# Table of contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Context</td>
<td>450</td>
</tr>
<tr>
<td>Map 20.1: Locator map</td>
<td>450</td>
</tr>
<tr>
<td>Map 20.2: Basin map</td>
<td>451</td>
</tr>
<tr>
<td>Location</td>
<td>450</td>
</tr>
<tr>
<td>Physical characteristics</td>
<td>450</td>
</tr>
<tr>
<td>Table 20.1: Hydrological characteristics of the Senegal River basin</td>
<td>450</td>
</tr>
<tr>
<td>Table 20.2: Summary of physical data</td>
<td>450</td>
</tr>
<tr>
<td>Socio-economic characteristics</td>
<td>450</td>
</tr>
<tr>
<td>Population</td>
<td>450</td>
</tr>
<tr>
<td>Table 20.3: Summary of socio-economic data in the OMVS member states</td>
<td>451</td>
</tr>
<tr>
<td>Agriculture</td>
<td>452</td>
</tr>
<tr>
<td>Mining sector</td>
<td>452</td>
</tr>
<tr>
<td>Industry</td>
<td>452</td>
</tr>
<tr>
<td>Energy</td>
<td>452</td>
</tr>
<tr>
<td>Navigation</td>
<td>453</td>
</tr>
<tr>
<td>Table 20.4: Water use by sector within the OMVS area (in millions m³)</td>
<td>453</td>
</tr>
<tr>
<td>Water Resources</td>
<td>453</td>
</tr>
<tr>
<td>Hydrology</td>
<td>453</td>
</tr>
<tr>
<td>Rainfall</td>
<td>453</td>
</tr>
<tr>
<td>Surface water</td>
<td>453</td>
</tr>
<tr>
<td>Table 20.5: Seasonal changes in Senegal River discharge since 1951</td>
<td>453</td>
</tr>
<tr>
<td>Groundwater</td>
<td>453</td>
</tr>
<tr>
<td>Water quality</td>
<td>454</td>
</tr>
<tr>
<td>Impact of development on the population and on natural resources</td>
<td>454</td>
</tr>
<tr>
<td>Principal negative effects</td>
<td>454</td>
</tr>
<tr>
<td>Principal positive effects</td>
<td>455</td>
</tr>
<tr>
<td>Water resources database and information</td>
<td>455</td>
</tr>
<tr>
<td>Challenges to Life and Well-Being</td>
<td>456</td>
</tr>
<tr>
<td>A difficult context</td>
<td>456</td>
</tr>
<tr>
<td>The filling of dams</td>
<td>456</td>
</tr>
</tbody>
</table>
### Management Challenges: Stewardship and Governance

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legal and regulatory framework and governance</td>
<td>456</td>
</tr>
<tr>
<td>Finances</td>
<td>458</td>
</tr>
<tr>
<td>Managing multiple uses: an original approach</td>
<td>458</td>
</tr>
<tr>
<td>Approach/procedure</td>
<td>458</td>
</tr>
</tbody>
</table>

### Identifying Main Problems

<table>
<thead>
<tr>
<th>Problem</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degradation of ecosystems</td>
<td>459</td>
</tr>
<tr>
<td>Public health</td>
<td>459</td>
</tr>
<tr>
<td>Malaria</td>
<td>459</td>
</tr>
<tr>
<td>Diarrhoea</td>
<td>459</td>
</tr>
<tr>
<td>Schistosomiasis (bilharzia): urinary and intestinal</td>
<td>459</td>
</tr>
</tbody>
</table>

### Conclusions

| Box 20.1: Development of indicators          | 461  |

### References
The chameleon changes colour to match the earth, the earth doesn’t change to match the chameleon.

African proverb

The Senegal River represents a 1,800-kilometre lifeline for a multi-ethnic, multicultural population where livestock outnumber people. It runs through sub-Saharan Africa in a mostly desert region characterized by water scarcity and subsistence economies. The Organization for the Development of the Senegal River (OMVS) was created in 1972 with a mandate to ensure food security and harmony among all riparian users. Thanks to the construction of two main dams providing energy, irrigated agriculture and year-round navigation – and to an original management approach based on a concept of ‘optimal distribution among users’ rather than volumetric water withdrawals – the area is gradually developing. Ironically, dam construction has brought problems as well as benefits, and the major concern is water-related diseases.
THE SENEGAL RIVER BASIN is located in West Africa, between latitudes 10°30 and 17°30 N and longitudes 7°30 and 16°30 W. It is drained by the 1,800 kilometre (km)-long Senegal River, the second longest river of West Africa, and its main tributaries, the Bafing, Bakoye and Faleme Rivers, which have their source in the Fouta Djallon Mountains (Guinea) or in Mali.

General Context

Most of the Senegal River basin has a sub-Saharan desert climate, aggravated by more or less long periods of drought during the 1970s. Access to sufficient quantities of good-quality water is therefore a particularly sensitive issue and absolutely crucial for the health of the population and the economy.

Physical characteristics

The Senegal River basin covers a surface area of about 300,000 square kilometres (km²). The high plateaus in northern Guinea represent 31,000 km² (11 percent of the basin), 155,000 km² are situated in western Mali (53 percent of the basin), 75,500 km² are in southern Mauritania (26 percent of the basin) and 27,500 km² are in northern Senegal (10 percent of the basin). The basin has three distinct parts: the upper basin, which is mountainous, the valley (itself divided into high, middle and lower) and the delta, which is a source of biological diversity and wetlands (see map 20.2). Topographical, hydrographic and climatic conditions are very different in these three regions and seasonal temperature variations are extensive.

Socio-economic characteristics

Population

The Senegal River basin has a total population of around 3,500,000 inhabitants, 85 percent of whom live near the river. This figure includes approximately 16 percent of the total populations of the three OMVS member states – Mali, Mauritania and Senegal – plus the population of the Guinean portion of the upper basin.

The population within the basin is increasing at a rate of about 3 percent per year, which is slightly higher than the individual averages for the three member states.

A large ethnic diversity also characterizes the basin’s population, with, among others, Peuls, Toucouleurs, Soninkes, Malinkes, Bambaras, Wolofs and Moors. However, there is massive emigration among the young towards the major cities and to Europe.

Table 20.1: Hydrological characteristics of the Senegal River basin

<table>
<thead>
<tr>
<th></th>
<th>Senegal River basin</th>
<th>Senegal</th>
<th>Senegal</th>
<th>Senegal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface area of the basin</td>
<td>300,000 km²</td>
<td>27,500</td>
<td>27,500</td>
<td>27,500</td>
</tr>
<tr>
<td>Annual precipitation</td>
<td>680 mm/year</td>
<td>412 m³/s</td>
<td>412 m³/s</td>
<td>412 m³/s</td>
</tr>
<tr>
<td>Annual runoff (Bakel station)</td>
<td>Before 1985</td>
<td>680 m³/s</td>
<td>412 m³/s</td>
<td>412 m³/s</td>
</tr>
<tr>
<td></td>
<td>After 1985</td>
<td>412 m³/s</td>
<td>412 m³/s</td>
<td>412 m³/s</td>
</tr>
<tr>
<td>Annual discharge (Bakel station)</td>
<td>Before 1985</td>
<td>1,063 m³/s</td>
<td>1,063 m³/s</td>
<td>1,063 m³/s</td>
</tr>
<tr>
<td></td>
<td>After 1985</td>
<td>416 m³/s</td>
<td>416 m³/s</td>
<td>416 m³/s</td>
</tr>
</tbody>
</table>

Half of the basin is located in Mali, but the main input in terms of water resources comes from the upper basin in Guinea with an average of 1,600 mm of precipitation.
Table 20.3: Summary of socio-economic data in the OMVS member states

<table>
<thead>
<tr>
<th></th>
<th>Senegal River basin</th>
<th>Mali</th>
<th>Mauritania</th>
<th>Senegal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (million inhab)</td>
<td>3.5</td>
<td>11</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Annual growth rate (%)</td>
<td>3</td>
<td>2.37</td>
<td>2.9</td>
<td>2.8</td>
</tr>
<tr>
<td>Urbanization rate (%)</td>
<td>NA</td>
<td>41</td>
<td>50</td>
<td>51</td>
</tr>
<tr>
<td>Farmland (ha)</td>
<td>823,000</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Irrigated land (ha)</td>
<td>NA</td>
<td>78,830</td>
<td>48,200</td>
<td>71,400</td>
</tr>
<tr>
<td>Rice (ha)</td>
<td>4,003</td>
<td>6,427</td>
<td>1,394</td>
<td>2,827</td>
</tr>
<tr>
<td>Cattle (x1,000 units)</td>
<td>2,700</td>
<td>4,500</td>
<td>1,394</td>
<td>8,330</td>
</tr>
<tr>
<td>Sheep and goats (x1,000 units)</td>
<td>4,500</td>
<td>15,580</td>
<td>10,950</td>
<td>385,000</td>
</tr>
<tr>
<td>Fish catch (ton/year)</td>
<td>26,000 to 45,000</td>
<td>100,000</td>
<td>623,000</td>
<td>385,000</td>
</tr>
</tbody>
</table>

Population figures have been updated, based on growth rates in each country. Irrigation is the motor of development of the basin, especially in the valley and the delta, and livestock raising has always been a major activity. After agriculture, fishing is the second largest economic activity of the basin.
A recent OMVS study of fish resources indicates, however, and to their impact on the environment (significant decrease in observers link this to the river development projects (dams, dikes) drop in the tonnage caught throughout the OMVS region. Some question because for several years now there has been a steady valley and the delta. Today, however, the future of this sector is in after agriculture, notably for populations living near the river in the land, combined with the carrying capacity of the grasslands and the flood plains, the riparian populations, and even those living livestock-raising. These activities are generally profitable.

Livestock-raising has also always been a major economic activity in the basin. Due to the existence of rather high potential pasture land, combined with the carrying capacity of the grasslands and the flood plains, the riparian populations, and even those living elsewhere, practice transhumance and extensive cattle-, sheep- and goat-raising. These activities are generally profitable.

Fishing, in terms of the income of the work force that it employs, is undoubtedly the largest economic activity in the basin after agriculture, notably for populations living near the river in the valley and the delta. Today, however, the future of this sector is in question because for several years now there has been a steady drop in the tonnage caught throughout the OMVS region. Some observers link this to the river development projects (dams, dikes) and to their impact on the environment (significant decrease in salinity, proliferation of floating water weeds and eutrophication).

A recent OMVS study of fish resources indicates, however, that while it is true that some old species have disappeared, new fish species have appeared. It would even seem that the invasive aquatic plants are breeding grounds, which at the same time does not prevent them from seriously hindering the mobility of fishermen. The problem, therefore, needs to be studied in more depth to be able to objectively determine the actual impact of the dams on the fishing sector.

Mining sector

Before independence, mineral exploration carried out by the Geological Survey and Bureau of Mines (BRGM, Bureau de Recherches Géologiques et Minières) had already enabled the French to begin mining several economically profitable ores, notably gold in the Faleme River. The activity later became marginal and today only a few people still pan for gold in the Marian and Senegalese parts of the upper basin. Nevertheless, in light of the mining potential in the sector, with the energy provided by the Manantali dam, since September 2001, and the near completion of the river navigation project, mining will undoubtedly become one of the major development poles in the basin again.

Industry

The industrial sector is not sufficiently developed. The Senegalese Sugar Company (CSS, Compagnie Sucrière Sénégalaise) is the largest agro-industrial unit in operation in the basin. It has a production potential of more than 8,000 hectares of sugar cane in Richard-Toll, using water from both the Senegal River and Gueule Lake. Its two largest subsidiaries are the International Design Industry Services (IDIS), which manufactures polyvinyl chloride (PVC) pipes, and the Senal Cotton and Food Products Commerce and Industry Corp., which produces livestock feed. There are two other, smaller, companies in the Delta - the SOCAS canning plant near Ross Beths and the SNV, specialized in industrial tomato processing, in Diourbel, Senegal. There are also industrial and private rice paddies managed by the SAED and a public rural development enterprise (SONADER, Société Nationale de Développement Rural) in Mauritania.

Energy

The hydroelectric power plant in Manantali has been in operation since September 2001. The initial objectives of this project were to produce 200 megawatts (MW), to furnish an average of 800 gigawatts per hour per year (GWh/year) to electricity companies in the three OMVS member states. The projected electricity production figures used to estimate profitability were, however, based on hydrological data from 1950 to 1974. New simulations done with data from between 1974 and 1994 when flow coefficients were low, which might correspond better to current conditions, predict an energy production of only 547 GWh. As a result of this decrease in the...
energy capability of the Manantali power plant, the expected savings in OMVS member states expenditures for energy would unfortunately drop from 22 to 17 percent.

Navigation

Navigation on the Senegal River is today very limited. The OMVS is aware of the strategic importance of its development over the short term, and a navigation project is under study. Like the exploitation of mineral resources, the ability to transport heavy goods at a lower cost and, especially, access to the Atlantic Ocean for Mali could give a new impetus to the region’s economy. Table 20.4 summarizes the water use distribution between the different sectors.

Water Resources

Hydrology

Rainfall

The river’s flow regime depends, for the most part, on rain that falls in the upper basin in Guinea (about 2,000 mm/year). In the valley and the delta, rainfall is generally low and there is rarely more than 500 mm/year. During the 1970s (drought years), there was significantly less. This greatly accentuated the interannual irregularity of floods, which, before the dams were built, could vary six-fold between the wettest and driest years. The climatic regime in the basin can be divided into three seasons: a rainy season from June to September, a cold, dry off season from October to February, and a hot, dry off season from March to June. In the river, this creates a high-water period or flood stage between July and October, and a low-water period between November and May to June.

Surface water

The three main tributaries of the Senegal River produce together over 80 percent of its flow. The Bafing alone contributes about half of the river’s flow at Bakel. The two largest tributaries on the right bank, above Bakel, the Gorgol and the Oued Gharfa, supply only 3 percent of the water in the Senegal River that flows into the Atlantic Ocean at Saint Louis. At Bakel, considered to be the reference station on the Senegal River due to its location below the confluence with the last major tributary (the Faleme), the average annual discharge is about 690 cubic metres per second (m$^3$/s), which corresponds to an annual input of around 22 billion cubic metres (bcm). The annual discharge ranges between a minimum of 6.9 bcm and a maximum of 41.5 bcm. Table 20.5 provides some discharge data.

The total capacity of the Manantali dam, built on the Bafing River, is 11.5 bcm of water for a useful volume of around 8 bcm: it is the largest in the basin. Its purpose is to attenuate extreme floods, generate electric power and store water in the wet season to augment dry-season flow for the benefit of irrigation and navigation.

The Diama dam, located 23 km from Saint Louis near the mouth of the Senegal River in the delta, sits astride the territories of Mauritania and Senegal. Its threefold purpose is:

- to block seawater intrusion and thereby protect existing or future water and irrigation wells;
- to raise the level of the upstream water body, creating reserves to enable irrigation and double cropping of around 42,000 hectares at an altitude of 1.5 metres above sea level (m.a.s.l.) and 100,000 hectares at an altitude of 2.5 m.a.s.l.; and
- to facilitate the filling of Guiers Lake in Senegal and Lake Rkiz and the Aftout-es-Saheli depression in Mauritania.

Groundwater

The deep aquifers are, for the most part, represented by the Maestrichtian fossil formation and the Continental Terminal formation. The alluvial aquifer is the principal shallow aquifer. It is present in all of the flood plain at various depths, generally less than 2 metres, and has an average thickness of about 25 metres. This aquifer communicates in places with a discontinuous network of lensoidal aquifers in the permeable strata interbedded in the alluvium (see map 4.3 on the world’s groundwater resources in chapter 4, and map 12.4 on the aquifers in northern Africa in chapter 12).

---

Table 20.4: Water use by sector within the OMVS area (in millions m$^3$)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Mali</th>
<th>Mauritania</th>
<th>Senegal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>1,319</td>
<td>1,499</td>
<td>1,251</td>
</tr>
<tr>
<td>Domestic</td>
<td>27</td>
<td>101</td>
<td>68</td>
</tr>
<tr>
<td>Industry</td>
<td>14</td>
<td>29</td>
<td>41</td>
</tr>
<tr>
<td>Total</td>
<td>1,350</td>
<td>1,630</td>
<td>1,360</td>
</tr>
<tr>
<td>Per capita (m$^3$/year)</td>
<td>161</td>
<td>923</td>
<td>201</td>
</tr>
</tbody>
</table>

Reference year is 1985, except Mauritania (1985). Agriculture is by far the most important water use in the OMVS area.

Table 20.5: Seasonal changes in Senegal River discharge since 1951

<table>
<thead>
<tr>
<th>Period</th>
<th>Rainy season (m$^3$/s)</th>
<th>Dry season (m$^3$/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1951–1999</td>
<td>1,538</td>
<td>138</td>
</tr>
<tr>
<td>1951–1971</td>
<td>2,247</td>
<td>172</td>
</tr>
<tr>
<td>1972–1999</td>
<td>1,007</td>
<td>112</td>
</tr>
<tr>
<td>1972–1990</td>
<td>993</td>
<td>71</td>
</tr>
<tr>
<td>1991–1999</td>
<td>1,036</td>
<td>201</td>
</tr>
</tbody>
</table>

This table clearly shows the benefit of the Manantali dam construction in the flow regulation (beginning 1991): the discharge never falls below 200 m$^3$/s.
These aquifers are recharged by the river and by all of the tributaries, distributaries, ponds and lakes in the flood plain. On the edge of the valley, the aquifers tend to deepen, usually on a steep slope, but this is highly variable from one place to another. The water level in the alluvial aquifer varies with the seasons and river level, along with the general hydrological regime in the valley. Since the dams were filled, both the volume and duration of floods and the geographic distribution of the flooded areas have been disrupted, significantly modifying groundwater recharge and the piezometric surface. Reducing the volume of the floods and building dikes significantly reduces the area of natural recharge zones (refilling ponds). On the other hand, flow regulation during low water periods (maintenance of a minimum flow) and irrigation of large surfaces, rice paddies in particular, increase groundwater recharge during part of the dry season in some areas.

Water quality
In the Senegal River basin there is, at present, no database for water quality similar to those that exist for quantity and discharge, both of which have been monitored since 1964. There are, however, time series and locally monitored data, generally collected by national water supply companies in Mali, Mauritania and Senegal and within the framework of research carried out by universities, training institutes, cooperative agencies, etc. These data indicate, in some places, a degradation of surface water quality. This deterioration would be caused primarily by eutrophication due to a reduction of the flow velocity and oxygenation of the water caused by the new dams and dikes, the proliferation of water weeds, and chemical and biological pollution related to the discharge of wastewater and pesticides into the river. Furthermore, even if there are, as yet, no figures to confirm it, small alluvial gold-washing activities in the upper basin are a threat to water quality because of the products used (such as mercury and flashlight batteries).

Groundwater in the Senegal River basin is generally salty in areas where there used to be seawater intrusion before the Diama dam was built. The alluvial aquifer has a relatively homogeneous salinity, whereas the lacustrine, fluvo-deltaic aquifer formations have a slightly more heterogeneous salinity. As a result, there are large and sometimes abrupt variations, with concentrations rising from 1 or 2 grams (g) per litre to more than 150 g/litre. On average, salinity decreases as one moves away from the centre of the delta (more than 10 g/litre) towards the edge (10 to 0.15 g/litre). The aquifers have a higher load in high areas (with an average of 30 g/litre) than in depressions, which are regularly flooded (13 g/litre). However, the saltiest water is found in depressions such as the Aftout-es-Saheli (SAR) deposits of the ancient mangroves. The Sodium Absorption Ratio (SAR)\(^1\) of the aquifers is generally high, which means that there is a risk of alkalization of soil horizons in contact with these aquifers.

Impact of development on the population and on natural resources
More than ten years after the dams were filled in 1986 and 1987 and the structures (dikes, irrigation systems) associated with the implementation of the OMVS development programme were built, several studies have been carried out, making it possible to conclude that these interventions are having both positive and negative effects on the basin’s population and natural resources. Most important, the Senegal basin’s flood plain ecology has changed from a salty and brackish aquatic environment with marked seasonal changes to a low flow perennial freshwater ecology. There is, of course, a cause-effect relationship between the impact of human activities on the physical environment (water resources, soil, vegetation) and the impact of the restoration or degradation of this environment on people because the link between them is fundamental.

Principal negative effects
- Displacement of populations living in the areas where the dams were built;
- Proliferation of water-borne diseases (bilharzia [schistosomiasis], malaria, diarrhoea) due to changes in ecological conditions as a result of the blocking of seawater intrusion, with the Diama dam;
- Water pollution caused by the development of irrigated agriculture and the agro-industry (CSS, SAED in Senegal, SONDAM in Mauritania);
- Proliferation of water weeds in the valley and delta, clogging water courses and contributing substantially to making the ecosystem more uniform;
- Degradation of the fish population available for independent fishermen (quantity and quality);
- Reduction of pasture land;
- Riverbank erosion, especially in the upper basin where the topography is much more rugged;

1. Water is generally ranked according to the risk of alkalization: low hazard (2 to 10), medium hazard (11–18), high hazard (19–26), very high hazard above that (Fetter, 1994).

---

**Senegal River Basin, Guinea, Mali, Mauritania, Senegal**

---

**Water quality**

- In the Senegal River basin there is, at present, no database for water quality similar to those that exist for quantity and discharge, both of which have been monitored since 1964.
- Time series and locally monitored data, generally collected by national water supply companies in Mali, Mauritania and Senegal and within the framework of research carried out by universities, training institutes, cooperative agencies, etc. These data indicate, in some places, a degradation of surface water quality. This deterioration would be caused primarily by eutrophication due to a reduction of the flow velocity and oxygenation of the water caused by the new dams and dikes, the proliferation of water weeds, and chemical and biological pollution related to the discharge of wastewater and pesticides into the river. Furthermore, even if there are, as yet, no figures to confirm it, small alluvial gold-washing activities in the upper basin are a threat to water quality because of the products used (such as mercury and flashlight batteries).
- Groundwater in the Senegal River basin is generally salty in areas where there used to be seawater intrusion before the Diama dam was built. The alluvial aquifer has a relatively homogeneous salinity, whereas the lacustrine, fluvo-deltaic aquifer formations have a slightly more heterogeneous salinity. As a result, there are large and sometimes abrupt variations, with concentrations rising from 1 or 2 grams (g) per litre to more than 150 g/litre. On average, salinity decreases as one moves away from the centre of the delta (more than 10 g/litre) towards the edge (10 to 0.15 g/litre). The aquifers have a higher load in high areas (with an average of 30 g/litre) than in depressions, which are regularly flooded (13 g/litre). However, the saltiest water is found in depressions such as the Aftout-es-Saheli (SAR) deposits of the ancient mangroves. The Sodium Absorption Ratio (SAR)\(^1\) of the aquifers is generally high, which means that there is a risk of alkalization of soil horizons in contact with these aquifers.

---

**Impact of development on the population and on natural resources**

- More than ten years after the dams were filled in 1986 and 1987 and the structures (dikes, irrigation systems) associated with the implementation of the OMVS development programme were built, several studies have been carried out, making it possible to conclude that these interventions are having both positive and negative effects on the basin’s population and natural resources. Most important, the Senegal basin’s flood plain ecology has changed from a salty and brackish aquatic environment with marked seasonal changes to a low flow perennial freshwater ecology. There is, of course, a cause-effect relationship between the impact of human activities on the physical environment (water resources, soil, vegetation) and the impact of the restoration or degradation of this environment on people because the link between them is fundamental.

---

**Principal negative effects**

- Displacement of populations living in the areas where the dams were built;
- Proliferation of water-borne diseases (bilharzia [schistosomiasis], malaria, diarrhoea) due to changes in ecological conditions as a result of the blocking of seawater intrusion, with the Diama dam;
- Water pollution caused by the development of irrigated agriculture and the agro-industry (CSS, SAED in Senegal, SONDAM in Mauritania);
- Proliferation of water weeds in the valley and delta, clogging water courses and contributing substantially to making the ecosystem more uniform;
- Degradation of the fish population available for independent fishermen (quantity and quality);
- Reduction of pasture land;
- Riverbank erosion, especially in the upper basin where the topography is much more rugged;

1. Water is generally ranked according to the risk of alkalization: low hazard (2 to 10), medium hazard (11–18), high hazard (19–26), very high hazard above that (Fetter, 1994).
The installation of the dams has been accomplished without taking due account of other important aspects of planning.

Top-down planning has occurred without relationship to the local needs of the beneficiaries.

The large schemes for groundnuts, cotton and irrigation have been less than successful due to application of inappropriate technologies, lack of markets or access to markets, and lack of local capacity.

**Principal positive effects**

- Year-round availability of freshwater in sufficient quantities (for agriculture, domestic uses, agro-industry, groundwater recharge), accompanied by reverse immigration of people who had left to find employment in the cities;
- Development of irrigated agriculture in the valley (with double cropping);
- Partial opening up and stimulation of exchanges between areas where dams have been built and the rest of the subregion due to road construction;
- Access to healthcare for several villages near the dams with the construction of dispensaries and health clinics;
- Access to drinking water installations for populations living near the dams;
- Development of fishing activities for populations living near the Manantali dam;
- Reappearance of local fauna and regeneration of vegetation;
- Flow regulation to decrease or eliminate flooding;
- Cheaper electricity in the three member states thanks to the Manantali power plant.

Other positive effects expected over the short term concern:

- The electrification of villages near the dams (a study has been completed and funding obtained for the first phase); and
- Navigation on the river between Saint Louis and Kayes (a study is underway).

**Water resources database and information**

OMVS has abundant quantitative data thanks to a discharge monitoring network set up in 1904, with updated records stored in a database of the OMVS High Commission.

The Technical Department of the High Commission also publishes a monthly hydrological bulletin for the technical services of the member states and other actors (producers, development partners, NGOs, industrial projects) carrying out activities in the basin.

Major studies carried out by the French Research Institute for Development (IRD, Institut de Recherche pour le Développement) and the OMVS have also made it possible to estimate withdrawal and losses during low flow stages. The results are the following: evaporation during low water stages is estimated to be at 65.4 m³/s, withdrawal for human and industrial consumption at 2.6 m³/s, and withdrawal for irrigated agriculture during the off-season at 19 m³/s.

The average total water needs downstream from Bakel (reference station) are, therefore, at 87 m³/s during low water stages.

These studies have also made it possible to develop suitable resource management tools based on analysis of the hydrological behaviour of the river in relation to needs. Software (SIMULESEN) has been developed to evaluate the effects of the various Manantali dam management options on the degree of satisfaction of demands such as hydroelectric production, flow regulation, flow at Bakel as a function of needs downstream. Specific studies have also been carried out on how flooding is related to the functioning of basins, providing important information concerning their filling and emptying, and the volumes of water potentially available during this period.

Data on water quality, health, livestock-raising, agriculture, fishing, climate and the environment do exist, but are dispersed in various government services, laboratories, universities and research institutes, or even in cooperation institutions, such as the IRD, the United States Agency for International Development (USAID), the United Nations Development Programme (UNDP), and the World Bank.

Data have been collected for many projects, but the resulting databases are incompatible or have simply been lost or abandoned upon completion of projects. The most acute need is in the upper basin, including Guinea, where the lack of data is a concern not only for the government of Guinea but for the whole basin.

Data gaps have long been a handicap for the OMVS. Thus, the High Commission set up an Observatory of the Environment in...
November 2000 to create a network of all of the producers/possessors of thematic data and hook them up to a general database that would be managed by the OMVS’s Coordinating Centre. Agreement protocals will soon be drawn up by these organizations and the OMVS to formally define the roles and responsibilities of each of the actors in the data collection, processing and storage procedures, on the one hand, and data development, dissemination and sharing, on the other.

**Challenges to Life and Well-Being**

**A difficult context**

Before the dams were filled in the mid-1980s, activities of the local inhabitants depended directly on rainfall (rain crops) or on floods (flood recession crops), in particular in the upper basin in Guinea (Fouta Djallon Mountains). But the dramatic and continuous drop in rainfall during the 1960s and 1970s led to the degradation of almost the entire base of natural resources (soil erosion, disappearance of vegetation, drying up of surface water, salinity 200 km upstream from the mouth of the river, drop in the groundwater level, degradation and disappearance of pasture land). Under these conditions, the local inhabitants could not produce enough to survive and the only alternative was emigration. Each year, a large percentage of the population, in particular young people, left the valley and the delta for capital cities in the subregion (Abidjan, Bamako, Dakar, Libreville, Nairobi/Kenya) or Europe (usually France or Italy).

**The filling of dams**

In response to these difficulties, a dam-building project was implemented, in order to partially or totally control river flow and, consequently, enable the development of large areas of land for agriculture to contribute to food security. In addition, the dams built to regulate flow could also be used for hydroelectric power plants, to solve the problem of the low supply and high cost of electricity, and to maintain a sufficient flow depth in the river for fluid-maritime navigation to relieve Mali’s isolation by giving it access to the Atlantic Ocean and lower the cost of transporting heavy goods (making it possible to exploit the basin’s mineral resources). It is in this context that the OMVS programme was created.

After the dams were filled, sufficient quantities of water became available year-round, enabling local inhabitants to engage in various highly profitable activities. These new opportunities incited the young men who had left to try their luck elsewhere, without much success, to return home. People from the agrobusiness world also began coming into the area to invest in channels to market or to create small factories to transform the crops grown in the valley and delta. Preliminary studies showed that the irrigation system would establish the basis of profitable production. Flow regulation would guarantee a minimum discharge of 300 m$^3$/s at Bakel (reference station), and the storage capacity of the Manantali and Diama dams and the Guiers and Rkiz Lakes could be used to irrigate a surface area of 375,000 hectares, three times the surface area cultivated before 1986. Unfortunately, this initial enthusiasm diminished when, between the sixth and tenth year after the dams were filled, new problems arose. Two in particular, the degradation of ecosystems and the proliferation of water-borne diseases, very rapidly reached severe endemic proportions. These problems are described in detail further on in this chapter.

**Management Challenges: Stewardship and Governance**

The OMVS river basin organization was established about three decades ago by three out of the four riparian states. Mali’s principal interests are the maintenance of river levels so as to obtain navigable access to the sea and energy produced by the Manantali dam. Mauritanian and Senegalese interests converge in power production and irrigation, while Senegal seeks improved livelihoods for local populations. These varied interests are typical of a transboundary water management situation. The Manantali dam, although located in Mali, belongs to all the members of the OMVS authority.

**Legal and regulatory framework and governance**

The first institutions to develop the Senegal River valley were created during the colonial period. On 25 July 1963, very soon after independence, Guinea, Mali, Mauritania and Senegal signed the Bamako Convention for the Development of the Senegal River Basin. This convention declared the Senegal River to be an ‘International River’ and created an ‘Interstate Committee’ to oversee its development. The Bamako Convention was supplemented by the Dakar Convention, signed on 7 February 1964, concerning the status of the Senegal River. The Interstate Committee laid the foundation for subregional cooperation in development of the Senegal River basin. On 26 May 1968, the Labé Convention created the Organization of Boundary States of the Senegal River (OIRS, Organisation des Etats Riverains du Sénégal) to replace the Interstate Committee, broadening the field of subregional cooperation. Indeed. OIRS objectives were not limited to the valorization of the basin but aimed at the economic and political integration of its four member states. After Guinea withdrew from the OIRS, Mali, Mauritania and Senegal decided, in 1977, to set up the OMVS, which pursues the same objectives. The OMVS has since created a flexible and functional legal framework enabling collaboration and a co-management of the basin. The principal legal texts governing OMVS are:
the Convention concerning the status of the Senegal River (Convention relative au statut du fleuve Sénégal), 11 March 1972. By this convention, the Senegal River and its tributaries were declared an ‘International Watercourse’, guaranteeing freedom of navigation and the equal treatment of users;

the Convention creating the OMVS (Convention portant création de l’Organisation pour la Mise en Valeur du Fleuve Sénégal), 11 March 1972;

the Convention concerning the Legal Status of Jointly-owned Structures (Convention relative au statut juridique des ouvrages communs), 12 December 1978, supplemented by the Convention concerning the Financing of Jointly Owned Structures (Convention relative aux financements des ouvrages communs), 12 March 1982. These declare that:

– all structures are the joint and indivisible property of the member states;

– each co-owner state has an individual right to an indivisible share and a collective right to the use and administration of the joint property;

– the investment costs and operating expenses are distributed between the co-owner states on the basis of benefits each co-owner state draws from the exploitation of structures. This distribution can be revised on a regular basis, depending on profits;

– each co-owner state guarantees the repayment of loans extended to the OMVS for the construction of structures;

– two entities manage the jointly-owned structures for the OMVS: one dedicated to the management and development of the Diama dam (SOGED, Société de gestion et d’exploitation du barrage de Diama), the other to the Manantali dam (SOGB, Société de gestion de l’énergie de Manantali), both created in 1997.

In 1992, signature of a framework cooperation agreement between Guinea and the OMVS (Protocole d’accord-cadre de coopération entre la République de Guinée et l’OMVS), creating a framework for cooperation in actions of mutual interest concerning the Senegal River and its basin, including a provision allowing Guinea to attend OMVS meetings as an observer;

the Senegal River Water Charter, May 2002 (Charte des Eaux du Fleuve Sénégal) whose purpose is to:

– set the principles and procedures for allocating water between the various use sectors;

– define procedures for the examination and acceptance of new water use projects;

– determine regulations for environmental preservation and protection; and

– define the framework and procedures for water user participation in resource management decision-making processes.

The OMVS functions with the following management bodies:

Permanent bodies;

Conference of Heads of State and Government (CCEG, Conférence des Chefs d’Etat et du Gouvernement);

Council of Ministers (CM, Conseil des Ministres);

High Commission (HC, Haut Commissariat), executive body;

Permanent Water Commission (CP, Commission Permanente des Eaux) made up of representatives of the organization’s member states, and which defines the principles of and procedures for the allotment of Senegal River water between member states and use sectors. The CP advises the Council of Ministers;

Non-permanent bodies;

An OMVS national coordination committee in each member state;

Local coordination committees;

Regional Planning Committees (CRP, Comités Régionaux de Planification);

Consultative Committee (CC, Comité Consultatif).

This organizational framework, statutorily strong but flexible on the operational level, enables all of the actors and stakeholders to participate effectively in the efficient management of both the basin’s natural resources and its other economic potentials. For more than thirty years now, they have been able to find suitable solutions to all of the technical, social, political and other problems linked to the development of the Senegal River basin’s water resources.
Finances

Two types of funding are used to finance the development of the Senegal River basin. The first one covers the operating costs of the various OMVS bodies, and comes from the three member states; each of them pays one third of the total in January of every year. To finance the jointly owned structures and other development activities, funds are sought in the form of loans extended either to the states or directly to the OMVS. In this case, the member states must guarantee the loans. Each member state ensures the reimbursement of its share of the loans.

The apportionment of costs and debts is done according to an accepted formula, subject to revision, as stipulated in the conventions. The underlying principle of cost recovery is that the users pay, but economic conditions are also taken into consideration. Taxes paid to the organization are used to cover operating expenses.

Managing multiple uses: an original approach

Due to potential conflicts between power generation and the other uses of the Senegal River, the three governments have embarked through OMVS on the implementation of an environmental impact alleviation and follow-up programme (PASIE, Plan d’Atténuation et de Suivi des Impacts sur l’Environnement). It is an environmental programme specifically designed to address, monitor and mitigate the environmental issues raised by (or related to) the development and distribution of power from the Manantali power plant.

The OMVS’s fundamental conventions of 1972 and the Senegal River Water Charter signed in May 2002, which establish its legal and regulatory framework, clearly state that river water must be allocated to the various use sectors. The resource is not allocated to riparian states in terms of volumes of water to be withdrawn, but rather to uses as a function of possibilities. The various uses can be for agriculture, inland fishing, livestock raising, fish farming, tree farming, fauna and flora, hydroelectric energy production, urban and rural drinking water supply, health, industry, navigation and the environment.

The principles and procedures for the allocation of water were drawn up and a Permanent Water Commission (PWC) was set up to serve as an advisory body to the OMVS’s Council of Ministers that makes decisions and asks the High Commission to oversee their application. The OMVS’s process for managing needs has four steps.

First, an inventory of needs is taken by the OMVS National Committees under the Ministries in charge of water in each country. The ‘state of needs’ is then sent to the OMVS’s High Commission.

The High Commission centralizes all of the needs, writes a synthesis report and convenes a meeting of the Permanent Water Commission to vote on recommendations. It then draws up a record of the proceedings with precise recommendations for the Council of Ministers.

The Council of Ministers makes decisions based on the information provided by the Permanent Water Commission, either in a formal meeting or by informal telephone consultation. The High Commission receives instructions from the Council of Ministers and transmits to member states and other actors the procedures for carrying out the measures adopted by consensus by the member states in the Council of Ministers.

The work of the Permanent Water Commission and the criteria used by the ministers for decision-making are based on the following general principles:

- reasonable and fair use of the river water;
- obligation to preserve the basin’s environment;
- obligation to negotiate in cases of water use disagreement/conflict; and
- obligation of each riparian state to inform the others before undertaking any action or project that could affect water availability.

The objective of the OMVS method of water allocation is to ensure that local populations benefit fully from the resource, while ensuring the safety of people and structures, respecting the fundamental human right to clean water and working towards the sustainable development of the Senegal River basin.

Approach/procedure

The construction of the basic first-generation infrastructures (the Diama anti-salt dam and the Manantali multipurpose hydroelectric dam) marks the partial conclusion of a major phase, based on a development approach.

Today, the OMVS is attempting to redefine medium- and long-term development strategy for the entire basin, associating development with inextricably integrated and sustainable management. In March 2002, the OMVS began drafting a Master Plan for Development and Management (SDAGE, Schéma Directeur d’Aménagement et de Gestion des Eaux) of the Senegal River basin. This procedure enables progress to be made in the following areas:
next year. The participatory approach will be reinforced by the launching of the Master Plan and the start-up of environmental monitoring by the Observatory. Moreover, the May 2002 effective date of the Senegal River Water Charter and the increase in competitiveness between agriculture and pastoralism, with a big increase in the percentage of the population that is pastoral and therefore must compete for land. Increasing competition for agricultural land has been responsible for deforestation, which has been denuded due to overgrazing. As was shown in Table 20.3, a big percentage of the population is pastoral and therefore must compete for land, increasing competition between agriculture and pastoralism.

### Public Health

The degradation of the basin's ecosystems has affected the riparian population to various degrees. For example, there has been a drop in productivity in some economic areas (agriculture, fishing, livestock raising) compared to productivity during the first years after the dams were filled, which has led to a decrease in income and, therefore, a decrease in the standard of living.

### Degradation of Ecosystems

The flood plain ecosystems have been most affected by dam construction. In less than ten years, the degradation of these environments and the consequences on the health of the local population have been spectacular.

Upstream of Diama, the functioning of regularly flooded wetlands, lakes and ponds, such as the Djoudj, Guiers Lake and Lake Diawling, has been seriously disrupted. After 1986, Diama dam blocked seawater intrusion. The water above the dam is now fresh year-round, creating ecological conditions favouring the proliferation of freshwater plants (Typhas, Pistia, Salvinia molesta and various alga species). These are very invasive and eutrophication processes have begun at some places in the valley and the delta. Downstream of Diama dam, perturbations in the functioning of ecosystems takes the form of an increase in salinity and/or a drying-up during part of the year (Ndiaye wetlands) due to the reduction of flooding or the destruction of water inflow channels during construction of the development works (dikes, irrigated areas). Anthropogenic pollution is caused by the discharge of industrial and agricultural chemicals into these environments.

Other problems arise from increased competition for agricultural land and firewood. As marginal land on slopes and river banks is cleared, there is increased erosion. In addition, large areas of the basin have been denuded due to overgrazing. As was shown in Table 20.3, a big percentage of the population is pastoral and therefore must compete for land, increasing competition between agriculture and pastoralism.

### Identifying Main Problems

**Degradation of ecosystems**

The flood plain ecosystems have been most affected by dam construction. In less than ten years, the degradation of these environments and the consequences on the health of the local population have been spectacular.

Upstream of Diama, the functioning of regularly flooded wetlands, lakes and ponds, such as the Djoudj, Guiers Lake and Lake Diawling, has been seriously disrupted. After 1986, Diama dam blocked seawater intrusion. The water above the dam is now fresh year-round, creating ecological conditions favouring the proliferation of freshwater plants (Typhas, Pistia, Salvinia molesta and various alga species). These are very invasive and eutrophication processes have begun at some places in the valley and the delta. Downstream of Diama dam, perturbations in the functioning of ecosystems takes the form of an increase in salinity and/or a drying-up during part of the year (Ndiaye wetlands) due to the reduction of flooding or the destruction of water inflow channels during construction of the development works (dikes, irrigated areas). Anthropogenic pollution is caused by the discharge of industrial and agricultural chemicals into these environments.

Other problems arise from increased competition for agricultural land and firewood. As marginal land on slopes and river banks is cleared, there is increased erosion. In addition, large areas of the basin have been denuded due to overgrazing. As was shown in Table 20.3, a big percentage of the population is pastoral and therefore must compete for land, increasing competition between agriculture and pastoralism.
The development of intestinal schistosomiasis demonstrates even more clearly the impact of development on the health of the region. Unknown in Mauritania before the dams were filled, the first cases were reported in 1993. One year later, a survey showed that the population of school children in Rosso had an overall prevalence of 32.2 percent. In Senegal the situation is even worse, with a 44 percent rate of infestation in the Walo flood plain, 72 percent in the area around Guiers Lake where more than 90 percent of the villages are affected. In Mali, this form of schistosomiasis is still present in specific areas, with an infestation rate of 3.34 percent in 1997, but the situation calls for close monitoring.

Conclusions

The OMVS has demonstrated its effectiveness. It has been tested for more than thirty years now, and was recently improved by the adoption in May 2002 of the Senegal River Water Charter. This framework enables a collaborative management approach, with effective involvement of local actors/stakeholders, recognized and accepted by all of the riparian states including Guinea, who has signed cooperation agreements with the OMVS prior to being reintegrated into the organization. It also establishes the principles and terms of water sharing between the different usage sectors, based on the original concept of “water distribution” among the users and riparian states in which sharing the water resource is not a matter of withdrawal, but rather one of optimal satisfaction of usage requirements. The OMVS looks for an equitable managing and distribution of water resources among multicultural ethnic groups who are gathered around the river basin and its water resources. The new dams and institutional framework have brought greater prosperity and economic revenue and replaced a situation of water scarcity and conflict among users as that which prevailed before the 1980s.

However, these undeniable achievements cannot hide new difficulties emerging with the dams’ implementation: displacement of populations, water-borne diseases, proliferation of invasive aquatic vegetation, degradation of cultivated land and water pollution are the major issues the basin will have to cope with in the near future.
Box 20.1: Development of indicators

At the OMVS, the insufficiency or even total lack of temporal and spatial data for several sectors has made it almost impossible to correlate the increased availability of the water due to developments and the environmental and health problems that this has caused and their direct and indirect impact on the living conditions of local populations. Therefore, to eliminate this information control constraint, and to better understand the evolution of development in the basin, the OMVS is being reorganized so that it can collect, process and store all the data needed to monitor development project performance indicators from the upper basin to the mouth of the river. The Environmental Observatory was created by the High Commission in November 2000 for this purpose. Between November 2000 and December 2001, indicators were defined and strategies set up to gather, process and store data that will enable OMVS to correlate water availability, public health, the state of the environment and socio-economic development. These indicators concern:

- the productivity of activity sectors (agriculture, livestock raising, fishing, mining);
- the market rate of crops grown in the basin;
- the percentage of participation of women in economic activities;
- the impact of the involvement of women by activity sector;
- the quality and the quantity of domestic water use;
- the rate of access to drinking water of the populations living along the river;
- the prevalence of water-borne diseases (human and animal);
- the state of the environment (degradation of soil, forests, water bodies);
- the quantitative estimation of the degradation of ecosystems by sector of activity;
- the quantitative estimation of the health situation in each sector of activity;
- the rate of immigration and emigration in the zone; and
- the quantitative estimation of the corrective measures taken to eliminate the negative impact of developments.

References


SCP (Société Canal de Provence); Coyne and Bellier; Senagrosol. 2002. ‘Cost-Benefit Analysis to Develop an Optimal Dam Management Scheme’. Dakar.