea being upstream of the Manantali dam). 15,000 Mm^3/year is equivalent to an average of 479 m^3/s. Withdrawals: Agricultural withdrawals are calculated at 2,126 Mm^3/year for Senegal: 1,566 Mm^3 for SAED (average of SAED withdrawals 2013-2018, see Annex 1a) and 470 Mm^3 for Agribusiness (Inventory report of points of water and withdrawals, DGPRE 2020), plus 90 Mm^3 for Compagnie Sucrière du Sénégal (CSS), from Lac de Guiers (OLAG, 2020, Study on the pricing of OLAG services, Compagnie Sucrière sénégalaise, 2020) Drinking water withdrawals are estimated at 72 Mm^3/year, of which 87 per cent is for drinking water supply in Dakar. According to SDE, 33 percent of 2018 production – 191.2 Mm^3 – comes from Lac de Guiers (SDE, 2018). *Note: needs other than Senegal are currently estimated at ~5m^3/s (158 Mm^3/year) in Mali for agriculture and ~27m^3/s (852 Mm^3/year) in Mauritania (~25m^3/s for agriculture and 2m^3/s for DWS)*
Bassin du fleuve Gambie (77 053 km^2, of which 71 pour cent, or 54,631 km^2 in Senegal)	Water available on average: 5,203 Mm^3/yr, *to be shared with Gambia, which has no other sources*	Water available on average: Over the period 1970-2019, the average interannual flow observed at Mako - the first station at the entrance to Senegal located 40 km downstream from Kédougou - is 103 m3/s, which corresponds to a volume annual flow of **3,221** Mm^3. The Goulombo station is located only 20 km before entering Gambian territory. Between Mako and Goulombo, the Gambia River receives the contributions of many tributaries, the most important of which come from the very rainy south side: the Tiokoye, the Diarha and the Koulontou. At the Goulombo station, 20 km before entering The Gambia, the average interannual flow over the period 1970-2019 is 165 m^3/s, corresponding to an annual flow volume of **5,203 Mm^3, which must be shared with the Gambia**. It is estimated by experts that today around 4600 Mm3/year enters the Gambia Sea Reach – which is The Gambia's only source of water.

<table>
<tr>
<td></td>
<td>of surface water

<u>Withdrawals</u>: 20,4 Mm^3/yr (ag and mining)</td>
<td><u>Withdrawals:</u>
- Agricultural: 19.3 Mm^3, including 11.87 Mm^3 in the perimeters of SODAGRI and 7.44 Mm^3 of GIE in the Tamba area (DGPRE, 2020, Inventory report of water points and withdrawals)
- Mining: 1.1 Mm^3 in 2018, from the letter Petowal Mining Company to the DGPRE of January 31, 2019: Volume of water withdrawn from the Gambia River for the year 2018.</td>
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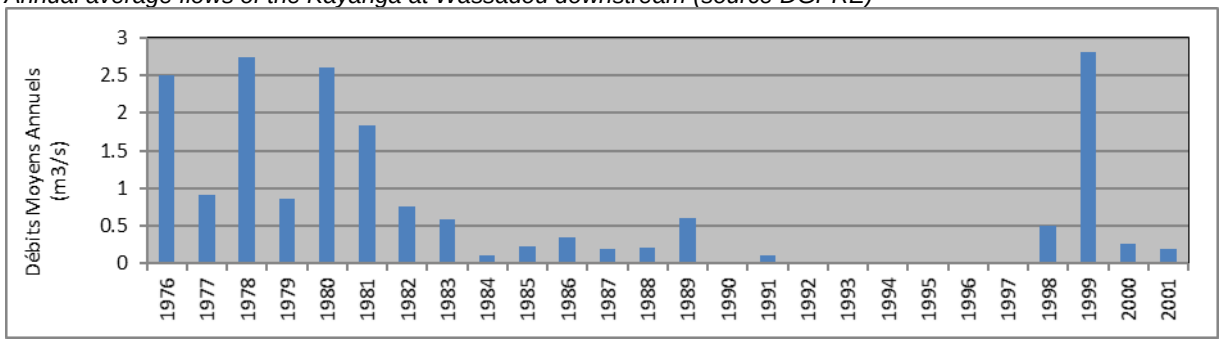
<tr>
<td>Kayanga River Basin, including the Anambé (12,418 km^2, of whic 34 percent, or 4170 km^2 in Senegal)</td>
<td><u>Water available on average</u>: 75 Mm^3/yr to share with Guinea Bissau

<u>Withdrawals</u>: 41 Mm^3/yr (ag)</td>
<td><u>Water available on average:</u> Estimation of average inflows to the dam. (Hydrology report, p.43)
On the Kayanga, water resources are partially controlled thanks to the construction of the confluence dams with a capacity of 59 Mm^3 and the Niandouba dam with a capacity of 85 Mm^3.
The study estimates the average inflows to the dams at around 75 to 80 Mm^3, to be shared with Guinea Bissau.

The following figure shows the evolution of the average annual flow at Wassadou downstream, which is the last station before the exit to Guinea Bissau. The average annual flow that flows past the station is 0.92 m^3/s, corresponding to an annual volume of 29 Mm^3.

Figure 2 Annual average flows of the Kayanga at Wassadou downstream (source DGPRE)
 

<u>Withdrawals</u>: average values 2013-2019 (calculated from the water needs of rice cultivation which take into account the climatic data of the area as well as the areas provided by SODAGRI from 2013 to 2019. Withdrawals are therefore estimated on the basis of a need in raw water of 13,000 m^3/ha in Anambé, for an average area developed between 2013 and 2018 of 3,148 ha, which gives 40.924 Mm^3/year. It should be remembered that according to the FAO method applied for this calculation water needs were determined on the basis of normal irrigation, where there were no data on withdrawals as in the case of Anambé.

Table : data shared by SODAGRI – cultivated area (ha) between 2012 and 2017
<table>
<tr><th>Year</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th></tr>
<tr><td>Cultivated area (ha)</td><td>1472</td><td>1449</td><td>1849</td><td>2747</td><td>4652</td><td>4627</td></tr>
</table>
</td>
</tr>
<tr>
<td>Casamance River Basin</td>
<td><u>Water available on</u></td>
<td><u>Water available on average:</u> This is mostly runoff water. Casamance imports vary greatly from year to year. In 1964, the flow reached 332 Mm^3, while in 1984 it was only 7.9 Mm^3. There is a station that was monitored between 1964 and 2004, the Kolda</td>
</tr>
</table>

<table>
<tr>
<td>(20 150 km^2)</td>
<td><u>average</u>: 440 Mm^3/yr

<u>Withdrawals</u>: 19 Mm^3/yr (ag)</td>
<td>station in Upper Casamance, which was therefore used in the context of this study to assess the water available on average in the Casamance river basin. The evaluation of flows was voluntarily stopped in 2004 because of the excessive silting up of the Kolda station which led to the derating of the station. Between 1964 and 2004, the flow volume observed at Kolda was on average 80.8 Mm^3/yr (source: DGPRE). On this basis, the volume corresponding to the entire catchment area is estimated at 440 Mm^3 (Vt = 80.8 * St/Sk where Vt = total basin runoff volume, St = total basin area = 20150 km^2 and Sk basin area at Kolda= 3700 km^2)

<u>Withdrawals</u>: 10 Mm^3/year in developed lowlands and 9 Mm^3/year for horticulture. Estimated on the basis of a raw water requirement of 6,300 m^3/ha in lowlands and 8,889 m^3/ha for horticulture. Precise data do not exist on development in the lowlands (equipped for full control irrigation), but we can estimate 10% of 15,000 ha developed or 1,500 ha. Similarly, experts estimate 1000 ha of fruit crops in Casamance. It should be recalled that according to the FAO method applied for this calculation, the water needs were determined on the basis of supplementary irrigation which takes into account the local rainfall, where there was no data on the levies as in the case of Casamance.</td>
</tr>
<tr>
<td>Sine, Saloum, CarCar ssytem (Groundnut Basin) (36,189 km^2, split between the Carcar- 10122 km^2, Sine - 9422 km^2 and Saloum - 16645 km^2 basins)</td>
<td><u>Water available on average</u>: 181 Mm^3/yr

<u>Withdrawals</u>: 2 Mm^3/yr (ag)</td>
<td><u>Water available on average:</u> Expert estimate (see hydrology report, table p.18): The annual flow and the levels of the rivers are very poorly assessed in the Saloum-Sine-Car Car system due to degradation or lack of hydrometric stations. The readings taken at other similar sites in the dry sedimentary zone show that the annual runoff coefficient is very low, less than 1% of the annual cumulative rainfall.
For the Sine Saloum system, the calculation of the annual volumes passed is therefore made from the surface of the catchment areas, the rainfall heights (minimum, maximum and average) and the value of the runoff coefficient of the order of 1%. We obtain the following values of renewable resources (max; min and avg):

<table>
<tr><th rowspan="2">Zone</th><th rowspan="2">Area in km^2</th><th colspan="3">Annual rain in mm</th><th colspan="3">Renewable Res. in millions m^3</th></tr>
<tr><th>Max</th><th>Min</th><th>Avg</th><th>Max</th><th>Min</th><th>Avg</th></tr>
<tr><td>Carcar and Sine Saloum</td><td>36,189</td><td>900</td><td>400</td><td>600</td><td>325,701,000</td><td>144,756,000</td><td>217,134,000</td></tr>
</table>
The value of 181 Mm^3 retained for the Sine Saloum and Car Car system is an average between the minimum and average value of this table.

<u>Withdrawals:</u> These data are provided by SODAGRI and SAED in tables between 2011 and 2019, development companies which are under the supervision of the Ministry of Agriculture and Rural Equipment.</td>
</tr>
<tr>
<td>Small coastal basins (Dakar and Thiès regions (Cap Verde peninsula and the coastal zone of the Thiès region)</td>
<td><u>Water available on average</u>: 22 Mm^3/yr (runoff)

<u>Withdrawals</u>: Temporary ponds used to recharge the water table or to</td>
<td><u>Water available on average:</u> Expert estimate. Runoff during wintering is generally low and has not yet been controlled. They feed the temporary ponds which are used for cattle feed until January-February. However, it is possible to capture surface water in certain favorable areas to create small reservoirs of water that can be used for recharging aquifers, agriculture, fish farming and livestock watering, and which can also help in the fight against against floods. Large urban areas offer extensive impluviums at which large quantities of rainwater can be captured. (Plateau of Thies, Tivaouane, Bambey, Touba, Diourbel, Kaolack, etc.)

Given the absence of monitoring data, as for the Sine, Saloum, CarCar system, the calculation of the annual volumes passed is therefore made from the surface of the watersheds, the rainfall heights (minimum, maximum and average) and the value of the runoff coefficient of the order of 1%. We obtain the following values of renewable resources (max; min and avg):</td>
</tr>
</table>

<table>
<tr><td></td><td>feed livestock.</td><td>
<table>
<tr><th rowspan="2">Zone</th><th rowspan="2">Area in km^2</th><th colspan="3">Annual rain in mm</th><th colspan="3">Renewable Res. in millions m^3</th></tr>
<tr><th>Max</th><th>Min</th><th>Moy</th><th>Max</th><th>Max</th><th>Min</th></tr>
<tr><td>Coastal waterways</td><td>4,840</td><td>700</td><td>400</td><td>500</td><td>33,880,000</td><td>19,360,000</td><td>24,200,000</td></tr>
</table>
The value of 22 Mm^3 retained for the small coastal basins is an average between the minimum and average value of this table.
</td></tr>
<tr><td>TOTAL</td><td>AVAILABLE SURFACE WATER: between 20,921 and 23,521 Mm^3/yr, of which 96 percent to share with other countries.

WITHDRAWALS: 2 280 Mm^3/yr</td><td>This table presents the state of surface water withdrawals, especially for irrigation and DWS. Other uncontrolled surface water needs are not taken into account in this assessment, which is therefore probably an underestimate of actual withdrawals.</td></tr>
<tr><td colspan="3">Groundwater (Tableau 2.2)</td></tr>
<tr><td>Recharge estimate</td><td colspan="2"><u>Methodology</u>: The specific data used here are taken from previous studies carried out by the DGPRE, which are sometimes too limited to certain areas for an overall assessment at the scale of the hydraulic system. For others, the results from modeling studies that show a spatial distribution were used in the assessment. Studies from the PSE, PELT and PAGIRE projects in addition to recent projects on the groundnut basin, Sine Gambia, Oussouye, Cap Skirring, Falémé, Bakel, PEAMU and PEAMIR largely contributed to this synthesis. For areas where the recharge values are limited and circumscribed by reference to the extent of the hydraulic system as the case of eastern Senegal, we started from these values to make an estimate based on a low hypothesis as stipulated in the hydrogeological thematic report . Potential recharge areas as indicated in the assessment have not been systematically defined and verified for application in the framework. However, these base (socle) zones made up of a horizon of alterites containing a superficial aquifer generally by wells and a fractured horizon captured by boreholes are under the influence of infiltration by rainwater where seasonal beatings of the aquifer of the order of 1 to more than 8 m have been observed. These variations are quickly blurred by a relatively rapid recession induced by natural flow following the hydraulic gradient or towards the surface water outlets and which results in the drying up of the wells. The low hypothesis used would make it possible to approach the renewal rate in relation to the orientation of the study, which is water security. These rates applied to the whole territory are too far even from the base flows of the rivers and tributaries identified in the hydrology report – The reference case of Goulombo is representative because it plays a role of collecting surface flows from tributaries and tributaries. where an annual flow of 5.5 billion m^3 was observed. This value is far from the renewable potentials.</td></tr>
<tr><td>Aquifer area estimate</td><td colspan="2"><u>Methodology</u>: The areas remain very approximate because calculated using ARC GIS. Here it should be specified that the hydraulic systems defined in the hydrogeology thematic report have been considered. For example, the Horst system was extended towards Fatick due to the continuity of Paleocene limestone. The same is true for the northern littoral system where the Eocene Lutetian limestones of Louga/Kebemer and Khombolebambey have been included in addition to the Quaternary sands from Kayar.</td></tr>
</table>

Infrabasaltic Sands (30 km^2 in the Cap Vert peninsula-Dakar)	Recharge: 4.3 Mm^3/yr Use: 17.15 Mm^3/yr	Recharge: Estimation from PELT Project (DGPRE, 2009) Use data: use data come from the inventory study for groundwater (water statistics, projects carried out and urban DWS, 2020).
Quaternary Sands of Thiaroye (300 km^2 between Dakar and Cayar – Banlieue)	Recharge: 9 to 18 Mm^3/yr. Use: abandoned for urban DWS due to excessive NO3 levels	Recharge: Estimation from PELT Project (DGPRE, 2009) Use data: use data come from the inventory study for groundwater (water statistics, projects carried out and urban DWS, 2020).
Horst de Diass system (1250 km^2 – Paleocene limestones and Maastrichtian sands hydraulically connected)	Global recharge: 30 Mm^3/yr from rain Use: 120 Mm^3/yr (of which 71,7 Mm^3/yr from Paleocene)	Recharge: Recent Horst and Littoral projects under the PEAMU and PEAMIR programs (DGPRE, 2017 and DGPRE; 2020) Use data: use data come from the inventory study for groundwater (water statistics, projects carried out and urban DWS, 2020).
Littoral Nord system (4900 km^2) quaternary sands connected to Eocene limestones	Recharge: 25,6 to 38,6 Mm^3/yr from rain, a good part of which flows towards the sea and thus repels the salt wedge Use : 92,7 Mm^3/yr (42,8 Mm^3 of quaternary sands and 49,9 Mm^3 of eocene)	Recharge: Gaye, 1990 ; Faye et al, 1997 ; Kaba, 2017 and Seck, 2018 ; PELT study (DGPRE, 2009) Use data: use data come from the inventory study for groundwater (water statistics, projects carried out and urban DWS, 2020).

Regional Maastrichtien (150 000 km^2 – present throughout the sedimentary basin)	Recharge : unknown in 2 of its 4 recharge areas (estimated between 68 and 75 Mm^3/yr between the Horst de Diass and base (socle) boundary, of which 30Mm3/yr in the Horst) Use: 166,7 Mm^3/an	Recharge: studies from the projects PSE (DGPRE, 2001), PELT (DGPRE, 2009), Horst (DGPRE, 2017) and AIEA/RAF 7011 Use data: use data come from the inventory study for groundwater (water statistics, projects carried out and urban DWS, 2020). *Nota : The deep Maastrichtian aquifer with an area of more than 150,000 km^2 over almost the entire country and a thickness varying from 50m (in the east) to 700m in the west constitutes the largest underground water reservoir in the Senegal. The reserves estimated between 300-500 billion m^3 (Audibert, 1971) can allow a potential exploitation of 30-40 billion m^3 of water. The latter, which is defined as the quantities that can be exploited without damaging the resource, was made on the basis of the assumption of a withdrawal of 10% of the total reserve. This reserve is however non-renewable – and as long as it is, it has not been included in the calculations of renewable water availability, per year.*
Continental Terminal and Oligo-Miocene (64 246 km^2)	Recharge: 1483 Mm^3/yr (887 Mm^3/yr for l'OM and 597 Mm^3/yr for CT) Use: 64,4 Mm^3/an	Recharge: Sine Gambie Project (DGPRE, 2015) ; Lepriol 1983 Cap Skirring Project (DGPRE ; 2016), Oussouye Project (DGPRE, 2018) Use data: use data come from the inventory study for groundwater (water statistics, projects carried out and urban DWS, 2020).
Base (Socle) aquifers (32 700 km^2)	Recharge: potential of 490 Mm^3/yr (flow of the Senegal River, the Falémé and the recharge of the Maastrichtian) Use: 4,7 Mm^3/yr	Recharge : In the base (socle), most of the recharge contributes to the flow of the Senegal River, the Falémé and the recharge of the Maastrichtian. It is therefore not really available for other uses – and that is why it is not included in the calculation of total groundwater availability (see text of para. 67 of the report). This renewal potential is not contradictory to availability since the latter participates in the flow of surface water and is therefore not available as a groundwater resource. It should therefore be noted that we are talking about two scales – the renewable hydraulic potential which is at the scale of the region which supports the base flows of the rivers and the exploitable potential which is only at the scale of sites. favorable (network of fractures) Use data: use data come from the inventory study for groundwater (water statistics, projects carried out and urban DWS, 2020).

TOTAL	SUSTAINABLY USABLE GROUNDWATER: **Between 1620 and 1649 Mm^3/yr** without considering base (socle) recharge. WITHDRAWALS : **417,4 Mm^3/yr** or 25 percent of usable resources	For withdrawals, it should be noted that in the table 120 Mm^3 is estimated in the Horst but 48.3 Mm^3 comes from the Maastrichtian sands and therefore they are also included in the "Maastrichtian" section. It should also be noted that 230 Mm^3/year (55% of total abstractions from groundwater) are abstracted from highly overexploited and endangered resources.
TOTAL AVAILABLE WATER (renewable, per year)	Between 20,921 and 23,521 (surface water) + between 1620 and 1649 (groundwater) = **Between 22,541 and 25,170 Mm^3/yr**	Total estimated renewable water availability hides strong regional disparity (see report) From this total, 21 percent should be subtracted for evaporation (ref. FAO and ODD), which would bring water availability in Senegal to **between 18,113 and 20,136 Mm^3/year.**
TOTAL WITHDRAWALS	2 280 (surface water) + 417,4 (groundwater) = **2 697,4 Mm^3/yr**	The samples are very little monitored in the country. The data presented above are therefore orders of magnitude, and have for the most part been estimates, based on irrigated areas and populations. They are therefore limited to the main uses, which are water supply to towns and villages, irrigation, including flood recession crops, and the mining industry (when these data were available). In general, for the samples, the following sources were used: - For agricultural levies: Sources data from SAED (2019), SODAGRI, (2019), and estimates based on project monitoring data from the Ministry of Agriculture and Rural Equipment between 2011 and 2018; Inventory phase of water points and withdrawals, Processing and Analysis of the information collected – DGPRE 2020 - For withdrawals from surface and groundwater (other than agricultural uses): SDE, Inventory phase of water points and withdrawals, Processing and Analysis of the information collected – DGPRE 2020

Annex 1a – ESTIMATION OF WATER CONSUMPTION OF IRRIGATED PERIMETERS IN THE VALLEY, 2011-2018 (SAED)

Seasons	**Crop**	**2010/11**		**2011/12**		**2012/13**		**2013/14**		**2014/15**		**2015/16**		**2016/2017**		**2017/18**	
		Cultiv area	**Water cons.**	**Cultiv area**	**Water cons.**	**Cultiv area**	**Water cons.**	**Cultiv area**	**Water cons.**	**Cultiv area**	**Water cons.**	**Cultiv area**	**Water cons.**	**Cultiv area**	**Water cons.**	**Cultiv area**	**Water cons.**
		(ha)	(Mm3)	(ha)	(Mm3)	(ha)	(Mm3)	(ha)	(Mm3)	(ha)	(Mm3)	(ha)	(Mm3)	(ha)	(Mm3)	(ha)	(Mm3)
WINTERING	Rice	34,657	624	32,623	587	28,216	508	25,938	467	29,445	530	69,400	1,249	25,	459	26,109	470
	Polyculture	2,211	40	1,826	33	2,204	20	2,613	24	1,871	17	6,628	60	1,315	12	914	8
	Total Wint	36,868	664	34,449	620	30,420	528	28,551	490	31,316	547	76,028	1,309	26,815	471	27,023	478
COLD DRY SEASON (CDS)	Polyculture	13,334	120	11,026	99	13,380	120	13,290	120	14,765	133	14,260	128	11,944	107	16,908	152
	Total CDS	13,334	120	11,026	99	13,380	120	13,290	120	14,765	133	14,260	128	11,944	107	16,908	152
HOT DRY SEASON (HDS)	Rice	21,419	386	29,171	525	29,237	526	28,130	506	36,200	652	57,150	1,029	43,685	786	46,918	845
	Polyculture	1,288	12	1,453	26	1,520	14	1,414	25	1,524	27	4,550	41	621	6	421	4
	Total HDS	22,706	397	30,624	551	30,757	540	29,544	532	37,724	679	61,700	1,070	44,306	792	47,339	848
Total cultiv. Area (ha)		**72,909**		**76,099**		**74,557**		**71,385**		**83,805**		**151,988**		**83,065**		**91,270**	
Total estimated water cons. (m^3)			**1,181**		**1,271**		**1,188**		**1,142**		**1,359**		**2,507**		**1,370**		**1,479**

Annex II – Water resources in Senegal: availability, challenges, demand

1. This appendix presents a more detailed analysis of the geographic and temporal distribution of water resources and the issues associated with them, distinguishing the situation of surface water from that of groundwater.

Surface water

2. A more detailed description of the situation for each of the six major river systems is presented below, together with some recommendations for improving their management:

The Senegal River Basin

3. On the northern and eastern borders, the Senegal River and its basin, shared with Guinea, Mali and Mauritania, concentrate 75 percent of national renewable water resources (82 percent of surface water) and play a strategic role in meeting the country's water needs, beyond the geographical limits of the basin.

4. In the far north of the country, despite the very low rainfall (between 300 and 400 mm/year and even 100 mm in some places such as Podor), the presence of the Senegal River – one of the best regulated rivers on the African continent has so far ensured a relatively high availability of water resources, although dependent on neighboring countries. This area is marked by an extreme contrast between the very humid regions bordering the river and the more distant and very dry lands of the Diéri. It is in this zone, along the left bank of the river, that 80 percent of the developed irrigated areas of Senegal are concentrated, and that 45 percent of the rice is produced.[40] In addition, the floodplains along its banks are also used for the production of sorghum, maize, cowpea and livestock, as well as the production of fish.

5. In the Delta area, upstream of the Diama dam, the Senegal River feeds Lake Guiers, the largest freshwater reserve in Senegal (300 km² and a volume of 600 million m3). Lac de Guiers is the source of transfers supplying Dakar and its suburbs, as well as the Bango reserve, a freshwater reserve for the city of Saint Louis. This area of the Delta is also the seat of intensive rice-growing activity and rich ecosystems (Bird reserves of Diawel, Djoudj and Langue de Barbarie). Water resources are threatened by significant agricultural pollution, as well as by the progressive clogging of hydraulic axes and water bodies by sedimentation and grass growth.

6. With regard to pollution, note in particular the situation of Lac de Guiers, whose water quality baseline was established in 2019 by the Office des Lacs et des Cours d'Eau (OLAC). It indicates the presence of around thirty pesticides, around ten heavy metals and various bacteriological germs, such as E.Coli and Salmonella, exceeding water potability standards.[41] The Compagnie Sucrière Sénégalaise (CSS), which manages an area of nearly 10,000 ha of sugar cane on the shores of the lake and discharges its drainage water there, loaded with pesticides and fertilizers, is one of the major sources of pollution.[42]

7. The gradual clogging of the hydraulic axes and water bodies in the Delta by the combined effect of sedimentation and grass cover is due to the major developments carried out on the Senegal River which, by

[40] 455 000 tonnes des 1 011 269 tonnes produites au niveau national en 2017 (SAED et PRACAS II, p.49)
[41] Reference study on the water quality of the Lac de Guiers system in OLAG/PREFELAG, 2019: Study on the pricing of OLAG services/Provisional report, p.98.
[42] https://www.memoireonline.com/04/11/4411/m_Le-lac-de-Guiers--etude-du-regime-et-des-bilans-hydrologique-et-hydrochimique13.html

tempering the hydraulic regime of its waters and by reducing salinity have favored sedimentation and the proliferation of aquatic plants on all of these hydraulic axes and water bodies, including 30 percent of the area of Lake Guiers. This progressive clogging reduces the flows transiting in the axes and the supply capacities for irrigation and other uses, causing shortages in peak conditions. On the other hand, the proliferation of aquatic plants also invades irrigated plots, prevents access to the banks, especially for watering livestock, and reduces fish production. These plants also constitute an ecological niche favorable to parasitic waterborne diseases such as schistosomiasis and malaria, which developed rapidly after these developments and whose prevalence rate remains high, especially in the Senegal River valley around Falémé.[43]

8. On the eastern border, the Falémé sub-basin, the main tributary of the Senegal River in Senegalese territory, is responsible for 40 percent of the average flow of the river and constitutes a border zone with Mali and Guinea. This sub-basin is not regulated and is subject to strong intra- and inter-annual flow variability. The needs are low compared to the availability of water because this area is sparsely populated and relatively isolated, but also well watered in its southern half. It is nevertheless the place of a mining activity in full swing, formal and informal, taking surface water and polluting. Gold panning – which in this area is poorly controlled – in particular leads to water pollution by heavy metals, such as mercury and cyanide, which are very harmful to human health and biodiversity. It is also often accompanied by the excessive destruction of the vegetation cover, exposing the soil to erosion and leading to the degradation of the banks.

9. In the southern part of the Senegal River basin, the Ferlo Valley, covering an area of 70,000 km2, i.e. more than a third of the national territory, is subject to progressive desertification. The Ferlo was a distributary of the Senegal River, which in the 1950s linked the River (in the regions of Matam and Bakel) to Lake Guiers at Keur Momar Sarr. The Ferlo valley is a silvo-pastoral, semi-desert area. The population mainly practices extensive livestock farming. Gathering and agriculture are in decline, but millet, cowpeas and groundnuts are still grown there. The Ferlo Valley is also home to national reserves (Ferlo Nord Faunal Reserve and Ferlo Sud Faunal Reserve). Although it is a fossil valley, the Ferlo valley has an untapped runoff potential, the control of which would make it possible to regulate the maintenance of rainfed agriculture.

10. **There is still significant mobilizable potential in the Senegal River basin, but without new regulating structures, the limits of secure withdrawals seem to have already been reached during low water periods.** A significant increase in withdrawals in the dry season would therefore require the development of additional regulating structures on the uncontrolled tributaries, in particular on the Falémé, and/or trade-offs in the management of the Manantali dam in relation to water sharing, as well as in the management of the other planned dams (Gourbassi, Bouréya, Koukoutamba and Balassa), once they have been built.

11. Indeed, the flows of the Senegal River are marked by strong inter-annual and seasonal irregularity. Thus, before the construction of the Manantali dam, annual flows at Bakel varied from 7.27 billion m3/year in 1984 to 42.83 billion m3/year in 1950, two exceptionally dry and wet years respectively. Seasonal variability is also very marked.

12. Several multipurpose works have already been carried out or are planned by the OMVS in order to moderate this variability. The Diama dams in 1986 and Manantali in 1988, for example, ensured a minimum flow in the dry season and reduced flooding in the wet season. In a normal year, it is possible to produce 800 GWh of hydroelectric energy in the basin, to irrigate 50,000 ha in flood recession crops and, in an

[43] http://www.pnlp.sn/wp-content/uploads/2016/08/PNLP_PSN_VFF_03-02-2016.pdf

average year, to secure the water supply in the dry season for 145,000 irrigated ha[44] (of which 98,000 ha in Senegal), the supply of drinking water to Dakar, Nouakchott, and other towns and villages and to allow navigation, while also ensuring a minimum environmental flow (52m3/s).[45] Three other reservoir dams are planned by 2030 (Boureya, Koukoutamba and Gourbassi).

13. In a moderately dry year, these regional objectives cannot all be achieved and trade-offs are necessary. In practice, maintaining the artificial flood for flood recession crops in Senegal and Mauritania seems to serve as an adjustment variable. In a dry year, the OMVS aims to ensure a minimum low water flow of 150m3/s, including 91 m3/s for irrigation[46] which includes 43,000 ha within the perimeters of SAED (50m3/s), AEP (5 m3/s), navigation (minimum 100 m3/s) and minimum environmental flow (52 m3/s). Figure 2.1 below shows the hydrograph at Bakel for 6 consecutive years (2013 to 2018), as well as the objective hydrograph (in red) recommended by the Reservoir Management Optimization Program (POGR) study. to guarantee 50,000 ha of flood recession crops. The objective of the artificial flood could only be ensured four out of six years. It is recalled that according to the Water Charter of the Senegal River ratified by the four member countries of the OMVS, artificial flooding must be guaranteed except in exceptional circumstances. [47] On the other hand, in the same period it was possible to maintain low flows above 150 m3/s. [48]

14. **The area cultivated during the low water period has reached the maximum guaranteed by the guaranteed minimum flow.** The minimum guaranteed low water flow allows SAED to irrigate around 40,000 ha[49] during the dry period, out of a total developed area of 138,052 ha. Traditionally, the land irrigated in the wet period is much greater than in the dry period. However, over the past five years, this trend has reversed. The areas irrigated during low water periods have increased sharply, reaching the limit guaranteed by the minimum low water flow; while those irrigated during the rainy season have rather decreased. Thus, between 2010 and 2014, the areas irrigated by SAED were on average 27,000 ha in the dry period, rising to 50,000 ha on average between 2015 and 2018. Over the same period, the areas irrigated in the wet season increased from 30,000 to 25,000 ha – which remains less than half of the developed land. The increase in cultivated areas during the dry period would be due to an improvement in water availability thanks to the many works carried out recently, particularly in the Delta. According to the explanations provided by some producers, the decrease in areas during the rainy season is due to problems of planning agricultural campaigns between seasons. The rainy season cannot be envisaged no later than the end of July, otherwise there will be a sharp drop in yield due to the coolness that occurs in November. In July, it happens that the majority of plots have not yet been harvested (availability of harvesting equipment, delay in the start of the previous campaign, availability of inputs, etc.). The areas available for the rainy season are then limited. With current mechanization policies, this factor could evolve positively in the future. Therefore, improving compliance with the cropping calendar can lead to consider cultivating more land during the rainy season, a period during which there are no limits as to the available flows.

15. The demand for water for irrigation during the dry period exceeds the guaranteed flow. Indeed,

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[44] Considering 42,200 ha in Mauritania, 98,000 ha in Senegal and 4,500 ha in Mali (PARACI preparatory study, 2007).

[45] Study on the vulnerability of the Senegal River Basin to climate change, p. 323. Source: Transboundary Environmental Diagnostic Analysis of the Senegal River Basin.

[46] Agricultural withdrawals are calculated at 67 m3/s for Senegal (50 m3/s for SAED – 52,200 ha off-season; and 17m3/s for Lake Guiers [industrial sugar cane and other agribusiness]); 20 m3/s for Mauritania and 4 m3/s in Mali, i.e. 91 m3/s in total. (OMVS SDAGE, 2010).

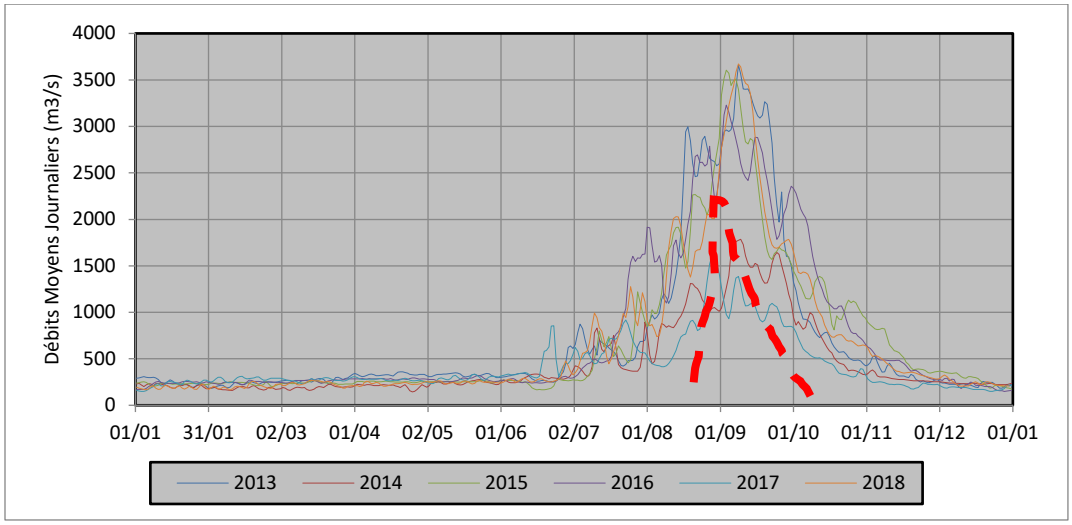
[47] Article 4 of the Water Charter of the Senegal River, ratified by the states, indicates that the integrated management of the resource must maintain the favorable ecological conditions in the basin of the River, by "creating the hydraulic conditions necessary for the" flooding of the valley and to traditional flood-recession crops", […] and by "guaranteeing artificial flooding except in extraordinary circumstances" (SDAGE OMVS, 2010. P.19).

[48] Over the 2013-2017 period, the minimum average monthly flow was recorded in February 2014, at 183 m^3/s.

[49] Minimum guaranteed flow = 50 m^3/s ; counter dry season = 150 to 180 days ; water needs = 18 000 m^3/ha (from SAED).

when the availability of water allows it (low water flow higher than the guaranteed flow), the areas cultivated during the dry period now exceed 50,000 ha. In 2015/16, for example, the area irrigated by SAED was 57,000 ha. The availability of water in the dry period is the limiting factor that determines the irrigated area.

Figure II.1: Hydrographs carried out at Bakel according to the recommendations of the Permanent Water Commission (CPE) during the period 2013-2018 - The theoretical target according to the POGR is indicated in red



16. **Recommendations:** Given the importance of the Senegal River in the country's surface water resources, it is recommended that actions be taken to: (i) secure access to drinking water by improving the quality of water in Lake Guiers and the Delta (reduce pollution from agriculture and domestic wastewater; optimize water renewal); (ii) limit the siltation and grassing of priority hydraulic axes (reprofiling of axes; weeding and cleaning; biological and chemical control; stabilization of banks and priority erosive areas); (iii) improve the management of gold panning sites (zoning, awareness of less polluting practices, reinforced control and regularization); and (iv) secure the living conditions of the populations of Ferlo (use of runoff water in the Ferlo valley in support of rainfed agriculture and livestock farming. In order to increase uses during the dry period, and to access to the mobilizable potential of the river, it will be necessary to develop new regulating works on the uncontrolled tributaries, in particular on the Falémé, and, once these have been developed, reconsider the rules for managing the dams.

Gambia River Basin

17. In the south, the Gambia River, shared with Guinea upstream and The Gambia downstream, is the second source of surface water in the country, with 12 percent of the resources. Current water requirements on the Gambia River in Senegal are below average water availability. Indeed, it is a relatively well-watered basin (1000 mm/year on average) and irrigation is underdeveloped, except for 1,200 ha of banana perimeters, out of an irrigable potential estimated at around 15,000 ha. .

18. However, due to the very great irregularity of the flows and its cross-border nature, the mobilizable potential is moderate. The average annual flow observed at Mako varies between 38 m3/s in 1983 and 233 m3/s in 2010. Flows in the dry season are very limited (they are sometimes zero between January and June).[50] The construction of the Sambangalou dam, programmed by the OMVG, is essential to have

[50] Source : DGPRE

sufficient flow in the dry season and to develop new uses. In addition, as this is a cross-border basin, the increase in withdrawals must be done with caution and in consultation with the countries sharing the basin. The Gambia, in particular, depends entirely on flows from Senegal, which averaged 2.5 billion m3/year between 1970 and 2019 (Goulonbo station). On Gambian territory, surface waters are in the maritime reach and are therefore fragile, as they are subject to the tidal regime, and more or less salty, depending on whether the seasons and the years are dry or wet.

19. Finally, as with the Falémé, the Gambia River is affected by heavy metal pollution due to mining activity in the Precambrian bedrock. Uncontrolled gold panning is particularly problematic.

20. **Recommendations:** In order to avoid conflicts with neighboring countries, it is recommended to relaunch hydrological monitoring in the basin, to carry out bathymetric studies of the two dams in order to update the references necessary for all decision-making, in consultation with neighboring countries, regarding the development of new uses.

Kayanga River Basin

21. In the extreme south of the country, the Kayanga River and its basin are shared between Guinea, upstream, where it has its source, and Guinea Bissau, downstream, where it flows into the Atlantic. The Kayanga receives the Anambé, its largest tributary before entering Guinea Bissau located about 40 km downstream from the confluence. It is a relatively small basin, 12,418 km2, of which 34 percent is in Senegal, representing less than one percent of Senegal's surface water resources. Despite relatively heavy rains, the flows are weak and intermittent, lasting on average 3 months a year between the beginning of August and the end of October. Current water needs are low because it is an isolated, sparsely populated and well-watered area. The irrigable potential is estimated at 16,000 ha.

22. The mobilizable water potential is low. The flows are low, the residual capacity of the existing reservoirs (Confluence and Niandouba dams with respective initial capacities of 59 Mm3 and 85 Mm3 respectively) is unknown, but certainly greatly reduced due to the importance of bedload and transport of sediments of this river, and it is necessary to maintain part of the flows downstream due to the transboundary nature of the basin. Consequently, the increase in irrigated areas envisaged beyond the current 5000 ha in this basin should be analyzed with caution and in consultation with the riparian countries. It should also be noted that the Kayanga has not been subject to hydrological monitoring for more than 10 years, the stations being out of service.

23. **Recommendations:** It is recommended to relaunch hydrological monitoring in the basin, to carry out bathymetric studies of the two dams in order to update, in consultation with neighboring countries, decision-making regarding the development of new uses.

Casamance River Basin

24. In the extreme south-west of the country, adjoining the borders with Gambia and Guinea Bissau, the Casamance River basin has a very limited mobilizable fresh surface water potential. Covering an area of 20,150 km2, this basin located in the sub-Guinean and Sudanese climatic zone is very well watered with 1200 mm/year on average, mainly between June and October.

25. Nevertheless, like the other basins of Senegal, the flows are very irregular, having reached 332 million m3 in 1964 and only 7.9 million m3 in 1984. Moreover, 82 percent of the basin is in the “maritime” part, located downstream of Kolda, subject to the fluctuations of the tide which rises up to 200 km from the mouth. In this part of the basin, the salinity of the Casamance waters, in an average year, varies between 19 and 37 g/l during the year, the peak occurring before the start of the rainy season, the minimum at the end.

On some distant tributaries of the estuary, the salinity can reach 150 g/l due to high evaporation, nearly 2000 mm. Salinity problems in land and water, including groundwater, remain a major problem in lower Casamance, despite the small dams and dikes built as part of anti-salt programs.[51] Food security in this area is seriously affected by the loss of more than 50,000 ha of cultivated land (irrigated and non-irrigated) due to land salinization in this area and, beyond the lost land, agricultural production is also seriously affected.[52] Today, out of 15,000 ha developed, on average only 1,500 ha are developed.

26. Surface freshwater resources are therefore very limited, the potential that can be mobilized is low and, even if the irrigable potential is estimated at 70,000 ha, it seems difficult to envisage substantial hydro-agricultural development in this area from surface water, which also has a generous rainy season. In addition to the loss of cultivated land, the excess of salt causes a reduction in forest areas, impacts the fish fauna, and gradually leads to the loss of income of the populations and their impoverishment. Salinity is also a major problem for access to drinking water in Lower Casamance where it is among the lowest in the country.

27. **Recommendations:** It is recommended to (i) develop protection measures against the rise of sea water and (ii) explore solutions such as transfers or collection of rainwater in order to improve the coverage of water services. potable water.

Saloun-Sine-Carcar River System

28. In the center-west of the country, the system of the Carcar, Sine and Saloum rivers in the heart of the groundnut basin is the site of localized flows only during heavy rains in its continental part and salty flows in its maritime part, downstream of Kaolack, located 90 km from the mouth. Mobilizable surface freshwater resources are very low, variable and poorly assessed due to the lack of a measurement system. With a total area of 36,189 km2, these basins are in the Sahelian climatic zone, with an average annual rainfall of 600 mm concentrated during the rainy period from July to October. The volume flowing through the basin is estimated at 180 Mm3/year. To deal with the salinization of the waters and soils in the maritime reach, anti-salt dikes had been built on certain rivers; most of them are now very dilapidated due to lack of maintenance and high salinity.

29. **Recommendations:** It is recommended to explore the feasibility of constructing new anti-salt works in the maritime reach and of storing runoff water in the favorable zones of the continental part of the basin in order to recharge the aquifers and to temporarily satisfy needs related to livestock watering, micro-gardening and fish farming.

The small coastal basins of the regions of Thiès and Dakar

30. The Dakar peninsula, the coastal area of Thiès and more generally the regions of Dakar and Thiès, include a large number of small coastal basins giving rise to small perennial or seasonal streams and lakes, some of which have been greatly modified by urbanization. In the center of Dakar and Pikine, for example, some of these rivers are dormant, but can give rise to floods and violent floods in the event of heavy rains (see section 2.5.1).

31. The mobilizable potential is very limited but should not be neglected due to the lack of water resources and the economic value of the uses in this area. In fact, many retention basins have been built in recent years in these regions to store runoff water for various purposes, including flood control, groundwater

[51] Affiniam dam on the Bignona backwater, Guidel de Guidel dam on the Guidel backwater, Dianah Malari dam on the Casamance river.

[52] FAO, 2006. Integrated irrigation and aquaculture in West Africa. Concepts, practices, and potential.

recharge, irrigation and livestock watering.

32. **Recommendations:** In order to strengthen the safety of people, property and infrastructure, it is recommended to: (i) improve stormwater management to fight against flooding; (ii) to take into account water resources (availability, flow, contamination) in urban planning, particularly in the extension areas of Dakar and (iii) to continue the development of structures for the collection of runoff water and surface, in addition to groundwater, which is often overexploited in these areas.

Groundwater

33. Groundwater plays an essential role in Senegal's water security, especially since the drought of the 1970s. Currently, about 85 percent of withdrawals for drinking water and livestock watering come from groundwater, of the 66 centers served by SONES. They also supply almost all industrial, mining and tourist units. A small, but growing, share of irrigated areas depends on it mainly for horticulture. Today, groundwater is exploited by 20,000 to 40,000 traditional structures (uncemented wells, ceanes and cesspools) which capture the vast majority of superficial aquifers and by more than 3,000 boreholes capturing mainly intermediate and deep aquifers depending on the base. data from the DGPRE.

34. The numerous hydrogeological studies carried out in Senegal have made it possible to identify most of the aquifer formations constituting the two major units (sedimentary and socle) mentioned below and to characterize those which supply Dakar and its suburbs. As we will see later, the aquifers that supply Dakar and its region are generally better known and monitored. The following table and maps provide an overview of the main exploited hydraulic systems (grouping of aquifers that have a hydraulic connection and whose impacts propagate throughout the system) of Senegal, where the water balance, risks and recommendations are given. There are five main systems:

- The system of discontinuous and fractured aquifers of the Precambrian socle;
- The deep aquifer made up of Maastrichtian sands which occupies almost the entire sedimentary basin;
- The Horst de Diass aquifer system, which includes the Maastrichtian, in hydraulic connection with the Paleocene limestones of the intermediate system;
- The Littoral Nord system which includes the Quaternary sands of Kayar in St-Louis and the Eocene limestones of Bambey and Louga;
- The superficial aquifers of the infrabasaltic sands of Dakar, the quaternary sands of Thiaroye, the clayey sands of the Oligo-Miocene and the Continental Terminal located in the central and southern part of the country and the alluvium of the Senegal River.

35. Very briefly, according to the estimates made within the framework of this study on the basis of a synthesis of current knowledge, renewable groundwater would represent about 8 percent of the country's renewable water resources, i.e. between 1 .62 and 1.65 billion m3/year without considering socle recharge.[53] This estimate, or exploitable potential, is still imprecise despite the numerous studies carried out. Moreover, even if groundwater is present throughout the national territory, its availability, quality and exploitability vary significantly, impacting its use. The following situations can be distinguished according to the geographical areas:

[53] Their annual renewal (particularly by rain infiltration).

- In the coastal zone, from Thiès to Saint Louis, the aquifers supplying Dakar and its suburbs, located along the coast, are either overexploited and increasingly affected by saline intrusion, threatening the long-term sustainability of the resource and all the uses that depend on it (Infra-basaltic aquifers, North Coast, Horst de Diass), or already abandoned (Sables de Thiaroye). In this specific case, the massive pollution of this free aquifer by untreated wastewater led to an overflow of the aquifer and the almost permanent flooding of certain areas in the suburbs of Dakar. Conflicts of use between agriculture, DWS and mining are prevalent in the case of Horst de Diass and Littoral Nord. In this context, access to water for irrigation will be more and more difficult to ensure from groundwater, and is expected to decrease, despite the importance of these areas for vegetable production (60 percent national production), supplying the national market (Dakar and its suburbs) and export.

- In the Groundnut Basin area, roughly delimited by the towns of Kaolack and Fatick to the west, Diourbel, a problem of access to water (drinking and irrigation) arises in the central salty strip (see map 2.4) . In this area, the water potentials of the deep Maastrichtian aquifer and the overlying aquifers (Oligo-Miocene and Continental Terminal) are low and in the coastal fringe the upper aquifers are saline; they are also fluorinated in the case of the Maastrichtian and the Paleocene. Despite the high fluoride and chloride content, the DWS of most towns and centers in this area is provided by groundwater, which is not drinkable, resulting in a major public health risk for a population of more than one year. million inhabitants. To the east of the central salty band up to the socle area, there is an interesting exploitable potential of good quality in the Maastrichtian, but also in the Oligocene-Miocene, south of Saloum, between Kaffrine and Tambacounda.

- In the western part of Lower Casamance, there is a serious problem of access to water (drinking and irrigation) due to saline invasion in the Oligo-Miocene and Continental Terminal aquifers and the presence of the central band salt in the Maastrichtian. Nevertheless, there are some pockets of fresh water in the superficial aquifers. Some areas also have fluoride levels exceeding drinking water standards (Map 2.5). The aquifers in this area are still insufficiently known and monitored.

- In the Socle area, covering 1/5 of the Senegalese territory, in the south-east of the country, there are also problems of access to drinking water due to the low operating flow rates of the boreholes supplying the towns and centres, but also from the high variability of the water table with the seasons, which means that in the dry period, a large number of wells dry up, the population then resorting to untreated surface water. Pollution by heavy metals due to booming mining production, and in particular to poorly controlled gold panning, is a problem that must be solved. The recharge contributes to supplying the flow of the Senegal River, the Falémé and to the recharge of the regional Maastrichtian.

36. The following paragraphs detail the situation of each aquifer system and the recommendations to improve their management:

The quaternary sand aquifers supplying Dakar and its suburbs

<u>Infra-basaltic sand aquifers</u>

37. The infra-basaltic sands are located in the Cap Vert peninsula in Dakar. They cover an area of 30 km2 and have a power of 0 to 30 m. It is a captive aquifer under basaltic flows, except towards the east where it becomes free and merges with the sands of Thiaroye. It is in contact with the ocean on three of its flanks (west, north and south-west), making it very vulnerable to saline intrusion.

38. Recharge is provided by rainwater through basalt fracturing and by lateral infiltration from the Thiaroye sands aquifer. It is estimated at 4.3 Mm3/year for an infiltration rate of 42.5 mm/year. The recharge has decreased due to the strong sealing of the area (urbanization) and the drainage of rainwater.

39. Exploitation of the aquifer began in 1925 to supply Dakar. Due to saline intrusion, withdrawals, which had reached 18,000 m3/d in 1987, have been reduced to 12,000 m3/d since 2006. With the problem of Dakar's water supply deficit, the emergency program allowed the construction of new structures (i.e. a total of 19 boreholes in service) and the withdrawals exceeded 47,000 m3/d (17.15Mm3/year) in 2018. This strong demand on the water table has the direct effect of lowering the level from 1 to 4 m and the progression of the salt wedge at the level of the coastal fringe, more intense on the Yoff and Hann axis, threatening the viability of the aquifer, and which must therefore be controlled.

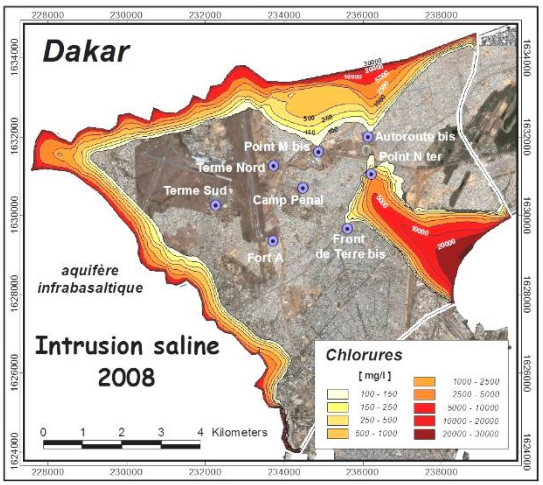
40. Apart from saline intrusion, the water table is polluted in certain areas where the nitrate content (from 140 mg/l to 207 mg/l) shows pollution due either to the infiltration of waste water, or to septic tank leaks.

41. **Recommendations:** The almost tripling of withdrawals in 2018 in order to meet the emergency needs for the supply of the city of Dakar has very significantly increased the overexploitation of the aquifer and threatens to compromise it definitively by an acceleration of the penetration of salty bevels. It is recommended to update the hydrogeological knowledge of the aquifer in this new context, by (i) updating the hydro dispersive model and the new recharge-exploitation balance; (ii) mapping the extension of the salt wedge and (iii) strengthening the high frequency monitoring system in sensitive areas. This will determine to what level the pumping in the aquifer will have to be reduced and distributed once the water from KMS3 is available for Dakar. It is also recommended to implement a policy to promote water saving. It is strongly recommended to review spatial planning and urbanization policies and to better plan investments to meet the growing needs of Dakar and its suburbs in order to avoid resorting to emergency withdrawals from the aquifers already overexploited.

The aquifer of the Thiaroye basin

42. The Thiaroye aquifer is located between Dakar and Cayar, covers an area of 300 km2, with a power of 50 m. Its recharge by rain is estimated at 60 mm/year, i.e. a renewable potential of around 9 to 18 Mm3/year. This aquifer, formerly exploited beyond its renewal capacity to supply Dakar (up to 17,000 m3/d, or 6 Mm3/year, in the 1970s) is no longer exploited by SONES today. because of its very high pollution by wastewater in urban, peri-urban and even rural areas in some cases. Very high nitrate levels (from 200 to more than 500 mg/l) were noted. In fact, the groundwater is now replenished by rain and wastewater (due to the lack of sanitation in the suburbs of Dakar), and its hydrological balance is in excess. The level of the water table has risen to such an extent that, very close to the surface, it regularly overflows, causing almost permanent flooding in the suburbs of Dakar. Thus, pumping by SONES is only operated today to mitigate these floods.

Map II.1 Simulation of salt intrusion in the Dakar area



43. **Recommendations:** Consideration should be given to recovering this aquifer for alternative uses that do not risk affecting public health; to map the areas flooded by the aquifer and to find sustainable solutions, and to encourage the current project which consists in recovering the water from the aquifer polluted by wastewater - due to the lack of an appropriate sanitation system - for agriculture in the Niayes

area. It would also be necessary to know the exact delimitation and the location of the existing boreholes for a necessary use for agriculture in the Niayes in order to fight against floods at the same time.

Horst de Diass system (Maastrichtian/Paleocene)

44. The Horst de Diass system located in the Cape Verde peninsula has a limited extension of approximately 1250 km2. It consists of Maastrichtian and Paleocene aquifers (Sébikhotane[54] and Pout zones), hydraulically connected and outcropping. Because of its importance for the urban DWS of Dakar in particular, this aquifer system is very well studied, having been the subject of numerous hydrogeological studies, and having a continuous piezometric monitoring system.

45. This system is recharged by rainfall infiltration, the Paleocene partially feeding the Maastrichtian. The recharge is estimated at 30 Mm3/year for an average infiltration rate of 24 mm/year. It is limited because the extension of this recharge zone is small and the rainfall (437 mm/year) is close to 300 to 400 mm/year, the threshold below which the aquifer would no longer recharge.

46. Due to the decrease in rainfall and its constantly increasing exploitation, this aquifer system has a very low water balance. Currently, withdrawals are 48.3 Mm3/year in the Maastrichtian and 71.7 Mm3/year for the Paleocene, i.e. a total of 120 Mm3/year, or four times the recharge estimated at 30 Mm3/year. This overexploitation of the system has led to a continuous decrease in piezometric levels since the 1970s and 1980s, on average in the order of 0.3 to 0.7 m/year. The piezometric depression at Horst has now reached -70 m below sea level. It has also led to saline intrusion in the Sébikhotane sector, close to the sea, which could increase if overexploitation continues. With regard to uses, it should be noted that agriculture represents 36 percent of withdrawals, urban drinking water 42 percent; mines 16 percent and rural DWS 6 percent.

47. Due to its outcropping nature, this system is vulnerable to anthropogenic pollution (notably there is high pollution by nitrates in the Cap Vert area[55]); its recharge is also sensitive to variations in the rainfall regime, all the more worrying as the average annual rainfall is already low in this area.

48. **Recommendations:** It is recommended to bring withdrawals throughout the Horst area to a level compatible with natural recharge, making it possible to stop the penetration of the salt wedge and to consider measures to restore this system by means of recharge devices. artificial (for example), as well as to consider the use of alternative resources for agriculture, including the nearby Thiaroye aquifer. Better arbitration between the different uses is also recommended.

Littoral Nord system (Eocene limestones and quaternary sands)

49. This system consists of two reservoirs in hydraulic communication which are the Quaternary sands to the west and the Eocene limestones to the east. It occupies an area of about 4900 km². It is located on the ocean frontage from Cayar to Saint Louis and encompasses the Niayes system which represents the main horticultural area of the country with 60% of market gardening production supplying the city of Dakar and its suburbs, as well as the export market. 20% of Dakar's drinking water comes from this system. This area is experiencing very intense economic development, with, in addition to market gardening, a booming mining industry (exploitation of phosphates by the Chemical Industries of Senegal (ICS) and Zircon by the

[54]The Palaeocene area of Sébikhotane is very small, between the Maastrichtian sands to the east and the Quaternary sands of Thiaroye to the west.

[55] République du Sénégal and UNICEF. Étude de Faisabilité des Forages Manuels.

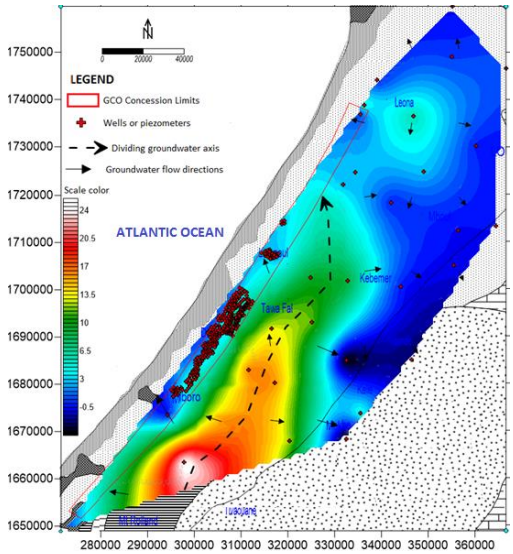
Grande Côte Operations (GCO)), fishing and breeding.

50. The Littoral Nord system has been relatively well studied and in particular has a piezometric network partly maintained by SONES since the 1980s. The aquifer is free, level or sub-level and in hydraulic communication with the sea. The groundwater flow is controlled by a piezometric dome of +25 m in the quaternary sands, parallel to the coast. From this dome, the aquifer flows to the west to retain the salty bevel coming from the sea to the east to feed the Eocene limestones and to the north where the aquifer is salty beyond the Louga-Léona-Potou axis.

51. The recharge results from the infiltration of rain, however the latter is relatively low, since the rainfall in this area slightly exceeds the recharge limit established at 300 to 400 mm of rain per year on average. The recharge would be 25.6 to 38.6 Mm3/year, for infiltration rates of 15 mm/year for the sands and 6 mm/year for the limestones. A large part of the recharge flows towards the sea to prevent the advance of the salt wedge.

52. This system is heavily exploited for DWS uses in urban centers and rural areas, agricultural, pastoral and mining activities, and the demand for water has increased sharply. The attractiveness of the coastal zone and the development of socio-economic activities have strongly contributed to the increase in water demand. For the DWS of urban centers (19 boreholes), the operating regime increased from 1.5 Mm3 in 1976 to 26.5 Mm3 in 2016. For the needs of rural hydraulics, the data provided by the statistical project of water are underestimated and moreover the samples do not indicate the system which is solicited. We made a calculation based on the needs for each rural municipality based on a consumption of 35l/person/day. The overall balance for rural hydraulics in the area in line with the hydraulic system is 21.8 Mm3/year. Added to this volume are the uses for livestock estimated at 6.7 Mm3/year and for market gardening between 108 Mm3/year (for two campaigns). For extractive industries such as ICS and GCO, most water needs are met from the deep Maastrichtian aquifer. However, depending on the exploitation techniques, by drawdown and by dredging and recycling, a significant loss by evaporation could affect the availability of the resource.

Map II.2: Piezometric map of the Littoral Nord (2017)



53. Overall, the flows withdrawn from the system (estimated at 92 Mm3) greatly exceed the renewal potential, which is around 25.6 to 38.6 Mm3/year. These high withdrawals have a direct impact on the groundwater flow regime, whose piezometric dome (water tower) has experienced a drop of around 10-12 m since the beginning of the 1970s, while the drop of the mean level of the water table in the sands and limestones is of the order of 2 to 4m over the same period. This decline has the direct consequence of the drying up of many traditional wells (problem of access) but also on the progression of the salt wedge which has appeared in Mboro, Lompoul and in the area beyond the Louga-Potou axis. . This intrusion threatens to expand if overexploitation continues. In this area there are serious problems of water availability and access, especially since the Maastrichtian is also brackish over a large part.

54. The system is also, due to its outcropping nature, highly vulnerable to pollution from intensive Niayes agriculture, booming industrial activity (chemical and mining), and domestic sewage. Localized pollution at the location of the structures is noted in the Quaternary sands. Its outcropping nature, the dependence on rainfall recharge, and its proximity to the coast, also make it very vulnerable to climatic

variations, such as the decrease in precipitation (already at the limit for possible recharge by rainfall), a increased evapotranspiration and a rise in sea level.

55. **Recommendations:** This is a strategic system because of its importance for DWS and irrigation of the Niayes and mining, but it is in deficit.

The deep regional Maastrichtian aquifer

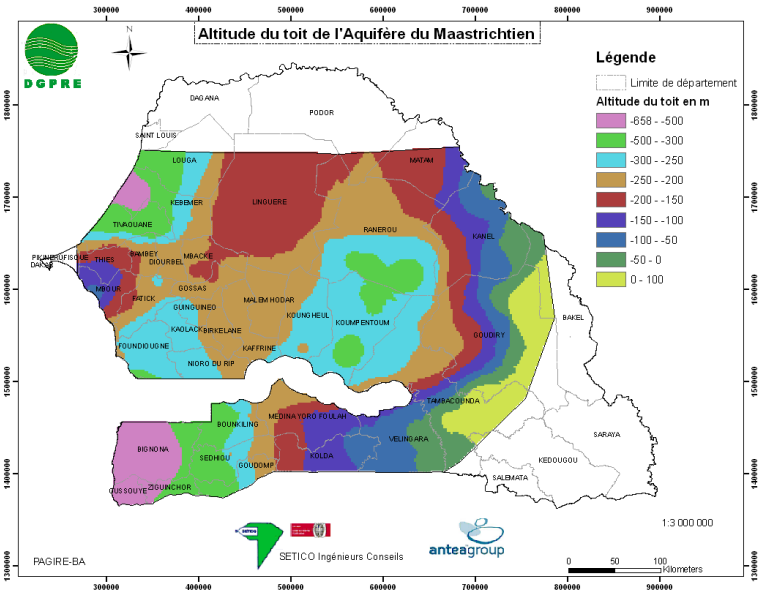
56. The Maastrichtian is undoubtedly the most important groundwater resource in Senegal with an extension over 4/5 of the territory, good hydrodynamic characteristics, significant reserves and good chemical quality over a large part of the territory. However, it is largely a fossil thousands of years old. Apart from the Horst de Diass area which supplies Dakar, its recharge and renewal potential and its operating regime are poorly known. The monitoring of the aquifer, beyond the Horst, is insufficient with an uneven distribution of the piezometers.

57. It covers an area of 150,000 km2, almost the entire sedimentary basin. It is made up of very old, largely fossil water. It is confined for most of its extent, under great pressure. Its renewable volume is not yet well known, except in the Horst de Diass area (Pout area), where the recharge of the outcropping Maastrichtian / Paleocene system is 82,700 m3/d or 30Mm3/year, from the Rainfall infiltration estimated, on average, at 24 mm/year. The other recharge zones are the zone of contact with the socle in the south-east from the infiltration of rains and the drainage of the crystalline socle where it would be around 28 to 48 Mm3/year and from the river Senegal, near Matam in the middle valley, where it is not yet estimated. A fourth unestimated recharge zone would exist in Guinea Bissau.

58. The cost of drilling can be a constraint to its exploitation. They generally capture 30-50 m from the top of the Maastrichtian which deepens from 0m IGN in the east to 660 m towards the west coast, with 200 to 250 m in the most exploited sectors (see Map 2.8). However, since the aquifer is loaded, the rise in water columns in the structures is around 200 to 300 m depending on the area, limiting pumping costs. The piezometric level varies from +30 m near the base in the east to a minimum of -70 m in the Horst de Diass, where it is very heavily exploited. The operating flow rates are very variable from 20 to 250 m3/h.

59. Water quality is a constraint to its exploitation in about 1/3 of the basin. The dry tailings values range from 13 to 2424 mg/l and show a spatial distribution of mineralization ranging from fresh water in the east, a central saline band (brackish water) from Casamance to the Saint Louis region and in the West zone a pocket of fresh water (see Map 2.8 above). This central saline band is characterized by waters with salt contents greater than 1000mg/l (water potability standards), fluorine contents greater than the potability standard of 1.5mg/l and higher chloride contents at 250mg/l (WHO standard) thus making the water unfit for consumption. This band particularly affects Lower Casamance, the regions of Fatick,

Map II.3 Ceiling of the Maastrichtian



Kaolack, Diourbel and part of the regions of Thiès, Louga, St-Louis and Kaffrine. In this area, particularly in the groundnut basin, where DWS is done in 60 percent of the cases identified using fluoridated water (ranging from 1.5 mg/l up to 3mg/l), for lack of alternative, and where the treatment is not available because of its high cost, a population of approximately 1 million people is at risk of Fluorosis, a cause of bone osteosclerosis, cervical and lumbar osteoarthritis and which may present disabling neurological forms.[56] Children under 10 are particularly exposed, an excess of fluoride can also have a negative impact on their intellectual abilities.[57] Beyond this saline central band, the Maastrichtian is saline at depth from 600 m in the entire west of the basin (from 10 to more than 100 g/l). These brines have been encountered by oil drilling. It should be noted that the high fluorine contents essentially affect, but not only, the Maastrichtian (see Table II.1).

Table II.1: Distribution of fluorides in the aquifers of Senegal (COWI, 2011)

Aquifer units and systems	Number boreholes with fluorides				Nb total boreholes analyzed
	<1mg/l	1-2 mg/l	>2 mg/l	>1 mg/l	
Infrabasaltic	**5**	**0**	**0**	**0**	**5**
Quaternary	**101**	**0**	**2**	**2**	**103**
Continental Terminal	**165**	**0**	**0**	**1**	**166**
Oligo-miocene	**92**	**8**	**6**	**15**	**107**
TOTAL SUPERFICIAL SYSTEM	**363**	**8**	**8**	**18**	**301**
Eocene	**394**	**9**	**16**	**26**	**420**
Paleocene	**51**	**32**	**70**	**106**	**157**
TOTAL INTERMEDIATE SYSTEM	**445**	**41**	**86**	**132**	**577**
TOTAL DEEP SYSTEM	**84**	**266**	**162**	**428**	**512**
TOTAL	**892**	**315**	**256**	**578**	**1470**

Source : COWI, 2011

60. The Maastrichtian is not very vulnerable to pollution, since it is confined under a thick impermeable layer, except in the recharge zones, mentioned above, where the aquifer is likely to be contaminated by activities in these zones, including agriculture and domestic or industrial wastewater.

61. Due to its strengths, the Maastrichtian is the most stressed aquifer, with a total of 166.7 Mm3/year. The DGPRE lists 1,300 catchment structures, mainly concentrated in the central salty strip and in the Horst de Diass; the eastern 2/3 of the aquifer being relatively little exploited.

- The concentration of withdrawals in the Horst de Diass area is due to the proximity of the urban centers of Dakar-Thies-Mbour, to the outcropping nature of the Maastrichtian in the area, and to the overexploitation of all the other water resources in the surroundings. Withdrawals greatly exceed recharge in this area (48.3 Mm3 for a recharge of 30 Mm3). A more detailed analysis of this zone is presented in the previous section dedicated to the Horst de Diass system.

- The concentration of structures in the central saline band may seem surprising, but is explained by the lack of alternatives. Indeed, the availability of surface water and in the overlying

[56] WHO 2020. Waterborne diseases. <https://www.who.int/water_sanitation_health/diseases/fluorosis/fr/>

[57] Much research has been devoted to this topic in China, a country strongly affected by the risk of fluorosis. For example: *X.S.Li et al, Fluoride, Vol 26, No.4, pp.189-192, 1995, "Effect of Fluoride Exposure on Intelligence In Children"*

intermediate and superficial aquifers (Eocene, Oligo-Miocene and Continental Terminal) is low in this area. Withdrawals would amount to 31 Mm3/year, mainly for urban and rural DWS, apart from a few agricultural boreholes intended for agricultural farms and pastoralism. The data provided by ANIDA for agricultural uses does not exceed 0.12 Mm3/year.

- The Maastrichtian is little stressed to the east of the central saline band due to the presence of other intermediate and superficial systems and a lower population density and economic activities. Withdrawals are estimated at 15.2 Mm3/year; the agricultural uses recorded by ANIDA would be 2.1 Mm3/year.

62. By comparing the total flows withdrawn from the central saline strip and from the eastern zone (46.2 Mm3/year) with the inflows at the sedimentary/socle border (28 to 46 Mm3/year), a deficit balance begins to forecast for the deep aquifer system with a drop in the groundwater level of 2 to 3 m. It is noted in the Kaffrine-Tambacounda zone from 2007-2017 (Balamboulou works), Boula, Fete, Diaba, Damaguen), in the Ferlo (since 1975 in Bele) and in the Horst zone (works where the decline since early 1970s is more important due to the pumping regime). However, this situation is far less worrying than in the case of the Horst de Diass because of the power of the aquifer and the strong rise in the water column induced by the captivity of the aquifer. It should also be noted that the recharge from the Senegal River and Guinea Bissau is not known.

63. **Recommendations:** The Maastrichtian system is the most important aquifer in Senegal, but also the most exploited. It is one of the most studied aquifers, however significant gaps persist. It is therefore recommended to update knowledge of the Maastrichtian by: (i) better estimating its recharge and its renewal rate, in particular, in Guinea Bissau, in the zone bordering the socle and from the Senegal River; (ii) updating the water balance at the scale of the extension of the aquifer; (iii) improving the groundwater monitoring system in the eastern and central areas where piezometers are lacking and (iv) extending the transfer programs to the southern regions where access to drinking water is a real challenge (in addition what is planned in the PAGIRE [Integrated Water Resources Management Action Plan]).

Aquifers of the Continental-Terminal and Oligo-Miocene

64. The aquifer system includes the CT aquifer proper and the underlying Oligo-Miocene aquifer. These are superficial aquifers that have been little studied and little monitored, where withdrawals are generally low compared to potential, but where quality problems, particularly salinity in coastal areas, limit their exploitation.

65. The Oligo-Miocene aquifer is located mainly in the south of the country, in Lower and Middle Casamance beyond the northern border of The Gambia (southern zone of the groundnut basin) and in the Kaffrine zone at Tambacounda on the southern edge of the Ferlo. It is in hydraulic communication with the overlying Continental Terminal in most of these areas.

66. Further north, beyond the axis of the Saloum River, where the OM is not identified, the Continental Terminal is also present, but its operating conditions are not favorable because, on the one hand, on the other hand, its useful power (saturated thickness) is relatively low to allow appreciable operating flows and, on the other hand, its aquifer is found at relatively great depths (80 m).

67. For the purposes of the analysis, we will therefore limit ourselves to the south of the groundnut basin and to Casamance, where the OM-CT system is present over a total area of approximately 64,246 km2, for an infiltration rate of 20 to 30 mm/year on average, and a combined recharge estimated at 1483 Mm3/year. Much of it is drained by The Gambia (OM and CT north of the Gambian border) and the Casamance River. The depth of the water table varies from 10 to 60 m, with the exception of areas close to

small rivers where the water table is superficial and maintains the base flows of the tributaries of the Saloum and Casamance rivers.

68. 68. The level of exploitation of the OM-CT system is not well known. The approach adopted to establish the level of abstraction in the area is to consider the needs of 35 l/person for all the municipalities in the region. The level of abstraction is 30.8 Mm3/year in the northern part of the Gambian border and 28.34 Mm3/year in the southern part. To these withdrawals are added those for agricultural uses of the ANIDA program which amount to 11,500 m3/d (4.2 Mm3/year) taken from the CT and 29.5 m3/d (1.06 Mm3/year) taken from OM. Overall, withdrawals are estimated at 64.4 Mm3/year, far below renewal potential. This positive balance allows the maintenance of the permanent flow of the many rivers in the region.

69. From the quality point of view, on the ocean front and in the areas near the Saloum and Casamance rivers, the OM and CT aquifers are salty due to exchanges of aquifer/river flows. In these areas, including the Saloum islands, serious problems of access to drinking water arise due to the salinity of the surface aquifers and the underlying Maastrichtian. Point pollution has also been identified at certain structures, mainly from human actions around these points. Apart from these aspects, the aquifers contained in these aquifers are generally of good quality suitable for DWS and other uses.

70. **Recommendations:** These are poorly known and poorly monitored aquifers. It is recommended to focus management in two priority areas: (i) Lower Casamance due to the salinity of the aquifer and (ii) the area from Kaffrine to Tambacounda in the Peanut Basin with a view to assessing its promising potential. To do this, it is recommended: (i) to update the hydrogeological study of Kaffrine-Tambacounda; (ongoing project) (ii) to identify areas with high potential in Casamance; (iii) to map the salinity and the extension of the salt wedge and (iv) to set up a monitoring network in the areas at risk.

The aquifers of the Precambrian Base (Socle)

71. The base covers 32,700 km2, or 1/5 of the national territory. These are discontinuous aquifers made up of weathered fringes of healthy rocks or fractures and cracks affecting the upper part of the rocks. The groundwater renewal capacity is relatively good, with abundant rainfall in the area (700 mm/year on average). The recharge is estimated very roughly and conservatively at 490 Mm3/year, considering a minimum infiltration rate of 15 mm/year. It largely empties to supply many waterways, including the Senegal River and its tributary, the Falémé. It also feeds the aquifers on the edge of the sedimentary basin, including the Maastrichtian aquifer.

72. Mobilizing this resource is difficult. Indeed, the boreholes require prior hydrogeological and seismic studies and their cost is high. The median and average exploitable flow rates of wells/boreholes of only 4m3/h and 7m3/h, at depths of 2m to 70m, and very variable, depending on the rock fracturing network. The piezometric level is favorable, generally between 10 and 20 m. Due to the low exploitable flow rates, abstractions are mainly made from traditional wells located in the valleys and lowlands. The total exploitation of these aquifers should not exceed 4.7 Mm3/year (boreholes and wells). The DGPRE database lists 251 boreholes in the bedrock, or 8 percent of national boreholes. The volumes withdrawn obtained as part of the DGPRE's "water statistics" project vary according to the municipalities from 0.04 to 1 Mm3/year in 2019, with peaks in the towns of Kidira (54,750 m3/year) and Kédougou (375,000 m3/year). The majority of boreholes and wells are intended for drinking water supply. However, the database shows that some water points are intended solely for market gardening and livestock on family and village farms. It should be noted that the rapidly expanding mining (Sabodola and Mako) and gold panning water needs are met by the storage of runoff water and rivers.

73. The waters are generally weakly mineralized with dry residue values ranging from 143 to 600 mg/l

and an average of 334 mg/l. However, they are very vulnerable to pollution due to the fracturing of aquifers; and in fact high nitrate values of up to 288 mg/l have been recorded in some wells (exceeding the WHO potability standards set at 50 mg/l.) indicating contamination by agriculture, livestock or Wastewater. Signs of contamination by heavy metals are noted in the gold panning areas (mercury varying from 1 to 34 µg/l, arsenic from 3 to 26 µg/l in the sites of Sabadola, Sounkountou, Diabougou, Tomboronkoto and Bantako). These values exceed those issued by the WHO, which are respectively 1 and 10 µg/l.

74. Resources are also very sensitive to seasonal and inter-annual rainfall variations. The groundwater renewal capacities are relatively good due to the good rainfall, but the process of emptying into the rivers mentioned above leads to a drop in the level of the groundwater during the dry season and causes the drying up of many wells as soon as the month of March-April due to the weak slices received.

75. In short, this is an area where the groundwater resource potential is low, due to exploitation constraints, but whose hydrological balance is in excess due to its remote and sparsely populated nature. It has alternative as it receives a lot of water. Nevertheless, the rate of access to drinking water (from groundwater) is among the lowest in Senegal, especially in large localities such as Kédougou, Kidira and Tambacounda. In their case, the low flow rate of the boreholes and, more generally for the AEP, the vulnerability of the aquifers to pollution are challenges that must be taken up. In particular, the impact of mining activity should be carefully monitored due to the ease with which harmful elements spread along fractures. In addition, in the absence of boreholes, many villages experience a drying up of their wells before the rainy season, obtaining supplies during the lean season and without prior treatment from backwaters, or even ceanes, which are often contaminated. For other mining and agricultural uses, obtaining sufficient water from groundwater is very difficult, hence the need to recommend the construction of micro-dams to retain runoff water.

76. **Recommendations:** The management of this aquifer should focus on two priority aspects: (i) vulnerability to mining and gold panning pollution and (ii) meeting DWS needs in large localities whose access are low compared to the rest of the country. To do this, it is recommended to: (i) assess the capacity of aquifers in fracture zones; (ii) map vulnerable areas and pollution by harmful elements in the mining area; (iii) design a groundwater monitoring program in vulnerable areas; (iv) conduct an epidemiological study of toxic elements in the impacted areas; (v) strengthen control and sanctions related to pollution by mining companies and (vi) conduct a gold panning supervision program in order to limit pollution of vulnerable areas.

Current water withdrawals

77. Withdrawals are not closely monitored in the country. The data presented below are therefore orders of magnitude, and have for the most part been estimates, based on irrigated areas and populations. They are therefore limited to the main uses, which are the water supply of towns and villages, irrigation, including flood-recession crops and the mining industry.[58]

78. The country's water withdrawals are currently estimated at 2.7 billion m3/year on average, including 2.3 billion m3/year from surface water and 417 million m3/year from surface water. underground. Agriculture accounts for 82 percent of withdrawals, drinking water supply 15 percent and mining 3 percent. Rice cultivation alone accounts for 60 percent of withdrawals.

[58] In general, for withdrawals, the following sources were used: (i) For agricultural levies: Sources given by SAED (2019), SODAGRI, (2019), and estimates based on project monitoring data from the Ministry of Agriculture and Rural Equipment between 2011 and 2018; Inventory phase of water points and withdrawals, Processing and Analysis of the information collected – DGPRE 2020 (ii) For withdrawals from surface and groundwater (other than agricultural uses): SDE, Inventory Phase of water points and withdrawals, Processing and Analysis of the information collected – DGPRE 2020

Irrigation water needs

79. Currently, in Senegal, 171,252 ha are developed on an irrigable potential estimated on the basis of soil suitability first, and then the availability of water resources, at 440,700 ha, [59] of which 80 percent is or 138,000 ha in the Senegal River basin, 5,000 ha in Anambé, 15,000 ha in Lower and Middle Casamance, 1,200 ha in the Gambia River basin (banana areas) and 12,000 ha in Niayes. Water withdrawals for irrigation in Senegal are estimated at nearly 2.2 billion m3 per year, or 81 percent of withdrawals, including 1.57 billion m3 for rice, 470 million m3 for horticulture (Niayes, Lake Guiers, groundnut basin, Gambia River) and 90 million m3 for sugar cane. Agricultural water needs are set to increase rapidly in response to public policies set out in the PSE.

Rice today

80. Withdrawals for rice are mainly from surface waters. They benefit from a developed area of about 158,000 ha, [60] while the average irrigated area between 2011 and 2018 was only 82,000 ha, or 52 percent of the developed areas, highlighting serious problems of development. Average water withdrawals are 1.62 billion m3/year.

81. According to the second Program to Accelerate the Pace of Senegalese Agriculture (PRACAS2), in 2017, Senegal produced 1 million tons of rice, almost half of which was irrigated,[61] i.e. a doubling of the share of the irrigated rice in total rice production since 2013. Senegal, with an estimated average consumption of 80 to 90 kg per person, consumes between 1.25 and 1.5 million tonnes of rice each year. The irrigated part therefore represents about a third of national consumption.

Tableau II.2: Irrigated rice in Senegal

Area cultivated with rice	Irrigable potential (ha)	Equipped area (ha)	Cultivated equipped area (ha/yr, avg 2013-2018)[62]	Equipped area cultivated in dry season (ha/yr)	Yield (avg 2013/2017 ton/ha)	Total rice prod. (2017/2018)	Estimated water withdrawals[63]
Senegal River	228 000	138 052	77 695	42 417	6	455 000**	1 566
Anambé	16 000, mais difficile	5 000	3 148		4	12 592*	41*
Casamance (developed lowlands)	70 000	15 000	1 500*		2	3 000*	10*
Lowlands Eastern Senegal (Gambia)	15 000	--	--	--	--	--	--
TOTAL	**329 000**	**158 052**	**97 326**	**55 812**		**470 592***	**1 617**

* Estimations from study experts, ** SAED data

[59] Estimated based on soil characteristics. The PSE estimates 310,000 ha, which appears to be the irrigable rice area.
[60] Own calculation based on data sources from SAED (2019), SODAGRI, (2019), and estimates based on project monitoring data from the Ministry of Agriculture and Rural Equipment between 2011 and 2018.
[61] PRACAS2, 2018, p.49
[62] Magatte Report, p. 20 and SAED data 2010-2018. Precise data do not exist on the development in the lowlands (equipped for irrigation in total control), but we can estimate 10%, or 1,500 ha (Magatte, p. 31)
[63] Estimated based on a raw water requirement of 18,000m3/ha in the Senegal River basin (SAED), 13,000 m3/s in Anambé and 6,300 m3/ha in the lowlands (It should be remembered that with the FAO method the water needs were determined on the basis of normal irrigation, where there were no data on withdrawals as in the case of Anambé and Casamance).

Horticulture today

82. Withdrawals for market gardening are made both from surface water and groundwater and benefit from a developed area of approximately 41,000 ha, most of which is cultivated each year. The bulk of irrigated horticultural production is practiced in the Niayes area (60 percent, or 12,000 ha), in the Senegal River valley and around Lake Guiers (25 percent, or 24,000 ha – tomato, onion, sweet potato[64]), in Casamance and in the developed valleys of the groundnut basin (15 percent, especially fruit crops), the other areas practicing mainly rainfed horticulture. The water consumption of horticultural products is estimated at 675 Mm3/year.

Table II.3 : Horticultural crops in Senegal

Main areas cultivated in horticulture under irrigation	Equipped areas (ha)	% Production (2017/2018)	Water consumption (2019, Mm3/yr)[65]
Niayes	12 000	60% - Vegetable and fruit production	108
Senegal River (SAED)	18 608**	Polyculture	470
Lac de Guiers	6 000	25% - Tomato, onion, sweet potato	45
Easter Senegal – Gambia River Basin	1 200	Bananas	25*
Casamance	1 000*	Fruits	9*
Groundnut basin	2 000*	Fruits	18*
TOTAL HORTICULTURE	**40 808**		**675**
CSS (lac de Guiers)	10 000		90

* estimated by team[66]. ** cultivated areas (average over the last 5 years, SAED data) and water consumption, Inventory report of water points and withdrawals, DGPRE 2020

83. Note, in addition to rice and horticultural crops, sugar cane, grown on 10,000 ha from the Senegal River by the Compagnie Sucrière Sénégalaise with average withdrawals of 90 Mm3/year (OLAC, 2019) and a production of about 140,000 tons per year (gold, 16 per cent of national production). The Compagnie Sucrière Sénégalaise is also the leading private employer in Senegal, with 8,000 jobs during the campaign period. The Company plans to reach 200,000 tonnes by 2020/2023 to achieve the country's sugar self-sufficiency, which will likely increase its water demand.[67]

Potable water needs

84. Today, the country's drinking water needs are estimated at 346 Mm3/year, based on a population

[64] Rapport OLAG, 2019.

[65] Les données manquantes, à la fois les surfaces ou les besoins en eau, ont été estimées dans le cadre de cette étude: Pour les Niayes, besoins en eau moyens de 9 000 m^3/ha (saison sèche et agrumes) ; Lac de Guiers : 45 Mm^3/7 500 m^3/ha ; Sénégal Oriental : 1 200 ha*21 053 m^3/ha; Bassin arachidier et Casamance: 18 Mm^3/8 889 m^3/ha.

[66] 16,200 ha horticulture: 12,000 ha in the Niayes area, 6,000 ha in the Lac de Guiers area, 1,200 banana areas in eastern Senegal (Gambia), 2,000 ha in the groundnut basin, 1,000 ha in Casamance, the rest of the production being done in rain. Estimated on the basis of the water needs in 2035 of the different crops (divided by the total calculated by Magatte): for the Lac de Guiers area: 45Mm3/7500m3/ha; for the groundnut basin, 18Mm3/8889m3/ha and 9Mm3/8889m3/ha for Casamance. The banana plantations consume 21,053 m3/ha.

[67] https://www.css.sn/index.php/fr/

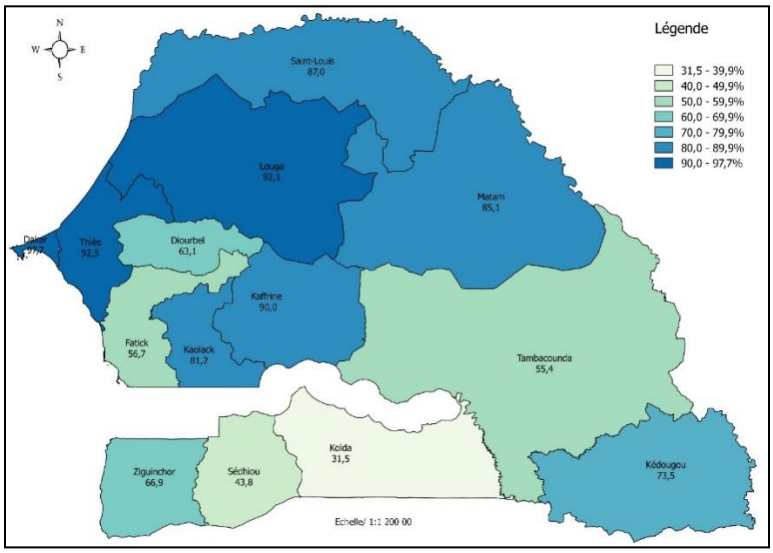
of 15.8 million, of which 52 percent is rural.[68] Withdrawals for DWS are mainly from groundwater (84 percent). [69]

85. Currently, the majority of households in Senegal (81 percent) get their water from an improved source, especially in urban areas (92 percent). About 1/3 of rural households continue to draw from unimproved sources.[70] It should be noted that access to an improved source means that, by the nature of its construction, it satisfactorily protects the water from external contamination, in particular faeces[71]), however it is not necessarily synonymous with access to drinking water, especially if the resource is naturally unsuitable for consumption (such as in a good part of the central salty strip). In comparison, access to an improved source in Mauritania is 70 percent, in Mali 78 percent, and in Burkina Faso 48 percent.

86. A survey conducted as part of the Millennium Drinking Water and Sanitation Program (PEPAM) and the National Agency for Statistics and Demography (ANSD), in 2017, the proportion of the population using safely managed drinking water services[72] stands at 7.8 percent. Consumption of safely managed drinking water is higher in urban areas (13.2 percent compared to 1.0 percent in rural areas) and in the highest income quintile of the population (21.5 percent).[73] From a regional perspective, the Dakar region clearly stands out from the other regions with a proportion of the population using safely managed drinking water supply services of 17.8 percent. It is followed by far by the region of Kédougou with 6.2 percent. On the other hand, Matam (0.9 percent) and Kaffrine stand out with almost zero levels. At Fatick, the value of this indicator is zero.

87. The maps below show, on the one hand, the distribution of access rates to an improved source by region (Map II.4) and, on the other hand, access to a "secure" water source (Map II.5).

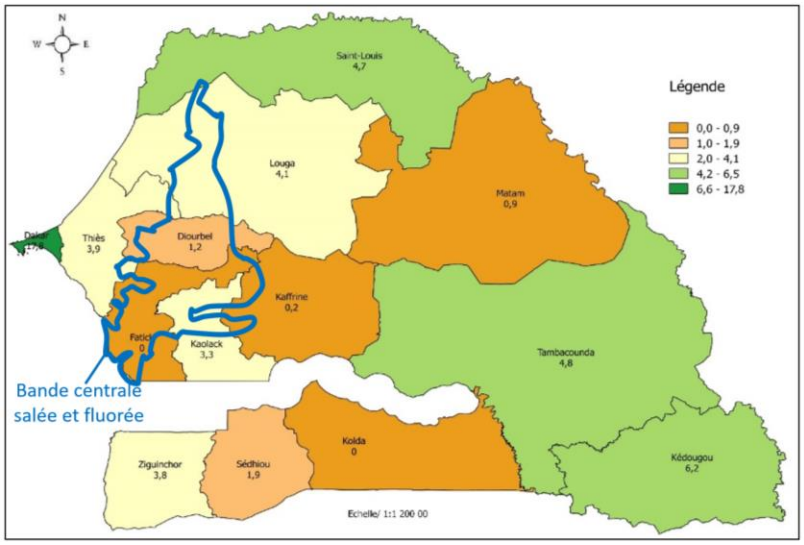
Map II.4: Improved household drinking water source (in %), by region (WASH, Senegal 2017)



[68] https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=SN. For rural areas, 35 l/p/day was considered and for urban areas, 60 l/p/d.
[69] COWI Report, 2011.
[70] PEPAM and ANSD, 2018. Survey on the baseline situation of water, sanitation and hygiene. WASH_ Senegal 2017.
[71] https://www.who.int/water_sanitation_health/monitoring/jmp2012/key_terms/fr/
[72] That is to say located at the places of consumption; available when needed; and free from priority faecal and chemical contamination. (https://www.sdg6monitoring.org/indicator-611/), World Health Organization.
[73] PEPAM and ANSD, 2018. Survey on the baseline situation of water, sanitation and hygiene. WASH_ Senegal 2017. The PAP2 indicates 99% and 92% as the rate of access to drinking water in rural and urban areas (p.35).

1.

Map II.4 Distribution of households according to access to safe drinking water (%) (WASH, Senegal 2017)



88. It should be noted that in the regions of Tambacounda, Fatick, Kolda and Sédhiou, 1.4 million people have access to DWS systems from which the water supplied is not drinkable, exceeding WHO standards concerning drinking water. Fluorine, salinity and in some cases Chlorides.[74] The catchment centers located in the groundnut basin north of the Saloum River and near the Casamance River (i.e. Lower Ziguinchor, Kaffrine and Kaolack) have serious problems of access to drinking water, because of excess salinity (Lower Casamance), iron, fluorine and chloride levels (in the central band).

89. Access to safely managed sanitation is 21.5 percent nationally, although open defecation is still practiced by 25 percent of the population in rural areas. Access to improved sanitation (i.e. access to improved facilities that are not shared with another household) is higher in urban areas where it reaches nearly 65 percent compared to rural areas (almost 40 percent). This indicates that a large proportion of the population – 30 percent nationally – has access to improved facilities but faeces are not safely managed or treated, which in turn has implications for water quality. water and impacts on the environment and public health. Indeed, diarrheal diseases were the second leading cause of child morbidity in Senegal in 2019.[75]

Mining activity

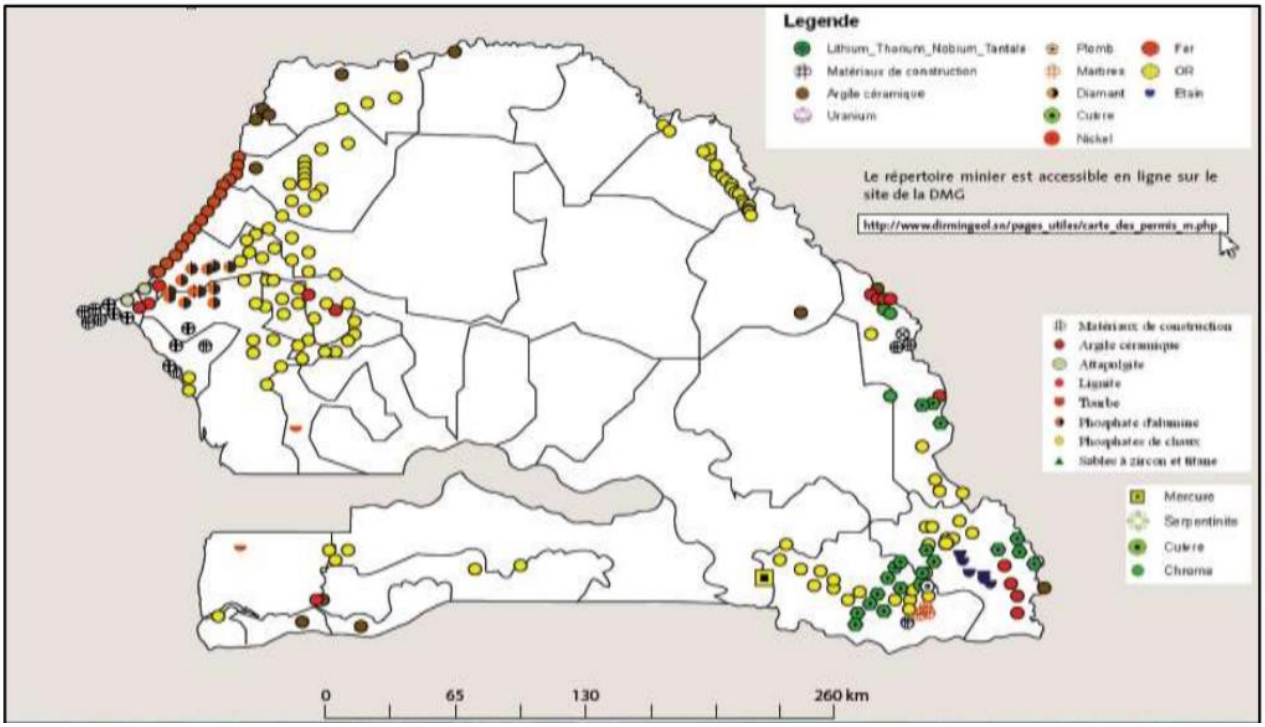
90. The mining sector represents 20 percent of the value of the country's total exports and contributes 2 percent of GDP and less than 0.5 percent of total employment. According to official data, the industrial mining sector consumes 13 million m3/year, most of which comes from groundwater. These activities are mainly located in the regions of Thiès, Diourbel, in the Niayes Valley and in the basement area (see Map II.4). It mainly concerns phosphate, zircon, iron and gold mines.

91. In addition to these industrial operations, there is artisanal gold mining, mainly in the regions of Kédougou and Tambacounda.[76] Although the legal framework exists to control mining pollution, the lack of capacity to enforce the law contributes to significant environmental degradation and pollution problems,

[74] https://www.who.int/water_sanitation_health/monitoring/jmp2012/key_terms/fr/
[75] Santé Sénégal. «Les maladies diarrhéiques "la 2ème origine de morbidité des enfants" » publié le 28 août 2019.
[76] ITIE Sénégal 2018

especially in artisanal and informal gold mining areas. A study led by Duke University has found dangerously high levels of mercury and methyl-mercury - between 10 and 100 times higher than the standards set by the WHO - in soils, sediments and near waterways. of artisanal gold mines in the Kédougou region (River Gambia).[77] In addition to pollution problems during the operational phase, abandoned sites can also pose long-term risks to the health of local communities and the environment, as they are not subject to any formal environmental management or rehabilitation.

Map II.6 : Location of mines in Senegal



[77] Jacqueline R. Gerson, Charles T. Driscoll, Heileen Hsu-Kim, Emily S. Bernhardt. Senegalese artisanal gold mining leads to elevated total mercury and methylmercury concentrations in soils, sediments, and rivers. ElemSci Anth, 2018 ; 6 (1): 11 DOI: 10.1525/elementa.274

Annex III – Estimation of water needs to achieve PSE objectives

1. In 2014, Senegal decided to adopt a new development model to accelerate its march towards emergence. The Emerging Senegal Plan (*Plan Sénégal Emergent*, PSE) is the benchmark for economic and social policy by 2035. The vision of the PSE is that of "An emerging Senegal in 2035 with a united society under the rule of law."

2. **In agriculture**, the implementation of the PSE should be accompanied by an increase in water demand, resulting mainly from the objectives of increasing agricultural production in order to achieve food self-sufficiency in rice, to develop horticulture for export, and to halve the trade balance deficit on irrigated crops (millet, rice, maize).

3. One of the means displayed to achieve these objectives is a significant expansion of irrigated areas (through the rehabilitation and extension of hydro-agricultural schemes, the replenishment of dead valleys, the development of reservoirs for water), which should reach 76 percent of the irrigable areas in 2018, i.e. 253,000 ha, or 110,000 ha more than in 2012.[78] It should be recalled that in 2020, the developed areas are 171,000 ha and the investments for the development continues. The PSE also provides for the mobilization of 2.2 million m3/year of groundwater for agriculture, compared to the 1.2 million m3/year withdrawn in 2012.[79]

4. The second phase of Senegal's Agricultural Pace Acceleration Program (PRACAS 2), designed for the implementation of the agricultural component of the PSE, announces specific objectives for the 2019-2023 period with production increases of:

a. Rice from 1,011,269 tons to 2,100,000 tons per year
b. Fruits and vegetables from 106,200 tons to 200,000 tons
c. Onions from 400,000 tons to 600,000 tons
d. Potatoes from 118,783 tons to 200,000 tons
e. Bananas from 30,000 tons to 55,000 tons

5. In terms of water control, PRACAS 2 interventions focus on:[80]

a. The development of 23,400 ha of new rice-growing areas in the river valley and 8,000 ha of polyculture areas.
b. The development, including the rehabilitation, of 137,303 ha of market gardening areas to ensure self-sufficiency (supply of the national market 12 months out of 12) and exports (regional and international markets) of fruits and vegetables.
c. The rehabilitation of 23,250 ha of rice fields in the Senegal River valley and 1,186 ha in the Anambé basin, to maintain their productivity.
d. The development of the export of horticultural products (fruits, vegetables, flowers and ornamental plants) on 10,000 ha developed in the Ngalam valley and the Lac de Guiers area.

[78] The PSE estimates that in 2012, 140,000 ha, or 45% of irrigable land was developed (p.27 and p.150). It therefore estimates an irrigable potential of 330,000 ha – when in the context of this study we estimate 441,000 potentially irrigable ha (including around 330,000 ha for rice growing).
[79] PSE, 2014 p.150
[80] PRACAS 2, 2018. P.26

e. Connecting the perimeters developed under PRACAS 1 and certain private farms to the Delta outfall, to maintain their productivity and prevent their abandonment due to salinization.
f. The development of valleys and lowlands over 28,600 ha for rainfed rice cultivation and market gardening as part of the development of surface water.

6. The PSE targets universal access to drinking water. However, these withdrawals will remain marginal compared to those for irrigation, although the investments required to achieve this objective may be very costly. It is planned in particular for the supply of Dakar and its suburbs, the realization of the third transfer from Lac de Guiers to Dakar and a water desalination unit in Mamelles.[81] The PSE also plans to improve access to sanitation in urban and rural areas - respectively to 86 percent and 65 percent by 2023 - with the implementation of the reform of the sub-sector, the construction and the strengthening of wastewater treatment and depollution systems in large cities, the extension of rainwater drainage networks in urban centers, the construction and rehabilitation of sewerage networks in urban and peri-urban areas and the construction of collective works for the evacuation of excreta in rural areas. Improving sanitation, especially in Greater Dakar, would help address the water quality challenges that already affect some of the aquifers that supply the area.

7. The PSE has ambitious industrial development goals. It provides for mining development, including iron, phosphates, phosphoric acid, gold and zircon, which will lead to an increase in extraction and the risk of pollution, even if environmental measures are planned to limit the latter, in particular with the supervision of gold panning. The PSE also provides for the construction of three integrated industrial platforms, the first of which is under construction in Diamniadio, covering 13 ha and 6 industrial companies, which will lead to an increase in water demand in the area.

Achieving the objectives of the PSE presupposes a substantial increase in water needs

8. These water needs are estimated at between 3.4 and 3.9 billion m3/year in 2035, an increase of 24 to 41 percent compared to current needs, estimated at 2.7 billion m3/year. This difference is dictated mainly by water withdrawals for irrigation in the two scenarios considered (discussed below).

Estimation of irrigation water needs by 2035

9. The irrigation water needs in 2035 have been estimated according to two scenarios, which assume different developed areas, development rates and yields:

Scenario 1 assumes that the recent rate of expansion of developed rice areas, of about 3,500 ha/year, is maintained until 2035. Everything else remains equal (development rate and yield). The water needs of market gardening remain constant at 391 Mm3/year.

Scenario 2, more ambitious, considers an increase in irrigated areas that leads to the achievement of rice self-sufficiency in 2035; a significant improvement in yields and development rates, particularly in the Senegal River Valley where the SAED target of 1.2 would be achieved. This scenario considers that the irrigated areas in horticulture increase by 25 percent, except for the Niayes where the water tables are already overexploited and where it is estimated, already optimistically, that the irrigated area would remain at the current level.

10. The assumptions and results of the two scenarios in 2035 are summarized in Table III.1:

[81] Plan d'Action Prioritaire II 2019-2023. 2018.

Scenario 1: Water requirements for irrigation would reach 2.85 billion m3 per year, an increase of 24 percent compared to today. For rice, the developed areas would reach 205,500 ha (about 50,000 ha more than in 2019) and the water needs for irrigated rice 2.17 billion m3/year, of which 2.09 billion m3/year for the Senegal River Valley; 66 million m3/year for the Anambé compartments and 9 million m3/year in the secondary valleys and lowlands. With a production of 0.64 million tons, self-sufficiency in rice, which would require an irrigated rice production of 1.24 million tons, would not be achieved. The water needs of market gardening would not change, at 675 million m3/year.

Scenario 2: Water requirements for irrigation would reach 3.31 billion m3 per year, an increase of 45 percent compared to today. For rice, the areas developed would reach 177,000 ha, including 137,000 ha in the Senegal River basin, similar to the current situation. This scenario shows that if substantial efforts are made to increase development and yields, especially in the Senegal River area, it would not be necessary to extend the area of irrigated perimeters. The water needs of market gardening would increase to reach 663 million m3/year.

Tableau III.1 : Irrigation water requirements (rice and horticulture) by 2035

Scenario 2035	Equipped areas (ha)	Cultivation (%)	Yields (ton/ha)	Total irrigated rice production (ton)	Water needs (Mm3/yr)[82]
Current situation	**198 860**				***2 292***
Rice cultivation	**158 052**			**470 592**	**1 617**
Senegal River	*138 052*	*56*	*6*	*455 000*	*1 566*
Anambé	*5 000*	*63*	*4*	*12 592*	*41*
Lowlands	*15 000*	*10*	*2*	*3 000*	*10*
Horticulture	**40 808**	***100***			**675**
Scenario 1 – recent past rhythm	**227 700**				***2 848***
Rice cultivation	**205 500**			**644 760**	***2 173***
Senegal River	*185 000*	*56*	*6*	*621 600*	*2098**
Anambé	*8 000*	*63*	*4*	*20 160*	*66*
Lowlands	*15 000*	*10*	*2*	*3 000*	*9*
Horticulture	***40 808***	***100***	**--**	**--**	***675***
Scenario 2 – PSE	**206 369**				**3 314**
Rice cultivation	***176 905***			***1 237 000***	***2 651***
Senegal River	*136 905*	*120*[83]	*7*[84]	*1 150000*	*2 464*
Anambé	*10 000*	*100*	*6**	*60 000*	*130*
Lowlands	*30 000*	*30*	*3**	*27 000*	*57*
Horticulture	***48 000***	***100%***	**--**	**--**	***663***
Niayes	*12 000*				*108*
Remainder	*36 010*				*555*

[82] Estimé sur la base d'un besoin en eau brute de, 13 000 m^3/ha dans l'Anambé et 6 300 m^3/ha dans les bas-fonds (estimations FAO). Pour le Sénégal, données SAED pour les prélèvements actuelles (moyenne 2013-2018) ; augmentation proportionnelle à l'augmentation de surface pour le scenario 1 ; besoin en eau brute de 15 000 m^3/ha pour le scenario 2 (augmentation d'efficience d'environ 20%)

[83] Tout en considérant que l'OMVS garantit à la SAED un débit minimum d'étiage de 50 m^3/s, ce qui permet d'irriguer entre 40 000 et 45 000 ha en contre saison sèche, soit 20% des 228 000 ha.

[84] Valeur moyenne prévue en 2023 pour le riz irrigué, objectif PNAR, 2018. PRACAS2, 2018, p. 51

	(+25%)
** Increase in demand proportional to the increase in irrigated areas*	

11. Rice self-sufficiency by 2035 is theoretically possible, but requires lifting serious constraints related to the rate of development during the rainy season and to yields, constraints which have not been able to be lifted so far. The Senegal River Valley and Delta would continue to produce most irrigated rice as this is where the potential to increase production lies. Without extension of the developed areas, the additional production in this area should come mainly from a substantial increase in development during the winter period, because in the dry season the irrigated area guaranteed by the minimum low water flow has already been reached (45 000 ha). The introduction of the Californian system, which increases the efficiency of water conduction to the plot, could allow a slight increase in irrigated areas in the dry season (50,000 ha), without increasing withdrawals. The major difficulty that a substantial increase in the development rate in the winter season would represent is that this would represent a reversal of the trend of recent years, marked by a reduction in the areas irrigated in winter, which went from 33,000 ha in 2010-11 to 25,000 ha in 2016-2017-2018. The reasons for this decrease are not clear, but could be linked to the lack of control of the cropping calendar and the difficulty of access to credit.

12. Thus, the increase in rice production in the Senegal River valley, as envisaged by the PSE, cannot count on an increase in water availability during the dry period, unless the rules for sharing the waters of the OMVS (which is not realistic) or to build new dams, especially on unregulated tributaries. However, the increase in production could be achieved: (i) by increasing the area cultivated during the winter period (which would require identifying and removing the current constraints that have led to their reduction over the recent period) and (ii) by improving water productivity in the dry period (either by reducing losses or improving yields).

13. **Horticulture faces major challenges related to water quality, overexploitation of groundwater and the lack of appropriate land regulations, aggravated by the strong progress of urbanization and the isolation of certain production areas (Casamance).** Even if at the global level it seems that these additional needs could be satisfied by the available water resources, this development will be difficult in certain areas. This is the case, for example, in the Niayes where the main source of water, the aquifer on the North coast, is already overexploited, with withdrawals reaching 2.5 times the renewable water available, and affected by the intrusion. saline to the north. In the Niayes, conflicts over land are also on the rise. It is for these reasons in the scenarios considered the irrigated area in this area will not increase by 2035.

14. Note that the PSE aims to mobilize an additional 2.2 Mm3/year of groundwater for irrigation between 2013 and 2018. If this trend were maintained, an additional 6 Mm3/year would be mobilized by 2035. This could cover the additional needs for horticulture estimated in Casamance and in the groundnut basin in scenario 2, but we must not forget the quality of the water, which in these areas is largely brackish and therefore not usable for horticultural crops. Consequently, the quality of the water should be the subject of serious attention, particularly in the Niayes to maintain current production and in the groundnut basin when the water comes from the aquifers located in the regions of Kaffrine in the west, Fatick and Kaolack. Groundwater monitoring will be a major challenge for the sustainability of horticultural crops in these areas without surface water.

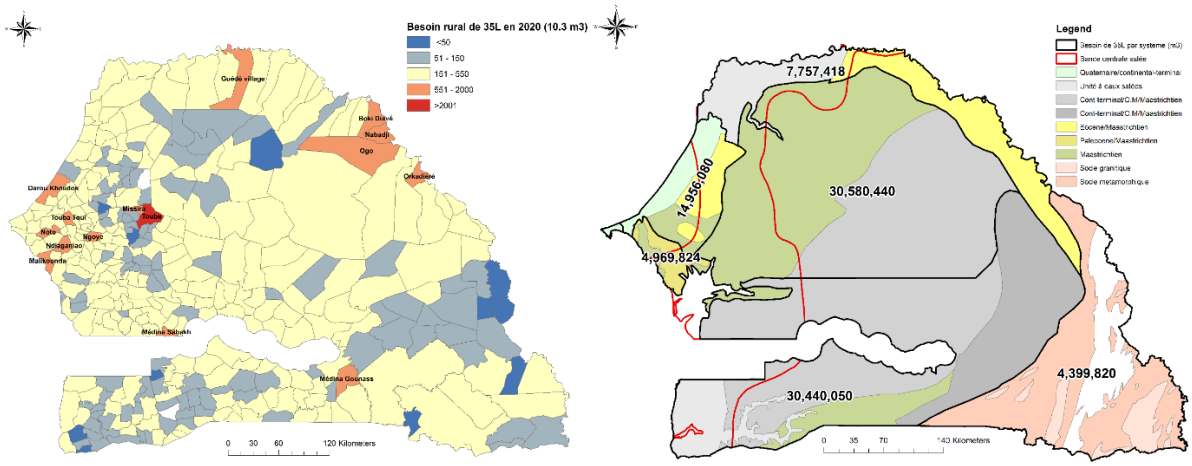
Drinking water supply needs

15. The PSE aims for universal access to drinking water by 2035. This section analyzes what achieving this goal implies in terms of water needs.

16. Due to strong population growth (24.2 million in 2035) and migration to urban areas, it is very likely that drinking water needs could reach 442 million m3/year by 2035.[85,86] Needs will increase particularly in urban areas, especially around Dakar, since rural population growth is decreasing (from 2.04 percent in 2014 to 1.92 in 2018). It was estimated in the context of this study that these needs in urban areas could increase from 166 Mm3 in 2020 to 318 Mm3 in 2035 (+91 percent), which should be met mainly from the Senegal River (which are shared waters).

17. With regard to rural water supply, while considering that the areas supplied by the Senegal River should not have problems in the future, we have simulated the impact of the increase in demand for drinking water on the underground waters. We have therefore considered the demographic data of the rural communes reported on consumption according to a scenario of 35 liters/person/day for future needs by 2035. These data by commune have been aggregated at the scale of the hydrogeological systems described above. above to enable the potential resource/needs balance to be established and areas with access problems to be identified. Aggregated on the scale of the hydraulic systems, the water needs are higher at the level of the Maastrichtian and CT/OM hydraulic systems around 30 Mm3/year - however these volumes remain small compared to the potential of these two systems which could easily support additional needs. On the other hand, the Littoral Nord zone and the Horst de Diass zone present increasingly gloomy situations with regard to future withdrawals for rural areas.

Map III.1 : Besoins en 2035 par commune rurale et par aquifère



18. It should be noted, however, that the problem of water quality skews the results, especially for populations living in the zone of the central salty strip (Maastrichtian). Indeed, the water needs of the DWS are very demanding in terms of water quality, which can make meeting the needs difficult, especially in rural areas where the users' ability to pay is low, if the water have high contents of elements whose treatment cost is high. The only quality resources that can still be exploited without risk of damaging the reserve are found in the Maastrichtian aquifer to the east of the central saline band where the recharge varies between 58 and 75 Mm3/year and could be used by transfer, and the aquifer CT/OM located north of the Saloum River. On the other hand, for the areas located in the river basin and

[85] Assuming 40% of the population in rural areas consumes 35 l/p/d and 60% in urban areas consumes 60 l/p/d.

[86] Faye Report, p.24. This assessment of future needs for the 2035 and 2050 horizons was made from the study of the SONES Master Plan dated 2014 with a projection until 2025. This updating was carried out from the demographic projection of the ANDS (growth rate of 2.7%) and universal access based on needs of 60 l/pers/d.

Casamance (CT and OM), the availability of water could support the demands by 2035 except in the coastal parts where the salinity (upper aquifer such as Maastrichtian) constitutes a limiting factor, thus making areas where access is a problem.

19. **The areas at risk in 2035 are therefore**:

a. Areas that already have drinking water supply problems, such as the Bassin Arachidier areas, especially north of the Saloum River (fluoride and chloride in the central band) and in the Lower Casamance region (salinity), where meeting the needs future would be problematic. In these areas, two solutions are possible: advanced treatment or transfers from nearby areas, in order to replace, or dilute, the water present locally so as to achieve quality standards. The choice between one or the other of these options depends on the context. Unfortunately, these are expensive options in both cases, both in terms of investment and operation and maintenance. The transfer option poses a higher security risk in the event of voluntary or involuntary rupture of the pipes. The evaluation of the socio-economic impacts of accidents occurring on the pipelines supplying Dakar from Lake Guiers should be made. Attention to the reduction of possible losses and waste will also be promoted.

b. In urban centers of the Greater Dakar region, if the management of aquifers and wastewater is not improved. This also includes the area that gets its supplies from the Horst de Diass system, which already has a very negative balance. Centers fed from the waters of Lac de Guiers and the Senegal River, – including the Littoral Nord area which is currently fed by groundwater, very vulnerable to saline intrusion and pollution from agriculture, l industrial activity and domestic wastewater.

Mining activity

20. The Emerging Senegal Plan provides for significant investments in the mining sector. We can expect the needs of the sector to grow in the coming years. Thus, within the framework of its projects for operating new mines, the mining company GCO plans to extract an additional 16 million m3 per year, and therefore extract 29 million m3/year, to be taken from the Maastrichtian to the west of the salty central band.

Conclusion

21. In conclusion, according to these estimates, the total water needs in 2035 could be between 3.4 billion m3/year and 3.9 billion m3/year, which means an increase from 24 percent to 41 percent. cent compared to withdrawals in 2019 (2.7 billion m3). The difference between the two scenarios is linked to the development of irrigated rice, which would need, according to the scenario, between 2.17 (continuation of current trends) and 2.65 billion m3/year (achievement of self-sufficiency in rice). Several constraints exist to achieve self-sufficiency in rice, particularly in the valley and the delta of the Senegal River where it implies a substantial increase in the rate of development during the rainy season and in yields. These estimates do not take into account withdrawals related to little known uses, such as livestock or wells, and certain agro-industries, for example around the Lac de Guiers and a good part of the mining activity, but their consideration account would only reinforce already visible trends.

Tableau III.2: Summary of current withdrawals and estimated needs for 2035 by use

Use	Estimated withdrawals 2020 (Mm^3/yr)	Estimated needs 2035 (Mm^3/yr)
Irrigation (rice and horticulture)	2 292	2 848-3 314
CSS	90	90

DWS	346	442
Mining	13	29
TOTAL	***2 741***	***Between 3,409 and 3,875***
Increase (%)		Between + 24 and + 41 %

22. In terms of the availability of water resources, if we consider the resources available globally (22 billion m3 per year, renewable), Senegal could satisfy these needs even with an extreme reduction of 20 percent in the average availability linked to climatic changes. **However, in some areas, indicated above, the availability of water and/or its quality, as well as competition between uses, could make it difficult to meet needs.**

Annex IV – Recommendations for the Hotspots

Hotspots	Management instruments provided for in the legal framework	Organizations	Infrastructure	Information
Greater Dakar and Horst de Diass zone	See Chapter III			
Niayes region and North Littoral	• Create links between land use planning and water resources management planning (PGE). • Regulate or limit mining activities to preserve other uses. • Classify groundwater as Zone I/Water Quality Protection Zone.	• Establish representation and increase DGPRE human resources in Thiès and Louga regions to carry out high-priority functions. • Create associated sub-Management and Planning Unit (UGP)/user group and prepare a specific PGE. Specific functions of sub-UGP and rules to be complied with to be defined.		• Improve the aquifer monitoring system and reduce current extraction to a sustainable level through collaborative arbitration. • With regard to planning: (i) map vulnerable zones and evaluate anthropogenic pressures (agriculture, mines, DWS) on quality and quantity plans to help identify zones (Water Quality Protection Zone I); (ii) study the impact of climate change on the plausible future of all uses; (iii) update the water balance sheet using fine-tuned modeling.
Salty and Fluorinated central zone	• Classify groundwater as Zone I/Water Quality Protection Zone.	• Create associated sub-Management and Planning Unit (UGP)/user group and prepare specific PGE. Specific functions of sub-UGP and rules to be complied with to be defined.	• Extend transfer and water purification programs to provide access to drinking water. • Explore the possibility of developing irrigation systems using runoff water.	• Improve knowledge and monitoring of groundwater to enable classifying groundwater and prepare DWS program.

		• Establish representation and increase DGPRE human resources in Kaolack-Fatick and Diourbel regions to carry out high-priority functions.		
Lac de Guiers and Senegal River Delta	• Clarify in the Water Code the interactions and complementarities between provisions of Senegalese national law and those of the Senegal River Development Agency (OMVS) Water Charter. • Take into account different demands and consider arbitrations when developing new dams along the river and operation of existing and future structures.	• Increase monitoring and management of Lac de Guiers to improve quality for DWS and other uses.	• Develop new regulating structures on uncontrolled tributaries, particularly the Falémé River. • Study and manage the clogging of waterways (water regime, sedimentation, invasive plants).	
Lower Casamance Valley	• Consider relevance of classifying this zone as Zone I/Water Quality Protection Zone.		• Explore solutions such as transfer or collection of rainwater to improve DWS and develop intake of runoff water • Put in place protection against backwash of seawater in coastal areas.	• Map salinity levels and extent of seawater intrusion to inform classification of zone. • Develop data and measurement system, and put in place monitoring network in risk zones. • Resolve issue of silting at Kolda station.

Gold-mining zone	• Carry out a gold-mining regulation program to limit pollution of vulnerable zones. • Increase level of control and sanctions linked to pollution by mining companies. • Classify zone as Water Quality Protection Zone.	• Establish representation and increase DGPRE human resources in Kédougou and Tambacounda regions to carry out high-priority functions. • Create associated sub-UGP and prepare specific PGE. Specific functions of sub-UGP and rules to be complied with to be defined.	• Put in place measures for managing erosion, especially that linked to the destruction of ground cover.	• Evaluate aquifer capacity in bedrock fracture zones. • Map vulnerable zones and pollution by harmful substances in mining zones and conduct epidemiological study by toxic elements in affected areas to inform classification of the zone. • Design a program for monitoring of groundwater in vulnerable zones.
Flood recession crop zone	• Consider adapting and modifying the operation of existing dams to prioritize flood support maintenance.			• Study socioeconomic importance of flooding and contribution to the national economy and Emerging Senegal Plan (PSE) objectives.

Annex V - Assumptions for calculating drinking water and sanitation needs in the DMT

1. Parameters and assumptions for meeting drinking water needs

1.1 Projections of drinking water demand in the Greater Dakar area by 2035 and beyond

1.1.1 Demand projection assumptions

a. Demography

The past evolution and the population projections considered center by center by SONES are those established by the Supply and Distribution Master Plan around the Urban Development Poles of Dakar and the Petite Côte (*Schéma Directeur d'Approvisionnement en Eau Potable*, SDAEP) carried out by the Merlin firm in 2015. The assumptions are based on projections of demographic data from the National Agency for Statistics and Demography (*Agence Nationale des Statistiques et de la Démographie*, ANSD) in 2013, the Master Plan for Regional Planning and Development (*Schéma Directeur pour l'Aménagement et le Développement Territorial*, SDADT) in the project area and the SDAEP.

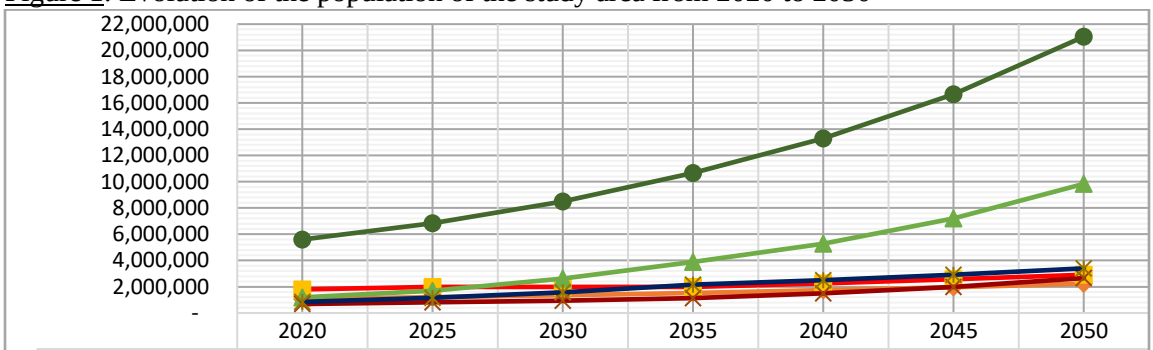
Table 1: Population growth rates

DR/CENTRES	Population groth rate
Dakar 1	2,54%
Dakar 2	2,61%
Rufisque	6,40%
Mbour	5,90%
Thiès	3,10%

Source : SDADT, 2015

Beyond 2035, the projections for 2050 are based on the 2035 population estimated in the high scenario proposed in the SDAEP (SONES, Merlin 2015) and on the growth rates of the SDADT (cf.: table above).

Figure 1: Evolution of the population of the study area from 2020 to 2050



	2020	2025	2030	2035	2040	2045	2050
DAKAR 1	1,073,420	1,209,744	1,363,381	1,536,531	1,741,838	1,974,578	2,238,417
DAKAR 2	1,798,747	1,979,289	1,979,289	1,979,289	2,251,426	2,560,980	2,913,094
RUFISQUE	1,192,152	1,701,522	2,622,436	3,879,374	5,290,172	7,214,030	9,837,530
THIES	687,180	807,149	951,510	1,125,857	1,499,557	1,997,298	2,660,251
PETITE COTE	844,909	1,149,764	1,569,969	2,150,350	2,504,970	2,918,071	3,399,297
TOTAL	5,596,408	6,847,468	8,486,586	10,671,401	13,287,963	16,664,956	21,048,589

b. Access rates

The planning assumptions are based on the objectives of the LPSD (2016 – 2025) for drinking water, namely:

- An access rate of 100% to improved drinking water services by 2025;
- An access rate of 100% to safely managed drinking water services by 2030 and beyond.

c. Specific consumptions

For the 2020-2035 period, we have retained the specific consumption of the high scenario of the SDAEP of the urban centers of Dakar and the Petite Côte (SONES, Merlin 2015) as well as the corresponding water needs.
To estimate the drinking water needs beyond 2035, the specific consumptions by center below will be considered, taking into account consumption habits, the social situation of the populations and recommendations from SONES:

Table 2: Specific allocations by 2035 – 2050

DR/CENTRES	Unit allocations (l/d/cap)
Dakar 1	125
Dakar 2	80
Rufisque	75
Mbour	75
Thiès	65

d. Parameters for estimating yields and peak requirements

Starting from the user's water demand, two parameters are considered in the evaluation of peak needs: the performance or yield of the networks, which refers to water losses en route, and the peak consumption coefficient of the supply system. Indeed, the state of the networks is a major factor in the overall functioning of the water supply and it can be improved by restoring the networks to limit leaks or by installing regulation systems and storage basins. Such an improvement in network performance can allow substantial water savings - between 10% and 20% of the distributed volumes.

In Greater Dakar, the efficiency of the ALG supply system was 97% in 2018. This value has been stable for a few years and will be taken into account in future calculations. At the level of the distribution networks, the yield values indicated in SONES and Operator activity reports are retained, as well as the peak consumption coefficients observed in 2018, see below.

DR/CENTERS	Network performance	Peak coefficient
Dakar Agglomeration	77%	1,10
Thiès Metropolis	87%	1,20
Mbour and littoral Sud cities	85%	1,30

It should also be noted that these yield and peak coefficient values are those used in the SDAEP study around the urban development centers of Dakar, Thiès and the Petite Côte (SONES, 2015).

1.1.2 Assumptions for water demand satisfaction options

The objectives of the project are:

- Satisfying water needs for all uses, including for irrigated agriculture and sanitation needs;
- The diversification of water sources;
- Rational management of water demand and improvement of water productivity;
- The quantitative and qualitative preservation of water sources and resources in Grand Dakar.

To meet the growing water needs of Grand Dakar for the various competing uses, several types of water resources are preferred:

- The surface water resources of the Lac de Guiers and those that can be collected at the level of the various hydrographic catchment areas in the area;
- Groundwater resources from the various aquifers in/outside the Greater Dakar area;
- Rainwater collected by impluvium;
- Secondary or tertiary treated wastewater, and
- Unnacounted for water (network losses).

The consumption centers and the horticultural areas targeted for the satisfaction of their water needs include the urban centers of Greater Dakar and their outskirts (Dakar, Rufisque, Thiès, Mbour and the secondary towns of the southern coast), in particular the new emerging urban centers, the large rural centers that are gradually being integrated into the existing urban fabric and the tourist sites that are developing along the southern coast. In the PGE Somone diagnostic report carried out by the DGPRE, seven agricultural areas totaling an easily irrigable agricultural area of approximately 21,600 ha were identified in the territory of Greater Dakar:

Agricultural poles	**Cultivable areas (ha)**
Pikine Niayes	100
Filfili– Sébi – Ponty– Deni– Mbirdiam– Keur Séga– Sococim– Bargny– Toll highway	2,000
Berr Thialane – Bayakh – Diender – Notto G. Diama – Mbirdiam – Pout– Keur Matar Guèye	1,400
Tassette (East Thiès)	10,540
Fandène – Notto (East Thiès)	5,000
Joal – Fadiouth	60
Kirène (West Thiès)	2,000
Pout – Keur Mousseu (West Thiès)	500
Total	**21,600**

Allocation of resources to users: The available water resources being of different quality, their allocation to the different uses is made according to the quality required by each use and on the basis of the rules below:

- Satisfy as a priority the water needs of households and industrial uses in urban centers;
- Use in priority the source of water closest to the place of consumption;

- Reduce or even suspend water withdrawals from the most threatened aquifers (see the protection program for threatened aquifers) for a period allowing their reconstitution;
- Only withdraw up to the amount of the renewable reserve in the water tables of Greater Dakar;
- Reserve at least 10% of renewable reserves to meet the needs of rural areas in Greater Dakar;
- Assign tertiary treated wastewater as a priority to irrigation and secondary treated wastewater to artificial groundwater recharge, maintenance of urban green spaces and restoration of urban forests.

2. Wastewater and excreta management parameters and assumptions

2.1 Planning assumptions

The public wastewater treatment service will be provided at the level of an urban center by a "mix" of solutions backed by 2 types of systems: collective sanitation (network) and autonomous sanitation (onsite).

The first stage consists in identifying the localities which, by 2035 -2050, could have a collective network. To do this, we build on current projects and master plans to establish an indicative distribution of the urban centers of Greater Dakar into four categories:

- Centers with network rehabilitation: department of Dakar (HLM, Grand-Yoff, Hann-Fann), Saly-Portudal, etc.
- Centers with new networks: Diamniadio, Sébikhotane, Bambilor, Bayakh, urban centers (Diamniadio, Daga kholpa, Diass, Lac Rose, Déni Malick Guèye, etc.), Popenguine-Ndayane, Nguékhokh, Sendou, Bargny, etc.
- Centers with network extensions: departmental suburbs (municipalities of Keur Massar, Guédiawaye, Guinaw Rail North and South, Diameguene Diack Sao, Mbao, Thiaroye Gare, Djida Thiaroye Kao, Gounass, Yeumbeul North and South)
- Centers with on-site sanitation only: all municipalities not listed above.

Figure 3: Planning of works by 2050 for the Dakar region

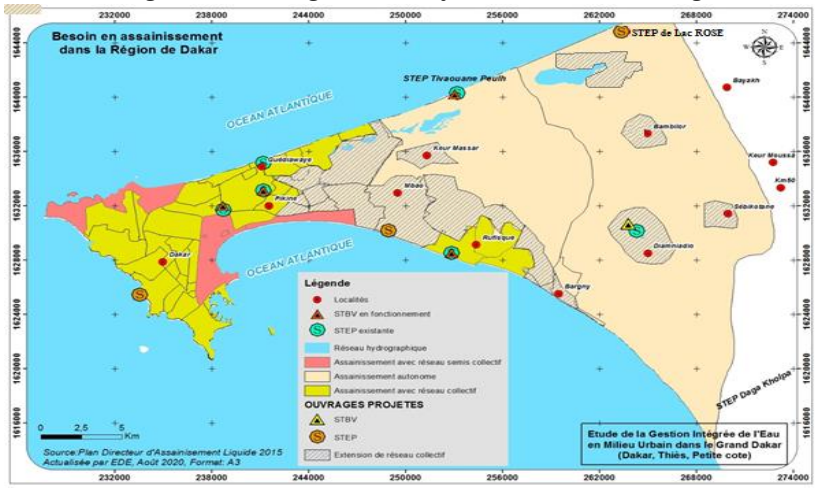
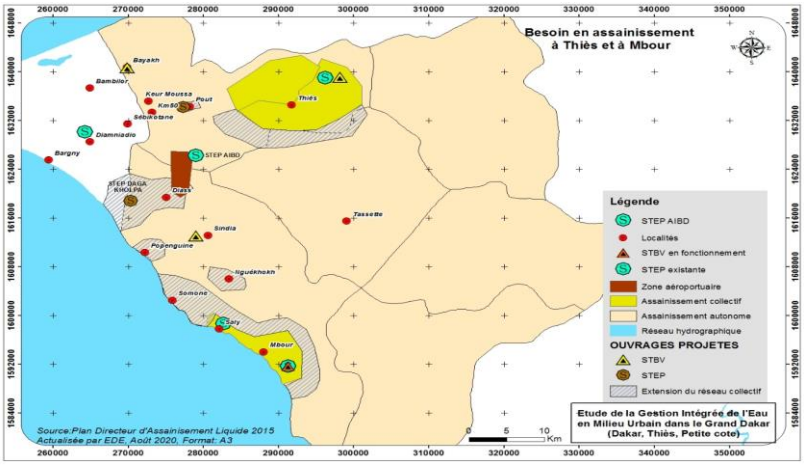


Figure 4: Planning of connections for Thiès and Petite Côte



The study of historical access rates from 2018 to 2025 as part of the ONAS financial model led to an average annual rate of variation of 1%. Taking this variation into account, the consultant made projections of the access rates to the ONAS collective network based on the reality of 2018:

- from 2018 to 2035: an annual variation of 1 % will be considered;
- beyond 2035 the consultant considers a variation of 1,2%.

Table 3: Access rate to the collective sanitation network (projected)

Agglomeration class	Projection of the average access rate to the network (Arc) by center								
	2018	Rate (%) 2018/2035	2025	2030	2035	Rate (%) 2035/2050	2040	2045	2050
Dakar, Pikine, Guédiawaye, Rufisque	30%	5%	35%	40%	45%	6%	51%	58%	66%
Thiès	8%		13%	18%	23%		29%	35%	41%
Petite côte (Mbour, Joal, Saly, Somone)	7%		12%	17%	22%		28%	34%	40%

The access rates are interpreted as follows:

- For example in the Dakar conurbation, household access to sanitation by 2050 will be 58% with collective sanitation and 42% with on-site sanitation (sum = 100%).
- The same reasoning applies to the other classes of localities.

The last step is to adjust the progression between 2018 and 2050 of the number of interventions needed, broken down by category of locality and by access technology, to achieve the SDGs.
The access rate of households to the sanitation service from the interventions is calculated with the following equivalences:

- Number of people per connection per center: 10 people
- Length of network per connection: 15 m
- Number of current connections per center:

Table 4: Number of connections to the network in 2018

Cities	Number of connections in 2018 (NCac)
Dakar, Pikine, Guédiawaye, Rufisque	112 700
Thiès	5 233
Mbour, Joal, Saly, Somone	4 384
TOTAL	122 317

For these reasons, the assessment of the physical interventions necessary to achieve the SDGs was carried out independently of the model, using data from the 2013 RGPH for Greater Dakar. The application of the planning method described above will be made using the formulas below:

Table 5: Calculation assumptions

Cities	Population in Hi	Population with sanitation in Hi	Number of connections in Hi	Number of additional connections in Hi	Additional network length
Agglomeration	Pi	Ps = Pi x Arc	NCi = (Ps)/NCac	NCadd = NCi-NCac	NLadd = NCadd x 15

3. Stormwater Drainage Parameters and Assumptions

3.1 Strategic axes

Improving access to sustainable drainage systems by rehabilitating and extending collection and disposal systems is one of the key orientations of this strategy. Climate change adaptation aims to reduce the risks of flooding associated with extreme rainfall, but if it is designed in synergy with urban development, it can also respond to certain problems associated with stormwater management.

Improving collection structures by rehabilitating the existing network and building new rainwater drainage infrastructure contributes directly to protecting natural resources and the environment, and mitigating the impacts of climate change. It relies on:

- Accurately mapping flood zones and identifying resilience measures
- Rehabilitating and reinforcing existing sections in order to remedy the saturation of certain parts of the drainage network;
- Proceeding with the extension of the drainage system to the scale of the communal watersheds;
- Encouraging the population to set up impluviums/collection tanks at the concession level for rainwater collection.

The basic principle of stormwater management (SWM) aims to retain the watershed approach as the appropriate framework for planning, mobilization, management and protection of resources such as stormwater. These waters must always be considered as a fraction of the resource to be valued and returned to its natural cycle.

3.1.1 Mapping of flood zones

The simulation models available in past studies of flood and inundated areas are taken from the following studies:

- Rain of August 22, 2005: mapping carried out by SCET Tunisia in 2007 as part of the Pikine rainwater drainage study.
- Rain of August 24, 2009: mapping carried out in 2010 as part of the post-disaster needs assessment report on urban flooding in Dakar in 2009, based on aerial shots dated October 14, 2009.
- The Drainage Master Plan has indicated three areas at high risk of flooding in Greater Dakar:
    - Area 1: located around the flooded areas of 2009. The footprints of the flooded areas calculated by the model are, in the vast majority of sectors, extremely close to the already flooded areas located in the suburbs of Dakar,
    - Area 2: located in the SICAP MBAO neighborhood,
    - Area 3: located in the Parcelles Assainies district of Keur Massar.

The main and priority objective is to map the risks of flooding on all of the Niayes to integrate them into land use planning studies and the development of the Flood Risk Prevention Plan (*Plan de Prévention des Risques d'Inondation*, PPRI). It includes:

- Collecting the physical, human, socio-economic and environmental parameters relevant for the establishment of a flood risk map.
- Establishing a flood hazard map indicating the territories likely to be subject to flooding by overflow of rivers as in Saint-Louis, by accumulation of precipitation as in Dakar or by the simultaneous combination of several factors; then, draw up a vulnerability map expressing the potential damage of elements that are vulnerable and sensitive to flooding risk, located in areas subject to this hazard; and, finally, develop a flood risk map expressing both hazard and vulnerability in the Niayes region.
- Determining a flood risk mapping methodology with, on the one hand, a hydrological methodology that would make it possible to grasp and understand more precisely the interactions between the parameters and to make a complete mapping update. On the other hand, a hydrogeological methodology of aquifers to understand their functioning and their vulnerability would be necessary from a (more interesting) perspective of forecasting and warning and rather than simply determining or locating risks.

3.1.2 Rehabilitation of the existing drainage system and extension of the network

The stormwater drainage network listed by ONAS has a total length of 255.4 km in Greater Dakar. It is presented as follows:

Table 6 : Distribution of stormwater management works

Cities	**Network length (Km)**	**Pumping stations (U)**	**Storage basins (U)**
Dakar et Rufisque	204	48	16
Saint Louis	32,4	14	3
Thiès	12	-	-
Mbour	7	1	-
TOAL	**255,4**	**63**	**19**

80% of drainage network in Greater Dakar needs interventions ranging from rehabilitation to simple reshaping or cleaning, i.e. a length of 200 km.

3.1.3 Extension of the drainage system at the catchment scale

For the extension of the drainage network, it is recommended to:

- Define the water routes on the main roads or boulevards in the municipalities most affected by floods
- Set up a dense network of secondary canals which will be connected to the water routes
- Channel all runoff water outside town centers to retention or infiltration basins

A study will be carried out to identify the needs by commune and define the linear extensions of the network.
Overall, for Greater Dakar, an extension network of 200 km should be planned to urgently manage the flooding problem. In the long term, the drainage network will have to be studied on a municipal scale. It is difficult at this stage of the study to define the length; however, the consultant proposes to take a pilot site like Keur Massar or Mbao or a 60 km linear, 3 pumping stations and a retention basin as an outlet in the cost estimate.

3.1.4 Impluvium systems for household rainwater reuse

Impluviums or rainwater harvesting systems are technologies that capture and store rainwater and runoff for later use. “Rainwater” solutions are increasingly considered in the design of houses, thus contributing to the sustainable management of resources. The preservation of water resources has become essential because, of its vulnerability to climate change on the one hand and of the relatively strong pressure exerted on these resources due to high population growth on the other hand. From this observation we can advance that climate change, as an additional factor, combined with anthropogenic activities, are the main factors accentuating water stress.

4. Estimation of the cost of untreated wastewater

To estimate this cost, we have adapted the methodology used in the Croitoru et al. study to the more general framework of our study. We first determined the quantities of water consumed in urban and rural areas based on 2017 population data (2013 RGPHE Projections) and daily consumption per inhabitant, distinguishing between rural and urban areas. Then, we used figures on the proportion of the population using adequately managed sanitation services (Safely managed sanitation: use of improved facilities that are not shared with other households and where excreta are disposed of safely on site or transported and treated off site) to determine the volume of untreated wastewater. Finally, we used the local cost of water treatment (evaluated according to the latest estimates at $0.32/m^3) to determine the total cost.

5. Estimation of the cost of waterborne diseases

The estimate of this cost is based entirely on the Croitoru et al. study, having been unable to determine regional costs. Access to poor quality water sources, coupled with inadequate sanitation services and a lack of hygiene, poses health risks to populations in terms of mortality and morbidity. Using data from urban and rural populations in different regions and mortality and morbidity rates, we estimate the number of deaths and morbidity in terms of the number of years of life lived with disability (YLL) associated with these health risks. The cost of mortality is based on the Statistical Value of Life estimated at $78,100 in Senegal and the cost related to morbidity is based on the methodology of lost income.

6. Estimation of the cost of floods

The cost of floods is calculated as a loss of revenue linked to a loss of economic activity and the destruction of assets. It is determined from the FATHOM model formerly SSBN which is a spatialized flood model providing information on the depth of a pluvial or river flood depending on the return period. The flood depth is then translated into a damage function that communicates the level of damage per plot. This level of damage is then translated into economic value based on the unit cost per type of land use, which amounts to $260,700 per hectare in urban areas and $12,800 per hectare in rural areas (value for areas probably very high due to the presence of the Metropolis of Dakar in the Croitoru et al. study on coastal areas). Due to the lack of data on flood-induced mortality according to different return periods, we were unable to calculate this cost.

7. Estimation of the marginal cost of water

The marginal cost was calculated on the basis of investments in the water production and transmission system over two periods (1996-2015 and 2015-2020) and according to the additional capacity represented by these investments. The table below summarizes the results of these calculations.

	CFAF	Volume (m^3)	Cost per additionnal m^3/d
1996 to 2015	$ 279,293,889,173	215,000	$ 1,299,041.34
2015 to today	$ 428,391,848,350	106,100	$ 4,037,623.45