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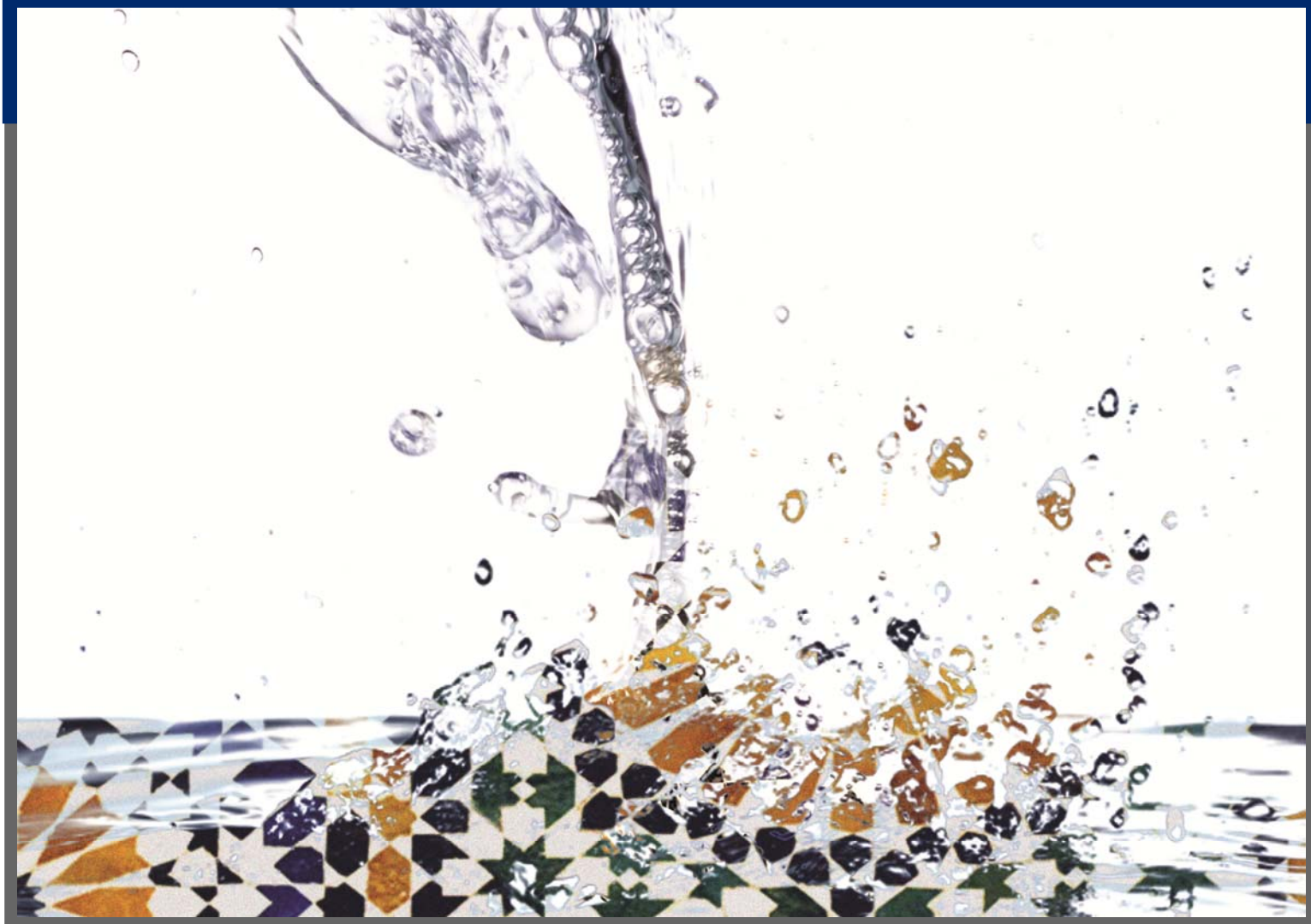
# MOROCCO ECONOMIC COMPETITIVENESS

## MOULOUYA AND OUM ER-RBIA WATERSHEDS: ORGANIZATIONAL IT AND MANAGEMENT SYSTEM NEEDS



**MAY 2010** **MEC DOCUMENT 9**

This publication was produced for review by the United States Agency for International Development. It was prepared by DAI.

# MOROCCO ECONOMIC COMPETITIVENESS

## MOULOUYA AND OUM ER-RBIA WATERSHEDS: ORGANIZATIONAL IT AND MANAGEMENT SYSTEM NEEDS

Submitted to USAID/Morocco, Economic Growth Office - Assistance Objective 3: Reduced barriers to trade and investment

By DAI

Contract Number: EEM-I-00-07-00009-00 : Task Order Number : EEM-I-07-07-00009

The authors' views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| **ABH** | Watershed Agency |
| **ABHM** | Moulouya's Watershed Agency; |
| **ABHOER** | Oum Er-Rbia's Watershed Agency; |
| **AECI** | Spanish International Cooperation Agency |
| **AEP** | Potable Water Supply |
| **AEPI** | Drinking and Industrial Water Supply |
| **APNEEI** | Support to the National Irrigation Water Saving Programme |
| **HCW** | High Council for Water |
| **DAI** | Development Alternatives Incorporated |
| **DPA** | Provincial Directorate for Agriculture |
| **GH** | Great hydropower station |
| **GIRE** | Integrated water resource management; |
| **GMAO** | Computerized Maintenance Management System (CMMS) |
| **GWH** | Giga Watt Hour |
| **KWH** | Kilo Watt Hour |
| **MDHS** | Million Dirhams |
| **MEC** | Morocco Economic Competitiveness |
| **$MM^3$** | Million cubic meter |
| **MNT** | Digital Terrain Model |
| **NTIC** | New Information Technology and Communication |
| **ONE** | Office National de l'Electricité |
| **ONEP** | National Office of Drinking Water |
| **ORMVA** | Regional Offices for Agricultural Development |
| **ORMVAD** | Office Régional de Mise en Valeur Agricole de Doukkala |
| **ORMVAH** | Office Régional de Mise en Valeur Agricole du Haouz |
| **ORMVAM** | Office Régional de Mise en Valeur Agricole de la Moulouya |
| **ORMVAT** | Office Régional de Mise en Valeur Agricole de Tadla |
| **RAP** | Regional Agricultural Plan |
| **PDAIRE** | Water Resource Modernization Plan |
| **PDPI** | Master Plan for Flood Protection |
| **PMH** | Small and Medium-sized hydropower station |
| **RADEJ** | Régie Autonome d'Eau et d'Electricité d'El Jadida |
| **RADEO:** | Régie Autonome d'Eau et d'Electricité d'Oujda |
| **PNEEI** | National Irrigation Water Saving Programme |
| **SGBD:** | Database Management System |
| **IT** | Information System |
| **SIBE:** | Biological and Ecological Landmark |
| **SIE** | Information System on Water |
| **SIG** | Geographical Information System |
| **SIWM** | Souss Integrated Watershed Management |
| **USAID** | United States Agency for International Development |
| **TAU** | Territorial Agricultural Unit |

# I INTRODUCTION

## BACKGROUND OF THE STUDY

The USAID Morocco Economic Competitiveness program (MEC), implemented by Development Alternatives Incorporated (DAI), is designed to meet USAID Morocco's strategic objective of reducing barriers to investment and trade.

The MEC project focuses on:

- Supporting policy and institutional reforms to improve Morocco's business environment.
- Fostering the optimal use of water resources for increased productivity, competitiveness, employment and incomes in Morocco's agricultural sector.
- Supporting workforce development aligned with market needs.

One key component of the project is the management and enhancement of agricultural water use. Here the overall objective is the optimal management of water resources for increased productivity, competitiveness, employment and income.

This work falls under MEC project activities:

- Task 2.2.3: Development of information management tools for the ABHOER, the ORMVAD for the Oum Er-Rbia watershed, and the ABHM and ORMVAM for the Moulouya watershed.
- Task 2.2.5: Improved management of the watersheds' groundwater throughout the region.

## MISSION GOALS

- Analysis and diagnosis of the existing parameters by collecting various data, carrying out prospective studies, systems and decision-making tools in place or under development in the field of water (ground and surface) with partners, i.e.: ABHOER, the ORMVAD respectively and others to a lesser degree (RADEJ, ONEP, ONE) for the Oum Er-Rbia watershed, and the ABHM and ORMVAM for the Moulouya watershed and others to a lesser degree (RADEO, ONEP, ONE).
- Evaluation of integrated management tools for the watershed's water resources in comparison with what has already been done in similar regions in Morocco, while trying to disseminate and/or adapt tools developed under the SIWM/USAID project. These tools would help supporting the implementation of an information system on water at Oum Er-Rbia.
  - Consideration of the need to deploy a water table contract.

Given the new policies under the Water Strategy, the Green Morocco Plan, the Plan of National Economy of Irrigation Water and the Regional Agricultural Plan (RAP), it is imperative to involve all partners and stakeholders in the watershed study (Oum Er-Rbia and Moulouya) and harmonize the various views.

This report's objectives are to:

- Evaluate the experience, willingness and apprehensions of key agencies involved in the watershed regarding the data exchange on water;
- Assess the database needs of each organization and present options for improving existing ones

and/or creating new databases;

- Identify organizations' opportunities and constraints in data sharing and propose means to facilitate this exchange process;
- Identify mechanisms and technical collaboration to achieve consensus on the development of a database on water resources;
- Contribute to the development of consensus among partners to monitor, exchange and manage databases;
- Recommend concrete actions to improve the efficiency of Oum Er-Rbia water resources' management and use.

This report is organized as follows:

This first chapter contains an introduction devoted to an overview of report objectives and framework.

The second chapter summarizes the general characteristics of the Oum Er-Rbia watershed including specifying its location, climate aspects, watershed specifics, economic context, hydro-climatic equipment, surface and groundwater water resources in terms of quantity and quality and use, and risks such as floods, droughts, erosion and siltation of dams.

Chapter provides a similar summary of general characteristics for the Moulouya watershed.

The fourth chapter presents current projects, including RAPs (Regional Agricultural Projects), their partnerships and stakeholders.

Chapter five highlights the necessary elements for integrated management of watershed water resources. Next, ICT needs are identified based on the cases of the Oum Er-Rbia and Moulouya watersheds.

Chapter six analyses the achievements, overall contributions, pre and post SIWM, focusing on lessons learned from the success of this project.

Chapter seven contains recommendations for an action plan.

# II OUM ER-RBIA WATERSHED

## LOCATION

The ABHOER's area of intervention is limited to the North by the Bouregeg and Sebou watersheds, to the northeast by the Moulouya Water watershed, to the southeast by the South Atlasic watersheds, to the south by the Tensift Water watershed, and to the west by the Atlantic Ocean (Figure 1). It covers a total area of 48,070 km$^2$, or 7% of the country's total area. It consists of the Oum Er-Rbia watershed (35000 km$^2$) and the Atlantic coastal watersheds located to the southwest of the Oum Er-Rbia watershed between El Jadida and Safi (13,070 km$^2$)

The Oum Er Rbia oued (river), 550 km long, originates in the Middle Atlas at 1800 m above sea level, travels through the Middle Atlas chain, the Tadla plain and the coastal plateau and empties into the ocean Atlantic about 16 km from the city of El Jadida.

The action area of ABHOER includes 8 provinces. The total population of the watershed is 4.96 million inhabitants of whom 61% are rural. The population density is about 100 people per km$^2$. This population is concentrated in the centers and areas surrounding watercourses and springs.

## CLIMATE

The watershed climate is arid to semiarid; this means rainfall decreasing from west to east (350 to 250 mm / year), in high altitude rainfall can reach 1000 mm (with snow above 1500m).

The average rainfall over the Oum Er-Rbia watershed and coastal watersheds is 500 mm/year. It varies between 1100 mm in the Middle Atlas and 300 mm in the downstream area of the river. It snows on average 20 days/year above 800 m.

The temperature varies between 10 and 50°C. The mean minimum and maximum are 3.5°C (January) and 38°C (August), respectively.

Evaporation can reach 1600 to 1800 mm/year. It stands at 1600 mm per year along the coast and 2000 mm inside the watershed with a monthly maximum of 300 mm in July and August

## ECONOMIC CONTEXT

The area has a fairly diversified economic activity including irrigated and non-irrigated agriculture, mining, food industries and many major manufacturing industries.

In the ORMVAD's area of intervention only, agricultural production is an important part of national production. It is 38% of production for beets, 20% for commercialized dairy, 7% for cereals, 20% for grapes, 20% for vegetables, 8% for market gardening.

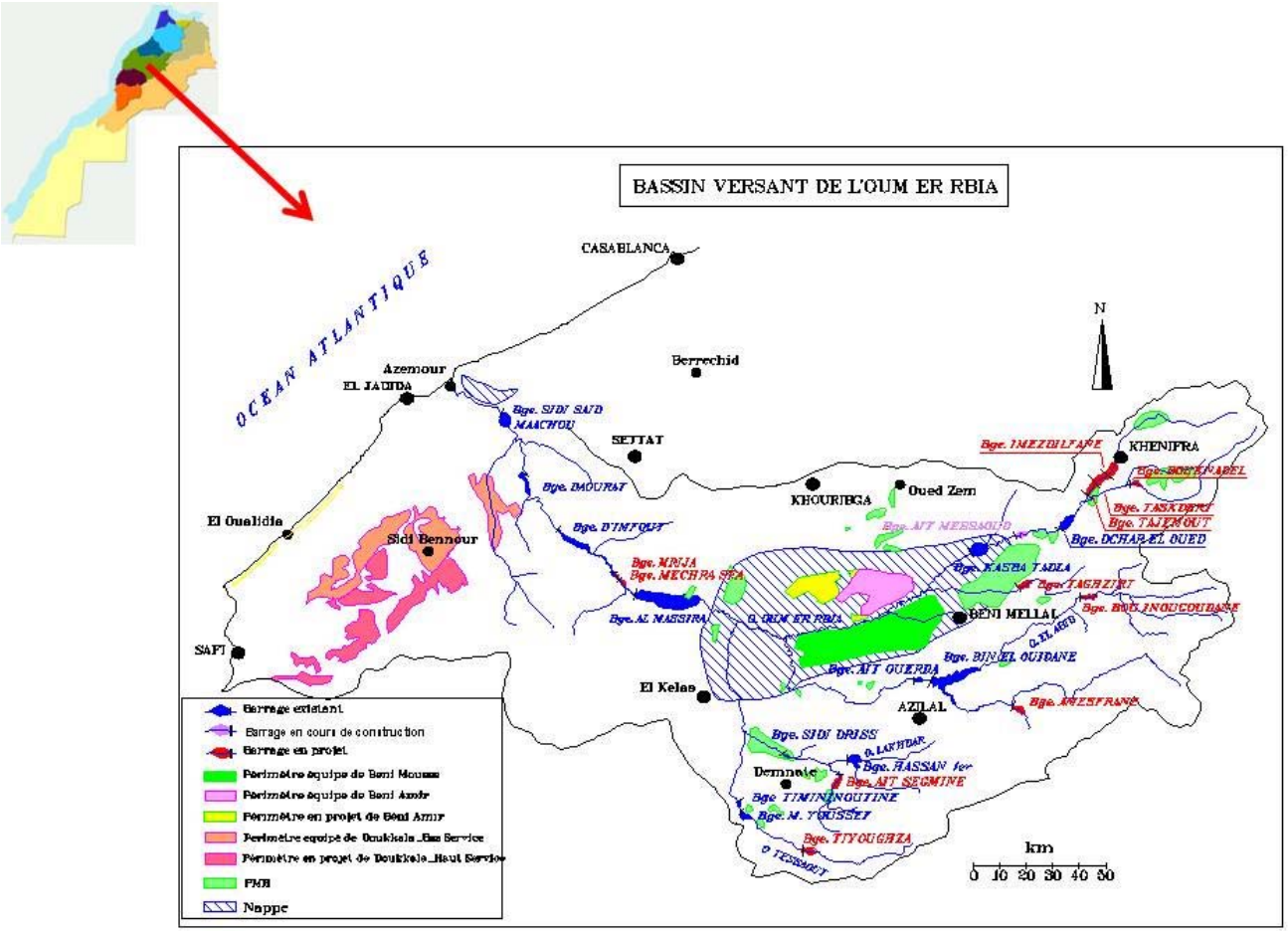
As for livestock, the ORMVAD's area of intervention accounts for 200,000 head of cattle, 90,000 dairy cows, 430,000 heads of sheep, 3,000 head of goats, 100,000 head of equine. In 2003, milk

production was 262 million liters of which 122 are sold. Red and white meat was 15,000 tons and 5,000 tons respectively.

The value of agricultural production (average of 5 campaigns) amounted to 3,850 million dirhams. Employment generated by agriculture is estimated at 10 million number of days/year.

Still in the ORMVAD's area of intervention, we note the existence of large agro-industrial units which allow the recovery of agricultural production. These are two sugar mills with a processing capacity of 17,000 tons/year, two dairies (134.4 million liters), 7 mills, two units of animal feed, a cellar of wine production, 22 tomato packing stations, three butcher units, a fresh yeast production unit, 1 cheese processing unit, and a pasta manufacturing unit, and a mining complex (Jorf-Lasfar) which represents the first industrial pole given its facilities and the many process industries.

**Figure 1: ABHOER's location and area of intervention**



# THE WATERSHED'S WATER RESOURCES

## II.1.1 SURFACE WATER

The watershed consists of the Oum Er-Rbia with three main tributaries: Oued Tessaout, Oued Lakhdar and Oued El Abid.

The annual average intakes of the Oum Er-Rbia watershed is estimated at 3250 $Mm^3$/year, with a maximum of 8,300 million $m^3$ and a minimum of 1300 $Mm^3$.

For the Atlantic coastal watersheds of El Jadida-Safi, the surface water inflows are estimated at 50 $m^3$/year. Added to that are the unused inputs upstream of the Oum Er-Rbia watershed. These inputs are recovered at the Massira Dam, much of which is transferred to the coastal watersheds.

Water infrastructure at the Agency's area of intervention accounts for several dams (Table 1) with a total capacity of about 5,300 million $m^3$ of which almost 70% (3,550 $Mm^3$) is regularized. Lastly, we add three major diversion canals (87 km).

## II.1.2 GROUNDWATER

The groundwater resources of ABHOER's area of intervention are relatively large and consist of several water tables (Figure 2). The main ones are briefly described below:

***The Turonirn groundwater of Tadla:*** This aquifer covers an area of 10,000 $km^2$. It consists of karstified limestone and dolomitic limestone. The thickness of the aquifer varies from 20 m at outcrop to 80 m in the South, near the Atlas Mountains area.

***Beni Amir's groundwater:*** Spans over an area of 600 $km^2$ and flows through alternating marl-limestone, lacustrine limestones and conglomerates with a thickness varying between 50 and 100 m. It grows of about 10 m in the North (south of El-Brouj and Boujaad) of 100 m in the South and can reach 200 m in the North of Dar Ouled-Zidouh.

***Beni Moussa's Groundwater*:** Covers an area of 885 $km^2$ and flows through limestone formations mainly limestone and marl-limestone of Villafranchian and old Quaternary, silts and marls and upper Quaternary sequences with late Quaternary conglomerates. The thickness of the groundwater is about 150 m at the Oum-Er-Rbia, and grows going towards the Atlas Mountains where it can be 300 m thick south of Dar Ould -Zidouh.

.

Table 1 Existing Dams

| *Dam* | *Watercourse* | *Commissioning* | *Use* | *Capacity (in million m³)* | *Regularized volume (in million m³/ year)* |
|---|---|---|---|---|---|
| **Dam maintained by the ABHOER** | | | | | |
| My Youssef | Tessaout | 1969 | I, E | 175 | 230 |
| Timin' Outine | Tessaout | 1979 | I | 5.3 | B.Compensation |
| Agadir Bouchiba | Tessaout | 1960 | I | 0,1 | Irrigation dam |
| Kasba Tadla | O. Er-Rbia | 1929 | I | 0,1 | Irrigation dam |
| My Hassan | Lakhdar | 1986 | I, E, AEPI | 263 | 346 |
| Sidi Driss | Lakhdar | 1980 | I, E, AEPI | 3.7 | Compensator |
| Al Massira | O. Er-Rbia | 1979 | I, E, AEPI | 2760 | 1554 |
| Safi dyke | Doukkala canal | 1965 | AEPI | 5 | |
| Ahmed El Hansali | O. Er-Rbia | 2002 | I, E, AEPI | 740 | 473 |
| Ait Messoud | O. Er-Rbia | 2003 | I, E, AEPI | 15 | Compensator |
| Sidi Daoui Dyke | O. Er-Rbia | 1984 | AEPI | 5.5 | Compensator |
| **Dams maintained by ONE** | | | | | |
| Bin El Ouidane | Laabid | 1954 | I, E | 1 300 | 945 |
| Ait Oouarda | Laabid | 1954 | I, E | 4 | C. |
| Imfout | O. Er-Rbia | 1940 | I, E, AEPI | 18.2 | C. |
| Daourat | O. Er-Rbia | 1950 | AEP, E | 9.5 | C. |
| Sidi Said Maachou | O. Er-Rbia | 1929 | AEP, E | 1.5 | C. |

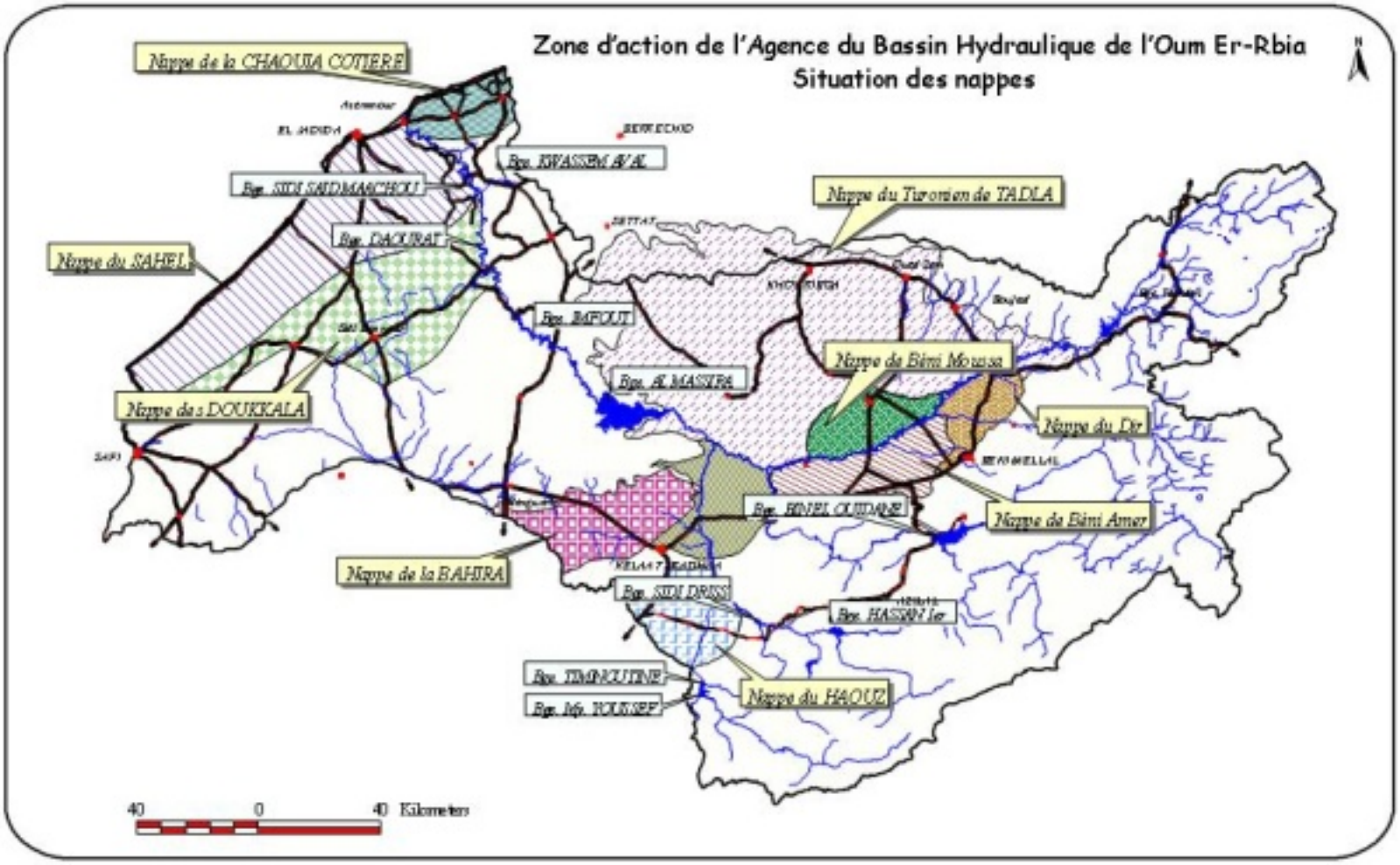



**Figure 2: Aquifers of the ABHOER's area of intervention**

***Dir water table*:** Covers an area of 450 $km^2$ and is located in Quaternary Mio-Pliocene sediments which are very heterogeneous, consisting mainly of alternations of limestones, marls and conglomerates. Its thickness varies between 100 and 200 m.

***The downstream Tessaout water table***: Covers an area of 500 $km^2$ and flows mainly within a sandy clay formation and plio-Quaternary conglomerate laying on the Eocene marly and transgresses in Turonian limestones. Its thickness varies usually between 10 and 20 m.

***The Bhira water table:*** Covers a 5000 $km^2$ area. The aquifers of this water table are composed of secondary and tertiary formations overlain by Neogene and Quaternary deposits in plains. Groundwater flows in the alluvial deposits in the eastern part and through stringers, sandy loams and sandy limestones of the Plio-Quaternary in the western part.

***The Sahel-Doukkala water table:*** The Sahel watertable stretches in a narrow strip of 3100 $km^2$ along the Atlantic Ocean. It flows in dune formations of Plio-Quaternary and Cretaceous limestone formations. It is used intensively for market gardening.

That of Doukkala extends over 3250 $km^2$ under the Doukkala plain with limited potential. It flows in Plio-Quaternary formations.

***The Chaouia Coastal watertable:*** Located between the right bank of the Oum Er Rbia and the Greater Casablanca.

As shown in Figure 3, these water tables are subject to a piezometric monitoring.

Moreover, the number of wells in ABHOER's area of intervention amounts to 12,323 with 85 for the AEP, 3938 in the bour, and 8300 in the irrigated perimeter.

According to PDAIRE's briefing note, the total volume of groundwater in the area of intervention is in deficit of 147 million $m^3$ (Table 2, Figure 4). The pumped samples make up for about 638 million $m^3$, that is 50% of the contributions on the balance. Contributions amount to 1331 million $m^3$ which is currently insufficient The samples pumped represent the equivalent of 638 $Mm^3$.

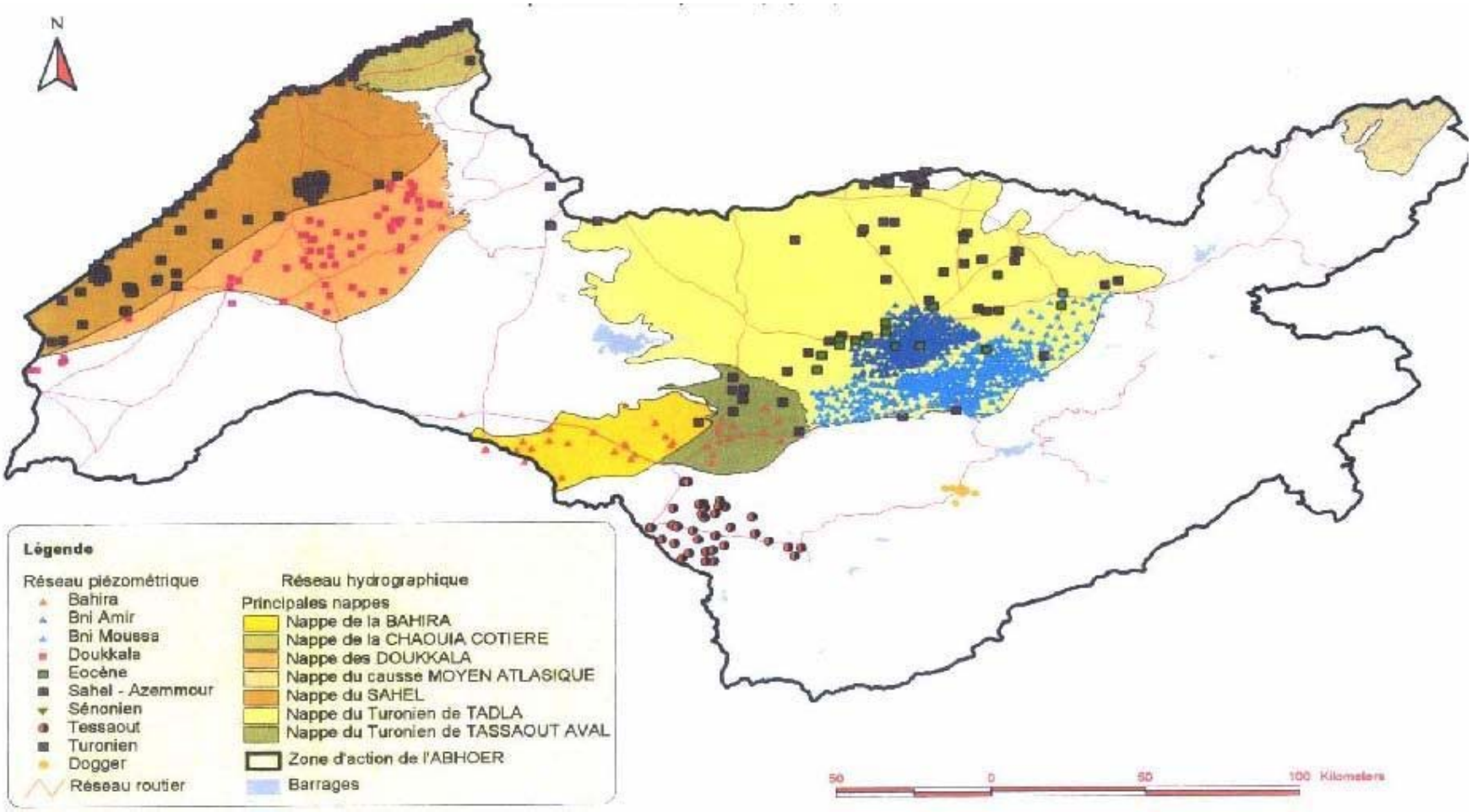



**Figure 3: Groundwater monitoring network in the ABHOER's area of intervention**

Table 2. Total volume ($Mm^3$/year) of the groundwater in ABHOER's area of intervention

| **Conclusions** | **Béni Amir** | **Dir** | **Béni Moussa** | **Tadla (deep)** | **Tessaout downstream** | **Bahira** | **Sahel-Doukkala** | **Coastal Chaouia** |
|---|---|---|---|---|---|---|---|---|
| Pluviometry | 7.0 | 5.3 | 10.0 | 413.5 | 4.0 | 45.0 | 145.0 | 17.5 |
| Infiltration of the oueds | 0.0 | 5.1 | 0.0 | 0.0 | 1.6 | 0.0 | 3.3 | 0.0 |
| Lateral inflow | 77.5 | 87.5 | 87.5 | 118.0 | 30.1 | 7.0 | 12.5 | 1.0 |
| Back water | 48.8 | 19.9 | 78.5 | 0,3 | 30.3 | 10.8 | 63.7 | 0.6 |
| **Total Inputs** | **133.3** | **117.7** | **176.0** | **531.8** | **66.0** | **62.8** | **224.4** | **19.1** |
| Springs captated | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Springs not captated & drainage through the Oueds | 17.9 | 1.6 | 11.8 | 360.3 | 12.9 | 2.0 | 9.8 | 1.2 |
| Pumping | 91.0 | 71.0 | 146.1 | 120.0 | 26.5 | 88.0 | 85.0 | 10.0 |
| Outflow through another groundwater | 45.0 | 60.0 | 45.0 | 90.0 | 32.5 | 3.0 | 130.0 | 5.0 |
| Overflow | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Evaporation | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.5 | 0.0 | 3.0 |
| **Total output** | **153.8** | **132.6** | **202.8** | **570.3** | **71.9** | **102.5** | **224.8** | **19.2** |
| **Balance** | **-20.6** | **-14.8** | **-26.8** | **-38.5** | **-5.9** | **-39.7** | **-0.3** | **-0.1** |

## II.1.3 WATER QUALITY

**Pollution source**

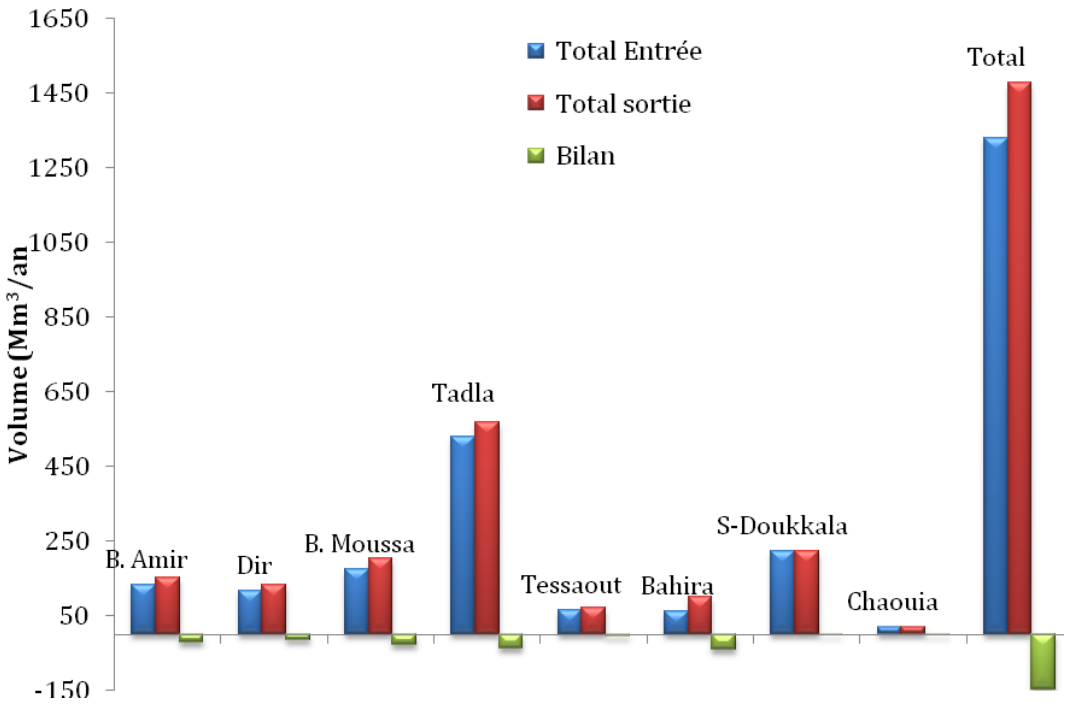



**Figure 4 : Total volume of the groundwater in ABHOER's area of intervention**

The main sources of pollution found in the Oum Er-Rbia watershed are mainly due to urban sewage, industrial discharges, and agricultural activities including the use of fertilizers and pesticides. In the case of coastal watersheds, pollution is mainly due to discharges from urban and industrial wastewater and fertilizers and pesticides. The direct and indirect effects of these various sources of pollution results in the degradation of the quality of groundwater and surface water resources.

**Domestic pollution:** The origin of domestic pollution in the watershed is from the population concentration in cities and urban centers. There are 70 centers where the volume of discharge is 40 $Mm^3$/year. These centers reject an annual quantity of 21,500 tons BOD5 and 42,000 tons of COD. There are 16 water treatment plants in ABHOER's area of intervention.

**Industrial pollution:** The key sources of industrial pollution are: sugar plants, canning plants and the centrale laitière dairy plant. These primarily have an impact of increasing nitrate and organic matter rates.

The annual quantity of releases from these sources is estimated at about 16 million $m^3$. The main source of organic pollution is the food processing industry which generates about 11,000 tons of BOD5 and 21,500 tons of COD.

**Agricultural Pollution:** Farming also contributes to groundwater pollution because of the irrational and sometimes abusive use of fertilizers and pesticides.

In the Agency's area of intervention the amount of nitrogen leached into groundwater or runoff to watercourses is approximately 10%. In the Tadla water table, we estimate the amount of leached nitrates and pesticides is 3,500 tons and 2.2 tons respectively.

**Water quality**

The quality of surface water is good overall in the upper catchment (upstream Khénifra) and degrades downstream of all discharges, be it urban or industrial. The most polluted stretch, especially in summer, is located downstream from the Kasba Tadla discharge and downstream of the Dar Ouled Zidouh discharge of Oum Er-Rbia.

The quality monitoring network of surface water currently contains:

- 8 primary stations located downstream of the main rivers.
- 10 secondary stations on small streams and downstream of major discharges.
- 11 water quality monitoring stations for the dam reservoirs and canal.

Groundwater quality deteriorates continuously—the nitrate rate reaches worrying levels (levels above 50 mg/l for most of the stations sampled). Salinity levels are high in some water tables, including those of Beni Amir and Beni Moussa West.

### II.1.4 RESOURCE ALLOCATION

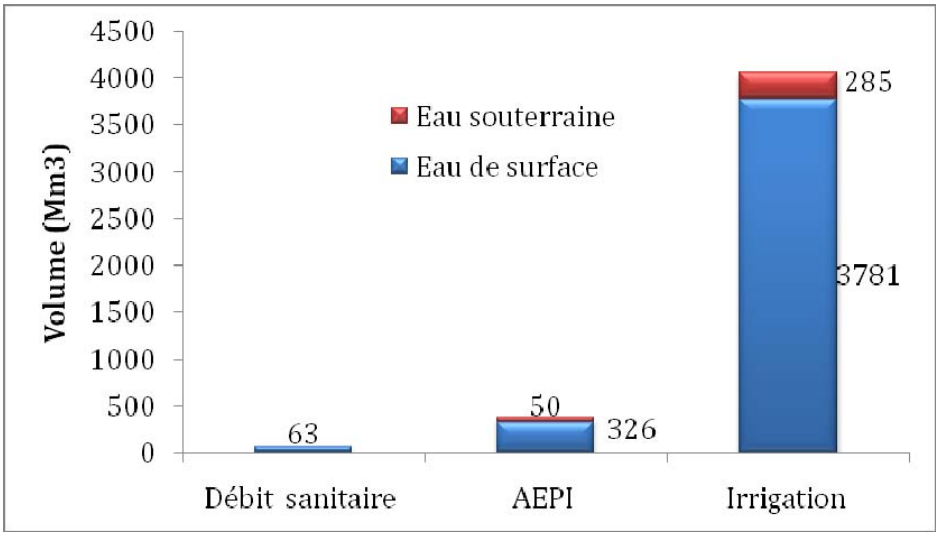
The volume of water used in the Oum Er-Rbia watershed amounts to 4505 million m³ shared between (Table 3, Figure 5):

- 4170 million m³ of surface water used at 90% for irrigation, and 8% for the AEPI, and 2% as sanitary flow;
- 335 million m³ of ground water used at a rate of 85% for irrigation and 15% for the AEPI.

Table 3. Water use in the ABHOER's area of intervention (Mm³)

| *Use* | *Surface Water* | *Groundwater* | *Total* |
|---|---|---|---|
| Irrigation | 3781 | 285 | 4066 |
| AEPI | 326 | 50 | 376 |
| Sanitary flow | 63 | | 63 |
| ***Total*** | 4170 | 335 | 4505 |

**Figure 5: Distribution of the water use in the ABHOER's area of intervention**




**Irrigation**

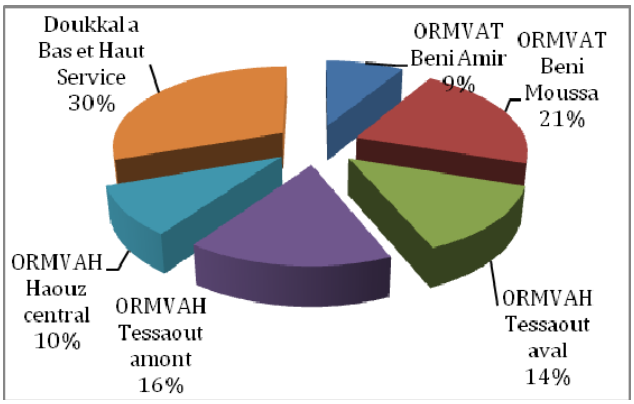
In the Oum Er-Rbia watershed Agency's area of intervention, the agricultural irrigable potential amounts to 450,000 ha. Irrigated area is 280,500 ha in GH and 64,400 ha in PMH.

A Great hydropower station from the Oum Er-Rbia water irrigates 324,700 ha (including 31,700 ha currently equipped in the central Haouz). This area is divided into six large areas (Figure 6):

The small and medium power stations in the Oum Er-Rbia river watershed and in the Doukkala coastal zone, involves more than sixty scattered perimeters in these areas.

**Figure 6: Perimeters irrigated by the great hydropower station in the ABHOER's area of intervention**

| *Office* | *Perimeters* | *Number of hectares)* |
|---|---|---|
| ORMVAT | B. Amir | 28 200 |
| | B. Moussa | 69 600 |
| ORMVAH | Downstream Tessaout | 44 000 |
| | Upstream Tessaout | 52 500 |
| | Central Haouz | 31 700 |
| ORMVAD | B. and H. Service | 98 700 |
| **Total** | | **324 700** |




Normal needs in irrigation water have increased from 2000 million m³ in 1980-81 to more than 2,500 million m³ in 2006. The comparative evolution of volumes of water supplied and the normal

needs of irrigation from dams in the AGBHOER's area of intervention over 25 years is illustrated in Figure 7. This figure shows that the irrigation needs have never been met since the year 1980-81. The average deficit is 33% with a peak of 67%.

One of the most important partners of ABHOER, in terms of water use, is the ORMVAD. The ORMVAD's area of intervention is located north West of the Oum Er-Rbia watershed (Figure 8).

The ORMVAD's area of intervention involves three areas:

- The area irrigated by the great hydropower station (GH),
- The area irrigated by private pumping, and
- The rain fed area

***Irrigated area (GH)*** in the Doukkala is essentially characterized by the production of sugar beet, cereals, market gardening, dairy and red meat. Other crops are grown such as sunflower, soybean, cotton and tobacco (Figure 9). The average crop intensification is 129%.

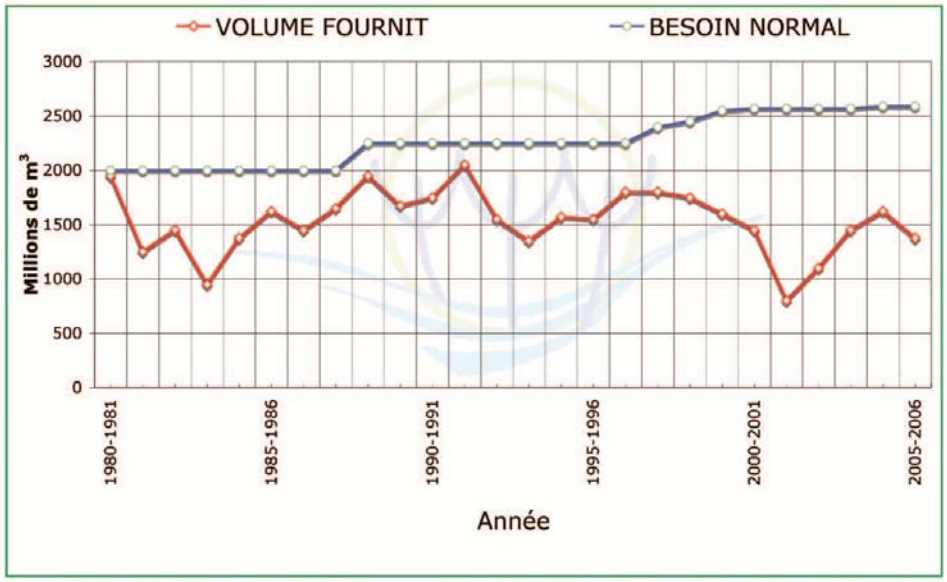



**Figure 7: Evaluation of volumes of water supplied for irrigation from the dams**

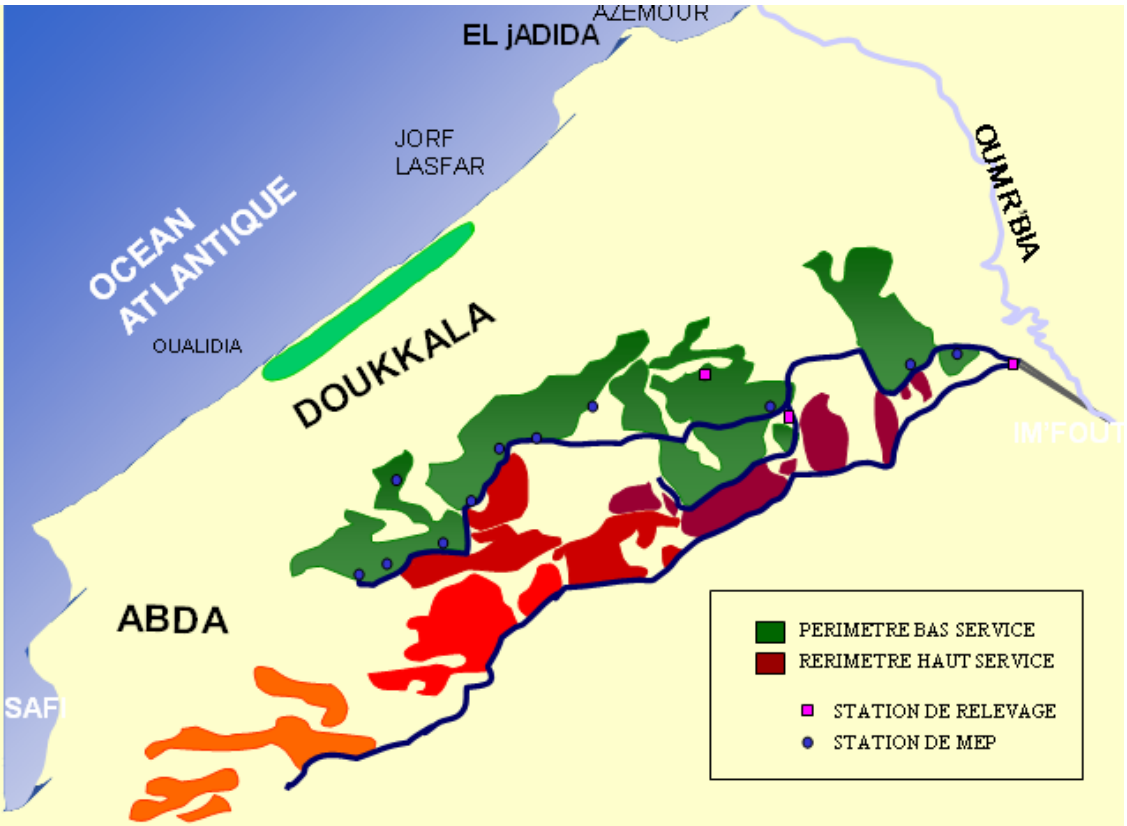



**Figure 8: ORMVAD's location and area of intervention**

| *Crop* | *Area (ha)* |
|---|---|
| Beet | 18 000 |
| Wheat | 28 250 |
| Fodder | 15,170 |
| Market gardening | 11 000 |
| Others | 9400 |
| **Total** | **81,820** |

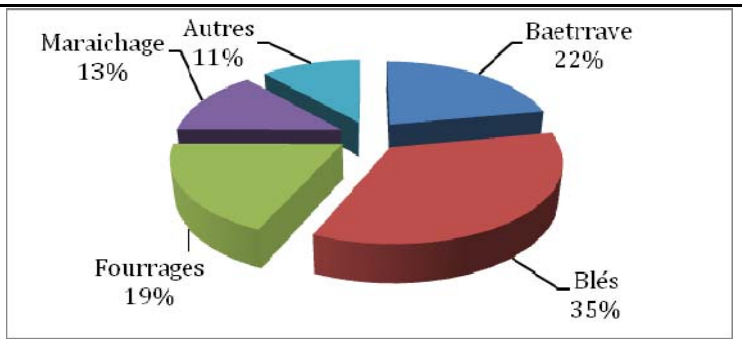



**Figure 9: Irrigated land occupation (1993-2002 average)**

- It stands out that cereal occupies a major area, followed by industrial crops (sugar beet) and finally by fodder crops.

The layout of the plains of Abda-Doukkala has ensured irrigation of 96.000 hectares distributed between two perimeters: the Bas Service perimeter with 61.000 hectares and the Haut Service perimeter with 35.000 hectares (1st & 2nd installments).

In the Bas Service perimeter, irrigation is provided by the mobilization of surface water from the Oum-Er-Rbia, regulated by the Al Massira dam and derived by the Imfout dam.

The irrigation infrastructure in the Bas Service perimeter consists of the Imfout gallery (16.7 Km), the Bas Service Main Canal (111 Km), the intermediate canal (24 km covered), the pumping stations (2 pumping station and 1 pressurization control station) with a total capacity of 40 MW, an irrigation system (2034 km), a track network (3500 km), and a sewerage and drainage network (1.800 km).

For the Haut service, this infrastructure consists of a 13 km gallery, a pumping station with a capacity of 24 MW, a main canal, an irrigation network (880 km), a trail system (1650 km), and a sewerage and drainage network ( 1555 Km).

As mentioned before, the irrigated area amounts to 96.000 ha, including 62.500 ha irrigated by gravity and the remaining 33.500 ha irrigated by sprinkling. The surface irrigation method accounts for 65%, while the sprinkler method accounts 35% (Figure 10).

The change in the priming dates shows that gravity irrigation was adopted in the early developments, but was later abandoned in favor of sprinkler irrigation for facilities created between the 1970 - late 80s. The reason for adopting such technique was mainly water conservation. However, with the high cost of energy, the sprinkler technique was abandoned for the re-adoption of surface irrigation (gravity irrigation) even though it technically consumes more water.

| ***Type of irrigation*** | ***Area (Ha)*** |
|---|---|
| Gravity | 62 500 |
| Sprinkler | 33 500 |
| **Total** | **96 000** |

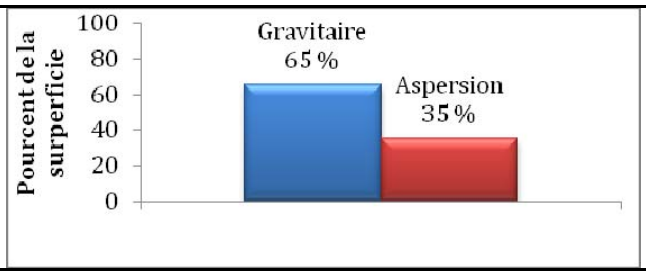



**Figure 10: Method of irrigation**

***The area irrigated by private pumping*** corresponds to the coastal zone (a 3,800 Ha area). It is located along the Atlantic coast, stretching over 50 Km, south of El Jadida. The land in this area is dominated by vegetable crops (potatoes and season vegetables) (Figure 11). There are about 850 wells with depths ranging from 8 to 50 meters and a salinity of between 0.25 and 1.6 grams per liter.

| *Crop* | *Area (Ha)* |
|---|---|
| Tomato S.S | 180 |
| Tomato P.C. | 450 |
| Carrot | 880 |
| Potato | 680 |
| Turnip | 530 |
| Squash & Zucchini | 450 |
| Tomato | 130 |
| **Total** | **3300** |

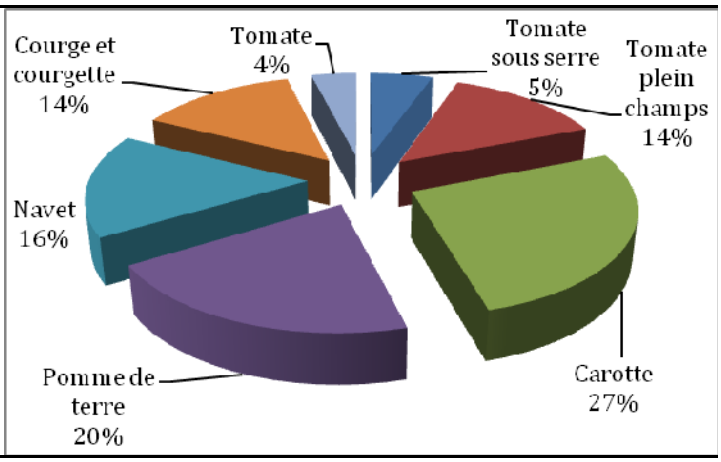



**Figure 11: Land Use - Area irrigated by private pumping (1993-2002 average)**

***The rain fed area*** is dominated by cereals (Figure 12), which occupy more than half the acreage, followed by fallow.

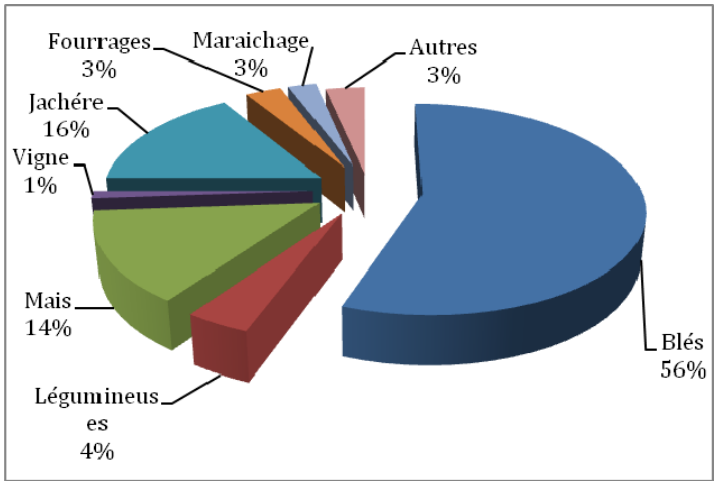



**Figure 12: Land occupation - Rain fed Area (1993-2002 average)**

| *Crop* | *Area (Ha)* |
|---|---|
| Wheat | 182 700 |
| Vegetables | 13 400 |
| Corn | 46 300 |
| Wine Growing | 3600 |
| Fallow | 53 000 |
| Fodder | 10 200 |
| Market Gardening | 7900 |
| Others | 11 000 |
| **Total** | **328 100** |

### Drinking Water

According to PDAIRE, the annual needs for drinking water in the ABHOER area of intervention was 216 million m³ in 2006 (Table 4). These needs would be of 335 million m³ in 2030. If we add to this the consumption in the cities of Casablanca, Marrakech, Settat and Berrchid, the total need would be 505 Mm³/year by 2030.

Table 4. Drinking water needs (Mm³/year) - ABHOER's area of intervention

| | ***2006*** | ***2030*** |
|---|---|---|
| Urban | 84 | 109 |
| Rural | 34 | 91 |
| Isolated industries | 96 | 117 |
| Tourism projects | 0 | 19 |
| **Total** | **216** | **335** |

### Hydropower

There are currently 14 hydropower plants in ABHOER's area of intervention (Table 5). Hydroelectric production of these plants is important nation-wide as it contributes about 70% of the total national production. Figure 13 shows the development of hydroelectric production between 1980 and 2005. The average production is about 1,680 million KWH / year. It was 1887 in 2007 (Table 5).

Table 5. Hydroelectric production in the Oum Er Rbia in 2007 (PDAIRE, 2008)

| ***Plant*** | ***Date of commissioning*** | ***Average production (GWH)*** |
|---|---|---|
| Bin El Ouidane | 1953-54 | 265 |
| Afourer | 1955 | 525 |
| Moulay Youssef | 1974 | 60 |
| Hassan 1er | 1991 | 116 |
| Al Massira | 1980 | 330 |
| Imfout | 1947-49 | 150 |
| Daourat | 1950 | 90 |
| Sidi Saïd Maachou | 1929 | 70 |
| Kasba Zidania | 1935-36 | 19 |
| Ahmed El Hansali | 2003 | 230 |
| Aït Messaoud | 2003 | 34 |
| **Total** | | **1887** |

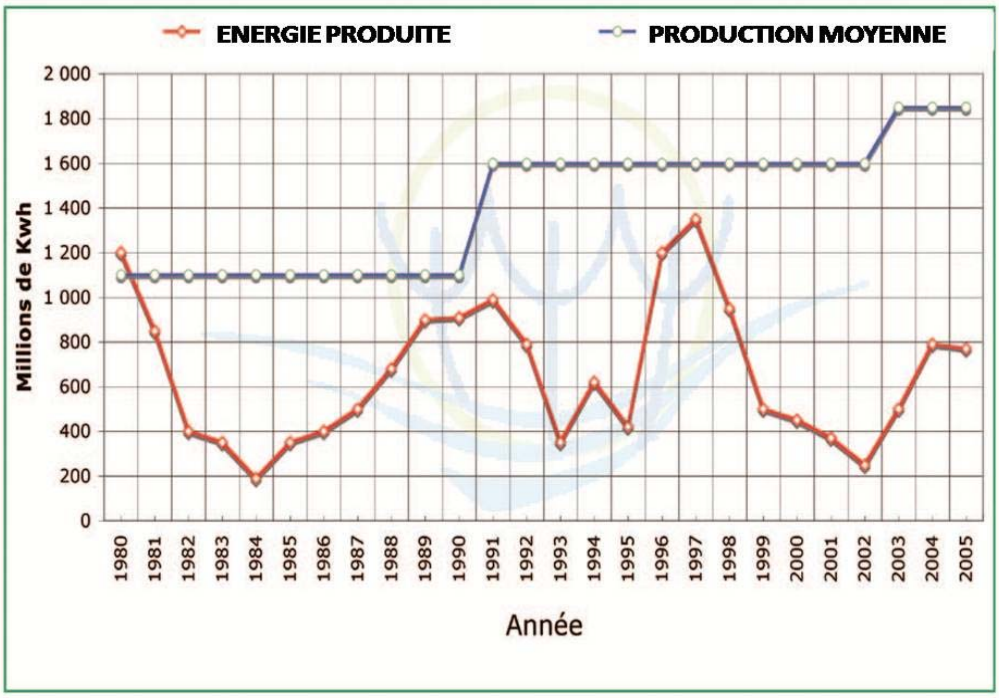



**Figure 13: Evolution of hydroelectric production in ABHOER's area of intervention**

### II.1.5 FLOODS, DROUGHT AND EROSION

**Floods**

According to the Master Plan for Protection against Floods (PDPI) and the provincial Prevention of flood risk, there are 100 "dark spots" in 71 urban centers in the ABHOER's area of intervention (Table 6).

Table 6. Number of sites with a flood risk in the ABHOER's area of intervention

| ***Province*** | ***Number of sites*** |
|---|---:|
| Béni Mellal | 43 |
| Azilal | 27 |
| Khénifra | 11 |
| Khouribga | 5 |
| Safi | 6 |
| Kelâat Sraghna | 5 |
| El Jadida | 6 |
| Settat | 1 |
| **Total** | **100** |

In all of these sites, flooding problems are due to a combination of some or all of the following:

- Morphology of the river bed (oued or châabat)
- Undersizing of some of the structures

- Expansion of the housing built in flood areas
  - Solid waste problem (waste discharge into waterways)
  - Failures and lack of sewerage network, thus increasing flooding

**Droughts**

Over the past three decades, droughts with severe intensity and duration have marked all of Morocco—especially the Oum Er-Rbia watershed. These droughts have seriously the agricultural sector, water supply and hydropower generation.

Figure 14 shows changes in rainfall between 1934-34 and 2002-03 for the Beni Mellal station. Upon examination, this graph shows a sawtooth evolution with amplitudes varying between 300 and 900 mm for the period prior to the year 66-67. The method of the moving average over 5 years was used to reduce the random component and identify trends where they exist. This figure clearly shows the existence of a clear downward trend, especially since the year 66-67.

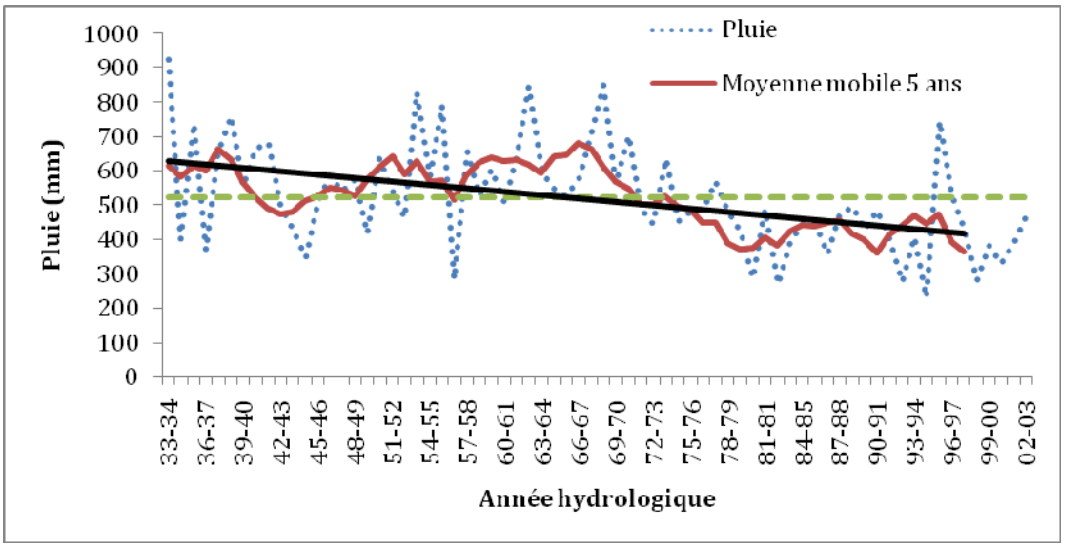



**Figure 14: Changes in rainfall - Beni Mellal Station**

According to the PDAIRE briefing note on all of the Oum Er-Rbia's sub-watershed, average intakes calculated on the last 26 years are much lower than the 1941-1980 period (Table 7). Indeed, for the entire Oum Er-Rbia watershed, annual average intakes of about 2314 million m³ for the 1981-2006 period, whereas it was at 3245 Mm³; an average decrease of 40 %

Table 7. Intermediate inputs of the Oum Er Rbia watershed

| ***Watershed / Dam*** | ***Volume (Mm³)*** | |
|---|---|---|
| | ***1941-1980*** | ***1981-2006*** |
| Hassan 1er Dam | 314 | 168 |
| Moulay Youssef Dam | 311 | 206 |
| Bin El Ouidane Dam | 1 229 | 632 |
| Ahmed El Hansali Dam | 996 | 544 |
| Taghzirt Station | 76 | 52 |
| Kasbat Tadla Dam | 259 | 205 |
| Sidi Driss Dam | 138 | 112 |
| Watershed between Kasba Tadla and Mechra Eddahk | 115 | 63 |
| Watershed between Mechra Eddahk and Ouaouirhint (including O, Abid) | 300 | 119 |
| Watershed between Ouaouirhint and El Massira (including O, Tessaout) | 51 | 151 |
| Watershed downstream El Massira | 63 | 63 |
| **Total** | **3 851** | **2 314** |

In terms of groundwater, the impacts of drought result in a very sharp water level decrease at the deep groundwater level ,where it shows an average decrease of 1 meter per year. To this, we must add the drying up of sources, like Ain Asserdoun, that reached throughput levels in the last years not witnessed since 1912.

### Erosion and siltation of dams

Table 8 presents the specific degradation rate (T/km² /year) for major watersheds that are part of the ABHOER's area of intervention. This table shows that the average specific degradation varies between 315 and over 2,000 t/km²/yr, with an average of 1075 T/km²/yr.

Table 8. Zone-specific degradation of ABHOER's area of intervention (CSE, 1991)

| ***Watershed*** | ***Area (Km²)*** | ***Average specific degradation (T/km²/yr)*** |
|---|---|---|
| Laabid | 1670 | 675 |
| Tessaout | 1441 | 916 |
| O. Er - Rbia | 6400 | 315 |
| Lakhdar | 28500 | 2 395 |
| Average | | 1 075 |

Furthermore, the Watershed Development Plan (PNABV) identified and classified across Morocco 22 priority watersheds upstream of the dams. Among these are four watersheds upstream of major dams of the ABHOER's zone of intervention (Table 9). This table shows that over 65% of the area of these watersheds is threatened by erosion.

In ABHOER's zone of intervention, the annual rate of silting the unusable storage is 3.2 Mm³ /year for the Bine El Ouidane dam, 1.1 Mm³/year for the Moulay Youssef Dam and 3.3 Mm ³/year for the Hassan I dam on the Lakhdar river (Table 10). Siltation leads to lower water availability for irrigation, drinking water supply and power generation.

Table 9. Risk of water erosion in priority watersheds in ABHOER's zone of intervention (MAMVA, 1995)

| ***Priority*** | ***Watershed / Dam*** | ***Watershed's surface (Km²)*** | ***Area at risk*** | |
|---|---|---|---|---|
| | | | ***(%)*** | ***(Km²)*** |
| 5 | Hassan I | 1 670 | 71 | 1 186 |
| 4 | Moulay Youssef | 1 441 | 75 | 1 081 |
| 9 | B. El Ouidane | 6 400 | 83 | 5 312 |
| 17 | Al Massira | 28 500 | 66 | 18 810 |
| **Total** | | **153 485** | | **112.349** |

Table 10. Dam siltation – Oum Er-Rbia watershed

| ***Dam*** | ***Area (Km²)*** | ***Capacity (Mm³)*** | ***Average siltation*** | | ***Area at risk*** | |
|---|---|---|---|---|---|---|
| | | | ***(Mm³)*** | ***Mm³/year*** | ***(%)*** | ***(Km²)*** |
| B. El Ouidane | 6 400 | 1 500 | 100 | 3.2 | 83 | 5 312 |
| My Youssef | 1 441 | 191 | 24 | 1.1 | 75 | |
| Sidi Driss | 2 930 | 9 | 5.5 | 1.1 | | 1 081 |
| El Massira | 28 500 | 2 720 | 83 | 7.5 | 66 | 18 810 |
| **Total** | | **4 418** | **205** | | | **25.203** |

# III MOULOUYA WATERSHED AGENCY

## LOCATION

The Moulouya watershed extends from the area where the Ziz and Oum Er-Rbia waters separate, to the Mediterranean (Figure 15). It is located between latitudes 32 ° 18 'and 35 ° 8' north and longitudes 11 ° 1 'and 5 ° 37' West. It is bordered by the northwest Coastal Mediterranean watershed, to the west by the watershed of the Sebou river, southwest by the watershed of Oued Oum Er-Rbia, south by the Oued Ziz watershed, southeast by the watershed of the Guir river and east by the Algerian territory. The watershed covers an area of 74,000 km². The main tributary of the Moulouya River is the Za oued.

## CLIMATE

Climate varies greatly across the vast extent of the Moulouya watershed. However, there are two distinct climatic zones:

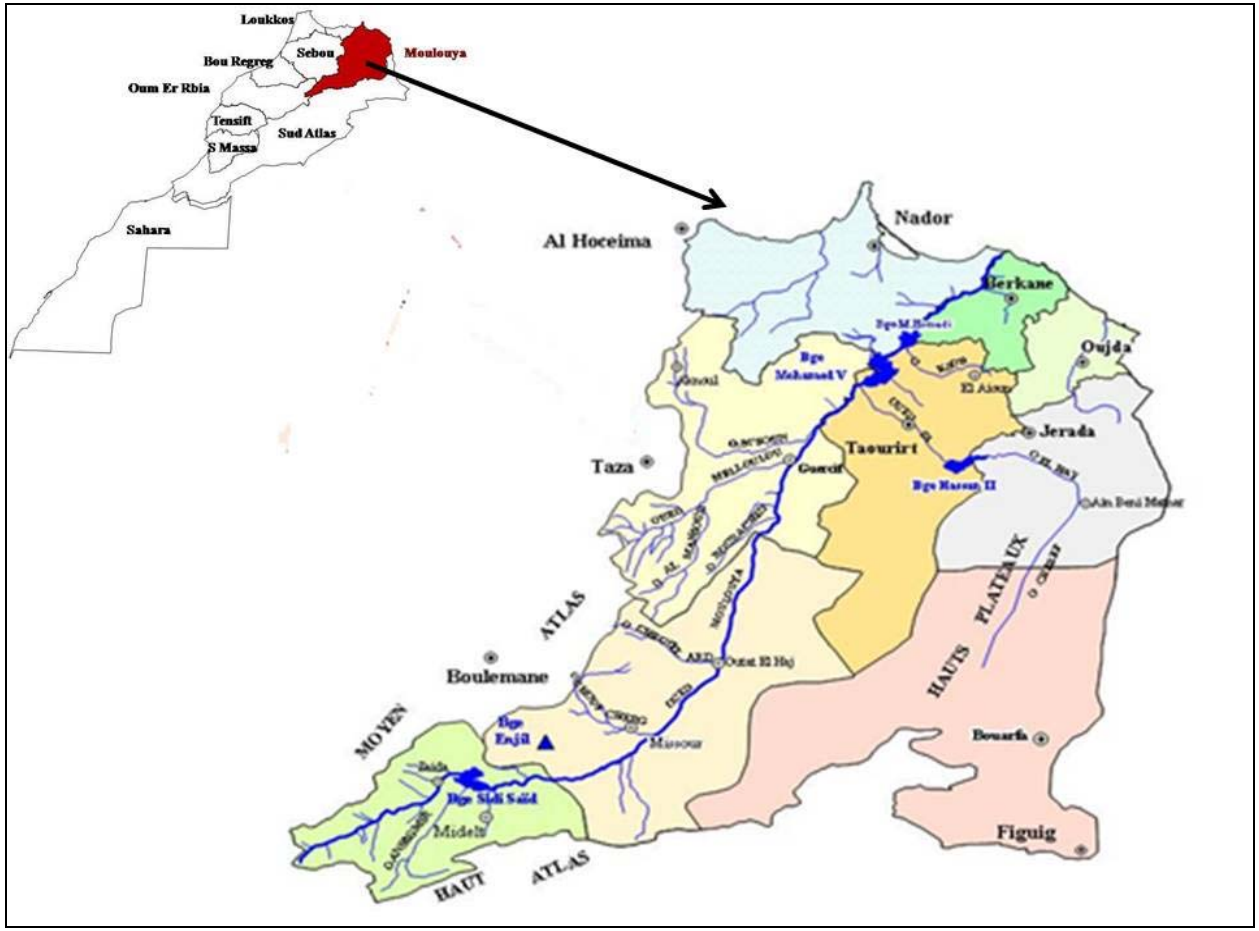



**Figure 15: ABHM's location and area of intervention**

- A semi arid climate with two seasons: a mild winter with little rain from October to May and a hot dry summer from June to September. This area is located north of the watershed along the Mediterranean coastline.
- The rest of the watershed where the climate is arid with low rainfall and a dry period that lasts almost all year long. Winters are often harsh, long, cold, while summers are very hot. The climate of this area depends heavily on the presence of mountain barriers of the Middle Atlas, the Rif and the chains of Beni Snassen and Beni Bouayach, reducing the Ocean's influence.

The average annual rainfall can exceed 600 mm in the mountains but still less than 350 mm across the plains. The average interannual water level of Moulouya watershed is about 245 mm, with a minimum of 110 mm (average for Moulouya Guercif and Figuig) and a maximum of 515 mm (Beni Snassen chains, and High and Middle Atlas).
The maximum average monthly temperatures range from 18 ° C and 29°C. While the minimum average monthly temperatures sometimes reach 2°C. Average annual temperatures vary between 9.3°C (Boulmane) and 19°C (Guercif).

## MOULOUYA WATERSHED SPECIFICITIES

Morphological, climatic and socio-economic diversity of the watershed can be broken down into three main areas: (Figure 16):

- Zone 1: coastal Mediterranean/ Rif up to 4% of surface
- Zone 2: converted into a great hydropower station (11%)
- Zone 3: Medium / High Moulouya / highlands with severe aridity and limited resource (85%)

Improvements must be made to this watershed with the following production systems:

- A modern, intensive system meeting the production needs of the great hydropower station,
- Traditional intensive system characterized by low water availability mainly localized in the oases,
- A mixed system (bour - irrigated) with diversified production,
- A cereal production system in bour, and
- A production system in pastoral or intensive sheep farming predominates.

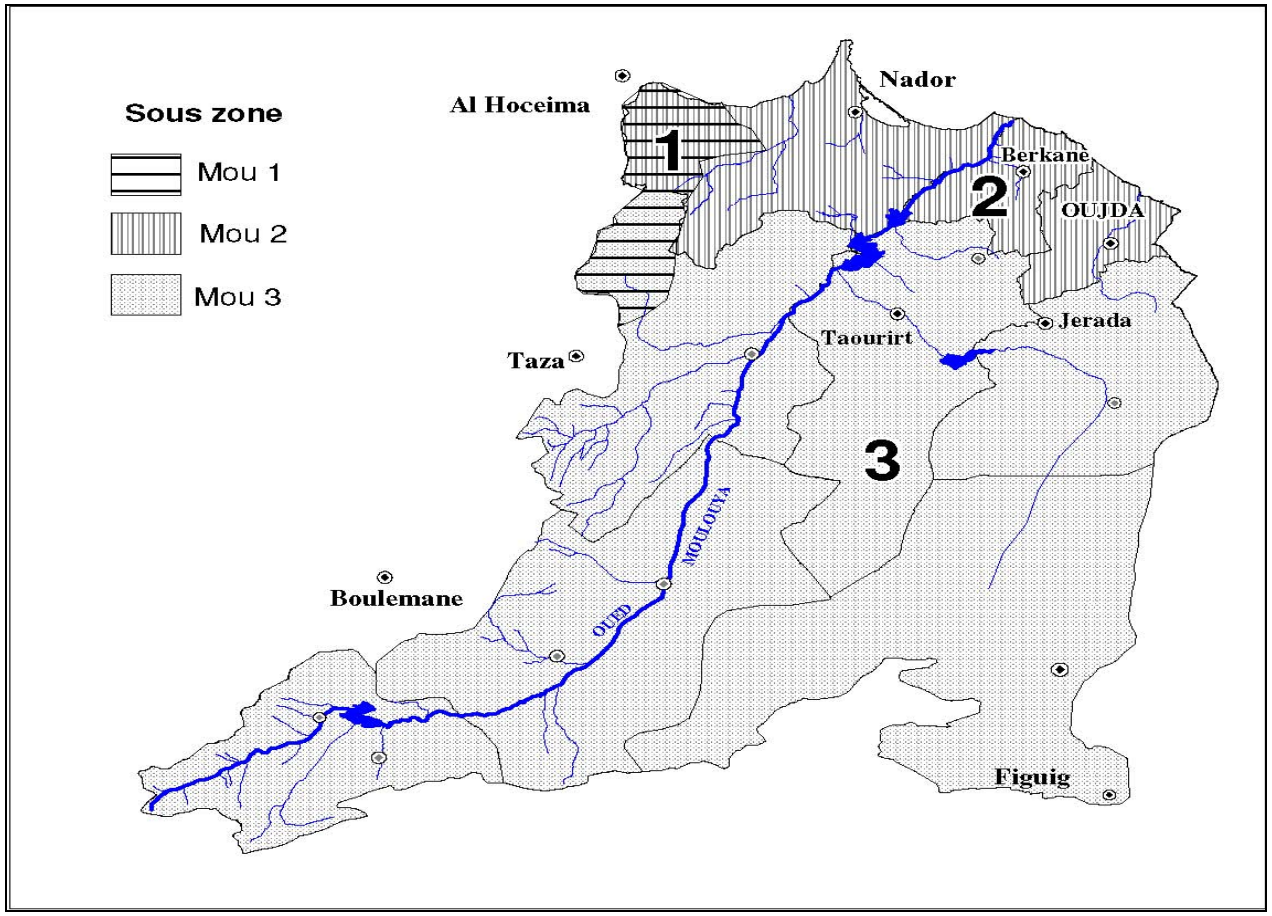



**Figure 16: Main areas of the Moulouya watershed**

- Two other characteristics of the watershed are important: (i) the presence of a Site of Biological Interest (SIBE) at the mouth of the Moulouya, and (ii) the downstream proximity of the Algerian border in terms of resources water.

## ECONOMIC CONTEXT

The Moulouya includes nine provinces with an estimated population of 2.4 million inhabitants, the majority of whom are concentrated north of the Taza - Oujda road.

In the ABHM's area of intervention both irrigated and in bour agriculture are important, especially in the northern watershed, while pastoral practice dominates the South. Mainly due to climatic conditions, forestry remains a fairly marginal economic activity.

The agricultural potential amounts to 148,400 ha, of which 65,400 ha and 83,000 ha in GH in PMH (permanent and seasonal) are largely located along the Moulouya oued, the Za oued, the Isly oued and the Kert oued.

Crop production is diverse but is dominated by cereal production at the watershed level. Fruit trees, industrial crops (Northern Plains), and vegetable crops occupy a predominant place in the region's economy. At the level of ORMVAM's area of intervention, the 2004/2005 gross annual production for crops amounted to 2115 MDH (Table 11).

Table 11. Gross output in MDH, ORMVAM's area of intervention

| ***Crop production*** | | ***Animal Production*** | |
|---|---|---|---|
| Tree farming | 924.3 | Cattle | 298 |
| Grains | 466.2 | Sheep and goats | 353 |
| Market gardening | 407.42 | Poultry | 124.6 |
| Industrial crops | 94.1 | Beekeeping | 7.6 |
| Fodder | 205.5 | | |
| Other | 17.6 | | |

Regarding livestock, rangelands play an important role in ABHM's area of intervention. The lands bearing a water course are estimated at over 2.7 million hectares. In this area we must add approximately 2.282 million hectares of esparto grassland and 364,000 ha of forest and meadow-forest. Livestock in the ABHM's area of intervention is made up of 84,653 head of cattle, 2,034,424 sheep, 418,406 goats and 1,707 camels, for a total of 2,537,483 heads.

At the level of the ORMVAM's area of intervention (Lower Moulouya), livestock production is valued at 45 million liters of milk, 15,450 tons (live weight) of red meat of which 4,400 tons are controlled and marketed, 90 tons of honey and 6,250 tons of white meat, and 41 million eggs. In 2004-2005, the gross output value of this area was estimated at over 78 million dirhams (Table 11).

Regional traditional fisheries rank first nationally, employing about 4,000 fishermen. The fishery industry has known significant growth from increased production at the port of Beni Ansar, the modernization of the fleet, and enhancement of fish production, including via a processing plant in the province of Nador).

The watershed has major agro-food, industrial and mining activities including a sugar mill, a smelter, a power plant, a steel complex, and a cement mill.

Additionally, the seaside tourist industry is booming. Some projects are already underway in Saidia. The increased pressure of seaside tourism in the region is already constrained regarding the management of water resources to meet the demand for water, sanitation and irrigation.

## HYDROCLIMATIC EQUIPMENT FOR THE MOULOUYA WATERSHED

The Moulouya Watershed Agency has access to a network of watershed-level water resource measurement and evaluation equipment:

- 25 hydrological stations,
- 29 rainfall stations,
- 11 Pluviographic stations,
- 18 climate stations,
- 11 water-gauging stations,
- 22 flood-gauging stations
- 72 periodic gauging points with 1050 gaugings carried out annually, and
- 153 piezometric watertable monitoring points

The agency also has a flood warning system consisting of two main phone stations, one in Oujda and the second in Guercif, as well as 19 primary substations including 8 radio / phone and 11 radio.
In terms of hydroclimatic equipment, the ORMVAM comprises two fully fledged climatic stations (type 'CAMPBELL SCIENTIFIC'): the Boughriba station 20km from the Berkane province and Zebra station in Zaio. Both stations are automatic and feature:

- Thirteen Sensors: temperature, relative humidity, net radiation, rainfall, wind speed, wind direction, soil temperature, psychrometer, and sunshine duration,
- Data Acquisition: "module CR10 X" with terminals (battery and memory 62000 data entries), a 4-inputs multiplexer (32 inputs), a cable box,
- Power (and battery) for the Boughriba station and solar energy for the Zebra Station,
- Startup software on Windows and PC Windows version 2008,
- Data Transfer: short distance transfer modem with surge protection,
- Microcomputer liaising with the station by electrical wiring 300 m from the station to transfer and store data.

## WATER RESOURCES

### III.1.1 SURFACE WATER

Oued Moulouya is the watershed's main watercourse. With a length of 600 km, it arises at the level of the High and Middle Atlas Mountains chain and the Highlands. The Moulouya's major perennial tributaries are Oued Ansegmir, Oued Melloulou, and Oued Za. Surface water contributions are limited and irregular. Like rainfall, the flows of the oueds have strong inter-annual variability; Moulouya water inputs vary in a ratio of 1 to 7. The mean annual input at the level of the Moulouya watershed has been decreasing since the 70s, as demonstrated by the 1611 million $m^3$ for the 1940-2002 period and 1444 $Mm^3$ for the 1970-2002 period (Table 12).

Table 12. Average inputs (in Mm³) Moulouya watershed;

| ***Watershed*** | ***Area (Km²)*** | ***inputs (1940-2002)*** | ***inputs (1970-2002)*** |
|---|---|---|---|
| Moulouya | 50.574 | 1 422 | 1 273 |
| Kert | 4 387 | 42 | 38 |
| Kiss - Issly | 3 617 | 27 | 24 |
| Figuig-Bouarfa | 16- 130 | 122 | 111 |
| **Total** | **74.708** | **1 611** | **1444** |

Figure 17 shows the evolution of average annual inputs at the Mohamed V Dam for the 1994/1996 - 2005/2006 period. These inputs range from 170 to 1569 mm³ with an average of 583 million m³, compared to the average over 50 years, which is almost double (810 Mm³).

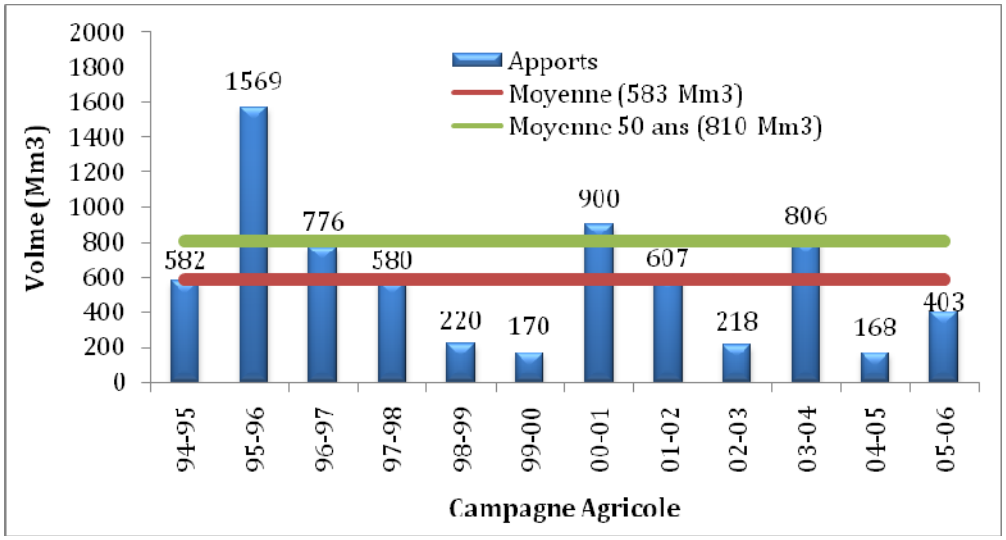



**Figure 17: Evolution of the inputs, Mohamed V Dam**

Water infrastructure built at the Agency's area of intervention currently accounts for five dams (Table 13) whose total capacity is 990 million m³, of which over 70% is regulated, and 40 hillside dams with a total storage capacity of 22 Mm³. To this is added two main bypass channels of 288 km, the left bank canal (17 m³/s) and the right bank canal (18 m³/s) and the Moulay Ali pumping station, commissioned in 1995 and sized for a 3.9 m³/s flow.

Table 13. Existing dams (Source: Moulouya's Watershed Agency)

| ***Dam*** | ***Commissioning*** | ***Use*** | ***Capacity (in million m³)*** |
|---|---|---|---|
| Mohamed V | 1967 | | 331 |
| Mechra - Homadi | 1956 | | 9 |
| Hassan II | 1999 | Irrigation, AEPI | 109 to 270 |
| Sidi Said | after Fall of 2005 | Irrigation, AEPI | 400 |
| Enjil | 1995 | Irrigation | 12 |
| **Total** | | | **990** |

### III.1.2 GROUNDWATER

According to the ABHM, the Moulouya river watershed accounts for thirty water tables whose size depend on the geological and lithological structure and rainfall. The characteristics of some water tables are listed in Table 14. The current state of knowledge helps us estimate the overall volume of groundwater recharge at 635 million $m^3$, of which only 60% is used (380 $Mm^3$).

Since the drought of the 1980's these water tables have been increasingly stressed with irrigation, drinking water and industrial needs. Therefore, most of the water levels show an annual decline in water levels, reaching 3 m/year in the case of the Jbel Hamra water table.

Table 14. Characteristics of some of water tables in the Moulouya watershed

| ***Water table*** | ***Area ($Km^2$)*** | ***Depth*** **m** | ***Refill rate*** **$m^3/s$** |
|---|---|---|---|
| Jbel Hamra | 16 | 50 to 100 | 9.5 |
| Angad | Outcrop | 20 to 70 | 27 |
| Béni Snassen | 450 | > 40 | 35 |
| Triffa | 550 | 3 to 70 | 75 |
| Bouhouria-Naima | 700 | 10 to 150 | 16 |
| Coulouir Taourirt-Laayoune | 1800 | 80 to 100 | 4 |
| Oued Za underflow | 23 | 10 | 5 |
| Ain Béni Mathar | 6500 | >220 | 40 |
| Horsts mountain chain | 500 | 5 to 250 | 12 |
| Sillon Itzer-Enjil & Haute Moulouya | 3300 | > 100 | 28 |
| Average multilayer system Moulouya | 6500 | > 200 | 70 |
| Guercif watershed | 6200 | 5 to 150 | 33 |
| Gourougou | 200 | 10 to 130 | 3.5 |
| Tlet Azlaf | 60 | 20 | 1 |
| Guerouaou | 275 | | 1 |
| Kert | 250 | 5 to 60 | 12 |
| Gareb-Bouareg | 420 | 20 | 54 |
| Ghis-Nekor | 100 | 2 to 50 | 19 |
| Figuig's superficial groundwater | 300 | 10 to 50 | 4.5 |
| Figuig's deep groundwater | 500 | 5 to 50 | 9 |
| Chott Tigri Lahouita | 3000 | > 120 | 11 |

It is also noteworthy to mention that, according to statistics provided by the RADEO, there are nearly 2,000 villas wells in the city of Oujda of which at least 270 have direct incidence on the collective with high risk of water contamination.

### III.1.3 WATER QUALITY

**Pollution sources**

The development of urban and industrial activities which generate wastewater and solid waste, and the intensive use of fertilizers and pesticides in agriculture in the Moulouya watershed have inevitably led to deterioration in water resource quality.

The list of pollutants produced by the ABHM shows that domestic waste is the main source of water resource pollution at 25 $Mm^3$/year, to reach 60 $Mm^3$/year by 2020. In most cases disposal is done in the natural environment, potentially directly into the oueds (80%). The global flow of pollution

carried by domestic sewage is 1760 tons of BOD5, including 33% rejected by the province of Oujda, 27% by the province of Nador and 14% by the province of Berkane.

To this, we must add the pollution caused by the many oil mills and traditional triturations packaging units in the Moulouya, especially in Taourirt and Guercif.

**Water quality**

The water quality of Moulouya is good overall, with the exception of the following areas:

- Oued Isly because of urban waste in the city of Oujda.
- Downstream of Moulouya from slight organic pollution and strong mineralization.
- Oued Cheraâ, downstream of the town of Berkane, where the organic and bacteriological quality is very bad.
- Oued Moulouya, downstream of Missour, because of wastewater discharges from this city.
- Oued Outat, downstream of the city of Midelt, because of wastewater discharges from this city.
- Oued Selouane, downstream of the center of Selouane, has very poor organic quality with a high degree of mineralization.

Regarding groundwater, the water quality in certain areas is a handicap to the development of water resources due to:

- The high salinity in the cases of the Gareb Bouareg, Triffa, and Guercif water tables;
- The high concentration of nitrates due to herbicides and pesticides misuse in the case of the Triffa watertable; and
- The high concentration of nitrates due to the spreading of sewage water in the case of the Angad water table in the North East of Oujda.

### III.1.4 USE OF WATER RESOURCES

The volume of water used in the Moulouya watershed amounts to 886 million m[15] shared between (Table 3, Figure 18):

- 506 million m³ of surface water used at a rate of 86% for irrigation and 14% for the AEPI.
- 380 million m³ of ground water used at a rate of 75% for irrigation and 25% for the AEPI.

Table 15. Water use in the ABHM's area of intervention

| | ***Water table*** | | ***Surface water*** | | ***Total*** | |
|---|---|---|---|---|---|---|
| | ***Mm³*** | ***%*** | ***Mm³*** | ***%*** | ***Mm³*** | ***%*** |
| Irrigation | 285 | 75 | 435 | 86 | 720 | 81 |
| AEPI | 95 | 27 | 71 | 16 | 166 | 20 |
| **Total** | **380** | **100** | **506** | **100** | **886** | **100** |

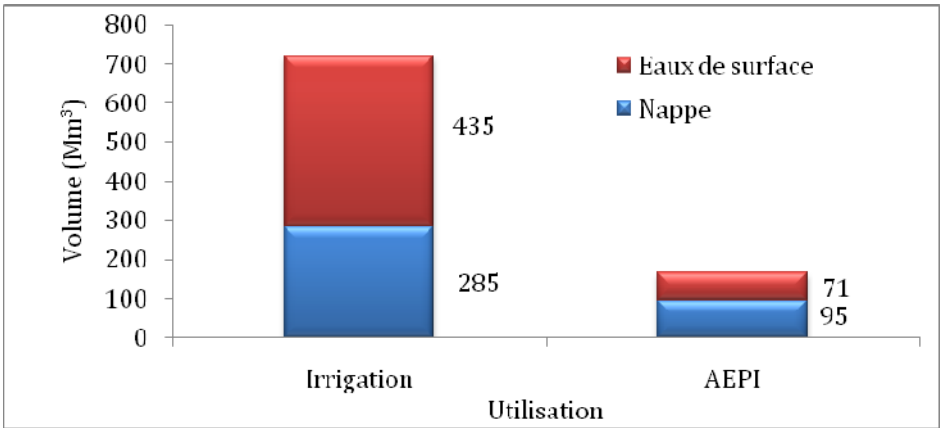



**Figure 18: Water use in AHBM's area of intervention**

**Irrigation**

One of the most important partners of the agency in terms of water use is the ORMVAM. ORMVAM's area of intervention is north of the Moulouya watershed between the Mediterranean and the highlands (Figure 19). It covers 26 rural towns including 7 in the province of Berkane, 15 in the province of Nador, and 4 in Taourirt. The total population target in ORMVAM's area of intervention is 714,515 inhabitants of which almost 52% are rural, there are 34,383 farmers (Table 16).

Table 16. Population targeted by ORMVAM's area of intervention (Census 2004)

| *Province* | *Urban* | *Rural* | *Total* | *Farmers* |
|---|---|---|---|---|
| Berkane | 156,145 | 118 895 | 275,040 | 16,400 |
| Nador | 192,079 | 212,385 | 404,464 | 13,200 |
| Taourirt | - | 35,011 | 35,011 | 4783 |
| **Total** | **348,224** | **366,291** | **714,515** | **34,383** |

ORMVAM's total area of intervention is 572,700 ha (Figure 20). The GH represents 11%, watercourses 47%, PMH2 2%, forests 10%, bour 15%, and wastelands 15%.

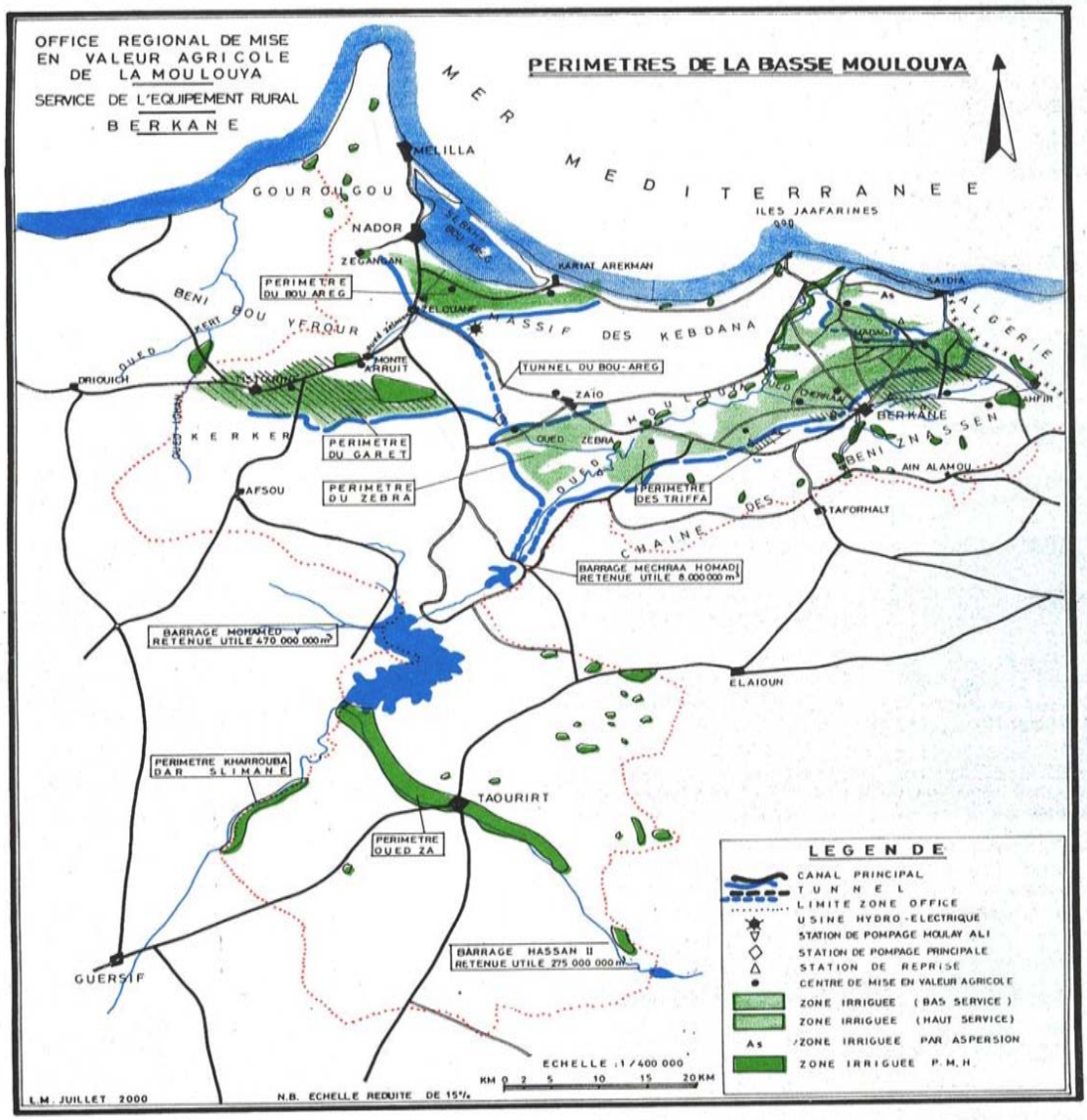
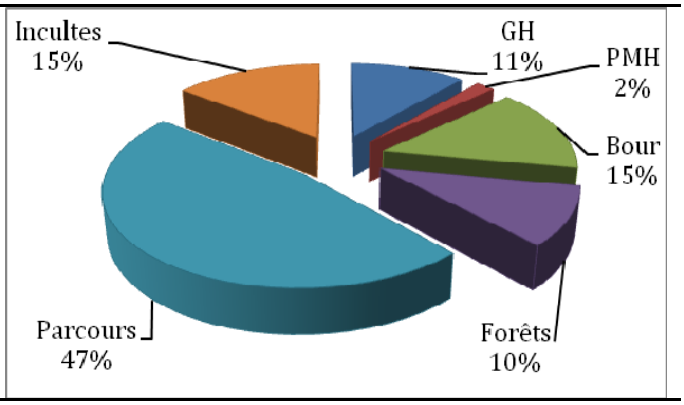



**Figure 19: ORMVAM's area of intervention**

In the ORMVAM's area of intervention, irrigated areas total 73,874 ha (Figures 21 and 22), including 58,343 ha in great hydropower station and 15,531 ha in small and medium hydropower stations. To this is added 66,000 ha of irrigated land in PMH, located outside the Agency's area of intervention in the form **of small perimeters and which fall within the DPAs.**

**Figure 20: Land use in the ORMVAM's area of intervention**

| *Use* | *ha* | *%* |
|---|---|---|
| GH | 65,400 | 11 |
| PMH | 10 700 | 2 |
| Bour | 83 900 | 16 |
| Forests | 57754 | 10 |
| Watercourse | 271,318 | 47 |
| Uncultivated | 83 628 | 16 |
| **Total** | **572 700** | **100** |




Irrigated agriculture is driven mainly by the three dams—Mohamed V, Mechra Homadi, Hassan II—for the lower Moulouya, as well as by springs and water table pumping (various sizes).

For the irrigated perimeters in GH, the average volume supplied is estimated at 232 million m³ of which 215 million m³ comes from the Mohamed V dam and 16 million m³ from the Moulay Ali station. The evolution in supply during the last 12 years is shown in Figure 23.

| *Culture* | *Ha* |
|---|---|
| Cereals | 2665 |
| Industrial cereals | 78 |
| Fodder | 2243 |
| Tree farming | 4755 |
| Market Gardening | 1938 |
| Other crops | 33 |
| **Total** | **11711** |

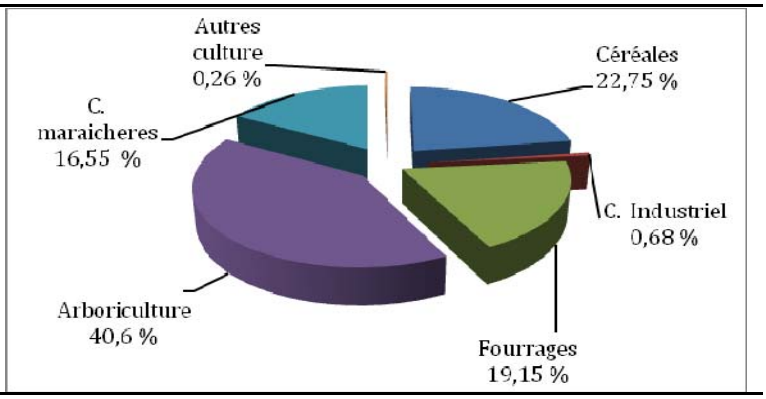



**Figure 21: Land occupation in the PMH-ORMVAM (Average for the period: 1994/1995-2006/2007)**

| *Culture* | *ha* |
|---|---|
| Cereals | 16 to 093 |
| Industrial cereals | 4812 |
| Fodder | 4236 |
| Tree farming | 21 810 |
| Market gardening | 9510 |
| Other crops | 356 |
| **Total** | **56 817** |

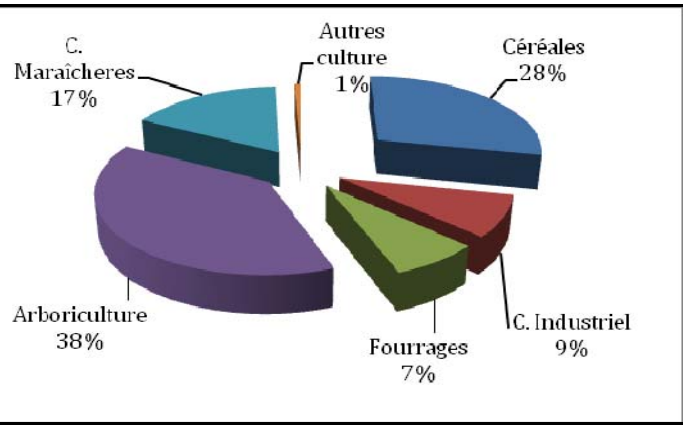



**Figure 22: Land occupation in the GH-ORMVAM (Average for the period: 1994/1995-2006/2007)**

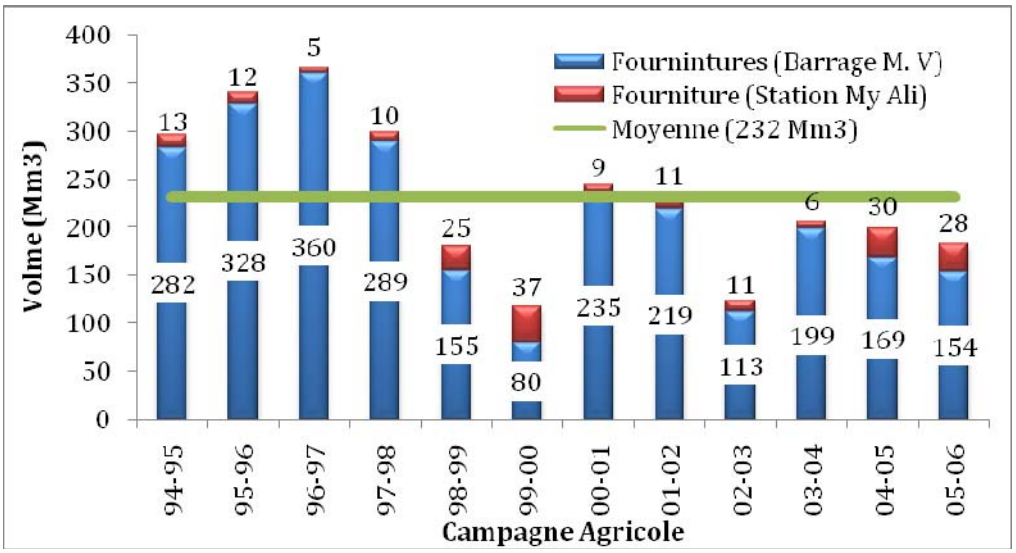



Figure 23. Evolution of the supplies (Irrigation), Mohamed V Dam

At the lower Moulouya, the surface irrigation technique is used on 74.5% of the irrigated area (Figure 24). Other methods of irrigation are sprinkling, drip irrigation (or micro irrigation) that covers respectively 21.5%, 6% and 0.5% of the irrigated area.

For surface irrigation, the overall efficiency of the network is estimated at 75% in the lower Moulouya and at 40-50% in the small perimeters' seguias of small and medium hydropower stations. The water at these seguias is not lost—it reappears in part at the Oued that acts like a drain, and therefore supplies other irrigations further downstream.

Crops grown in the perimeter of the great hydropower station include citrus fruits, grains, vegetables, industrial crops and fodder. There is a dominance of tree culture and cereals accounting for more than 80% of the cultivated area (Figure 22).

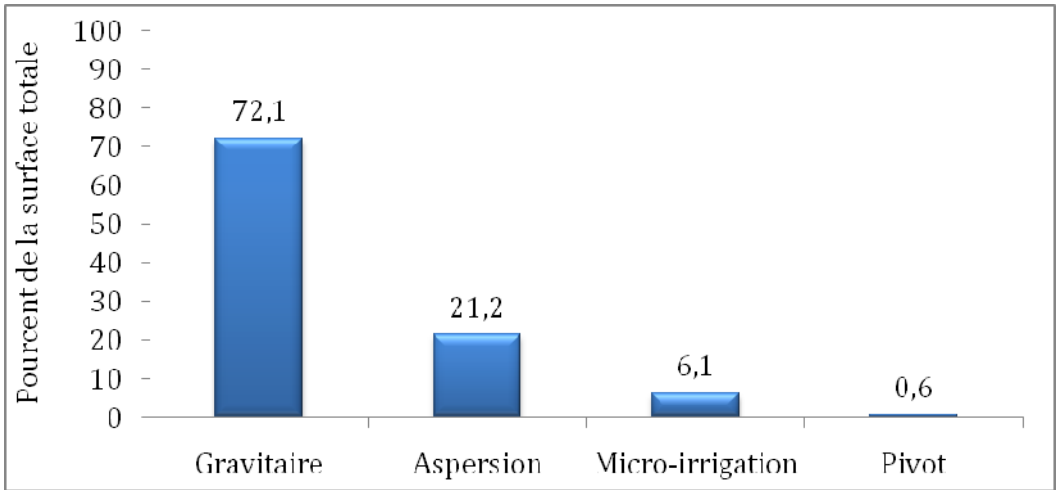



**Figure 24: Method of irrigation, ORMVAM**

**Drinking Water**

Urban areas such as Berkshire, Zaio, Nador and the neighboring centers, Oujda, Taourirt, and Laayoune are supplied from surface water. The average consumption in the network head is 71 million m³. The AEPI in other towns and centers is achieved through ground water whose annual samplings are estimated at 95 Mm³/year (see Table 5).

**Hydropower**

The installed capacity is 29 MW, with an average production of 50 GWh per year of hydroelectric power.

# FLOOD, DROUGHT AND EROSION IN THE MOULOUYA WATERSHED

## III.1.5 FLOODS

In the Moulouya watershed rainfall is rare, though the rains in April-May and October-November may be unusually strong and generalized to the entire watershed. When these exceptional rainfall episodes occur, they may exceed 200 mm in one day. These include the great floods of May 1963, April 1975. November 1993, November 2003 and September 2006. These floods whose flow can exceed 7000 m3/s not only cause a significant change in the morphology of the lower Moulouya but also significant damage. A national-level flood study helped to identify 391 sensible sites including 40 in the area of the Moulouya Agency.

The bedding of the city of Oujda, set on the natural water course, greatly increases the risk of urban floods. Arrangements are being made by the RADEO, in conjunction with the ABHM, to divert storm water by building retention ponds and a gallery.

## III.1.6 DROUGHTS

Droughts of severe intensity and duration have occurred throughout Morocco over the past two decades. In the Moulouya watershed, the drought sequences, which are on an average 2 to 5 years, have seriously affected agriculture, livestock, the drinking water supply, and hydropower.

### III.1.7 DAM EROSION AND SILTATION

The Mechra Homadi and Mohamed V dams were identified by the Ministry of Public Works (1996) as critical in volume silted for the former and in lifespan for the latter.

The volume of the Mechra Homadi dam went from 42 $Mm^3$ initially to only 7 $Mm^3$. It was already in 1995 at the center of a desilting project aimed at recovering some 3 million $m^3$ in volume lost.

The rapid siltation of the Mohamed V reservoir is another worrying phenomenon. The volume of the tank was 726 $Mm^3$ originally, but is now only approximately 331 million $m^3$, a loss of nearly 46% of the dam's initial capacity (Figure 25). Based on the estimates of the National Watershed Management Plan (1994), the capacity of the reservoir could be reduced to 0 by 2020, and the reservoir completely filled by 2030, only 64 years after its commissioning.

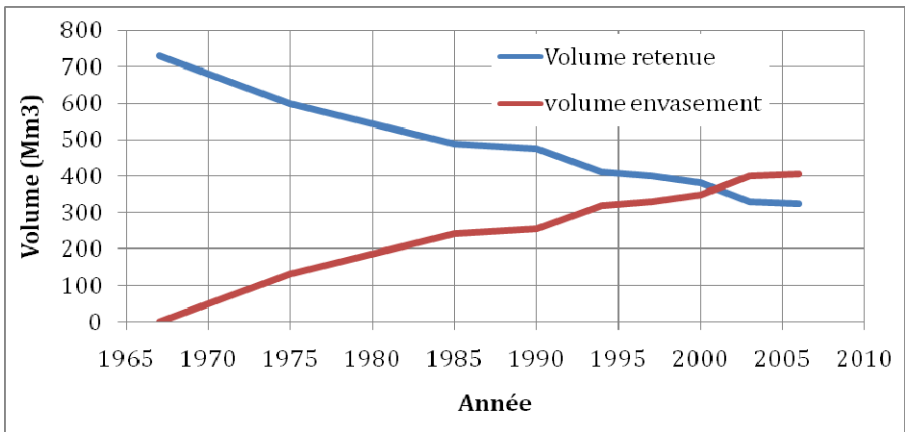



**Figure 25: Changes in reservoir volume and siltation, Mohamed V Dam (Source, ORMVAM)**

Specific degradation at the watershed is estimated at about 240 $t/km^2/year$ based on sediment yield and 330 $t/km^2/year$ from dam siltation. The extent of erosion is directly linked both to the geological nature and morphology of the land and also to the rapid degradation of vegetation cover—particularly the decline in esparto grassland. Erosion zones cover about one-fifth of the watershed.

# IV PROJECTS, PARTNERSHIPS AND STAKEHOLDERS

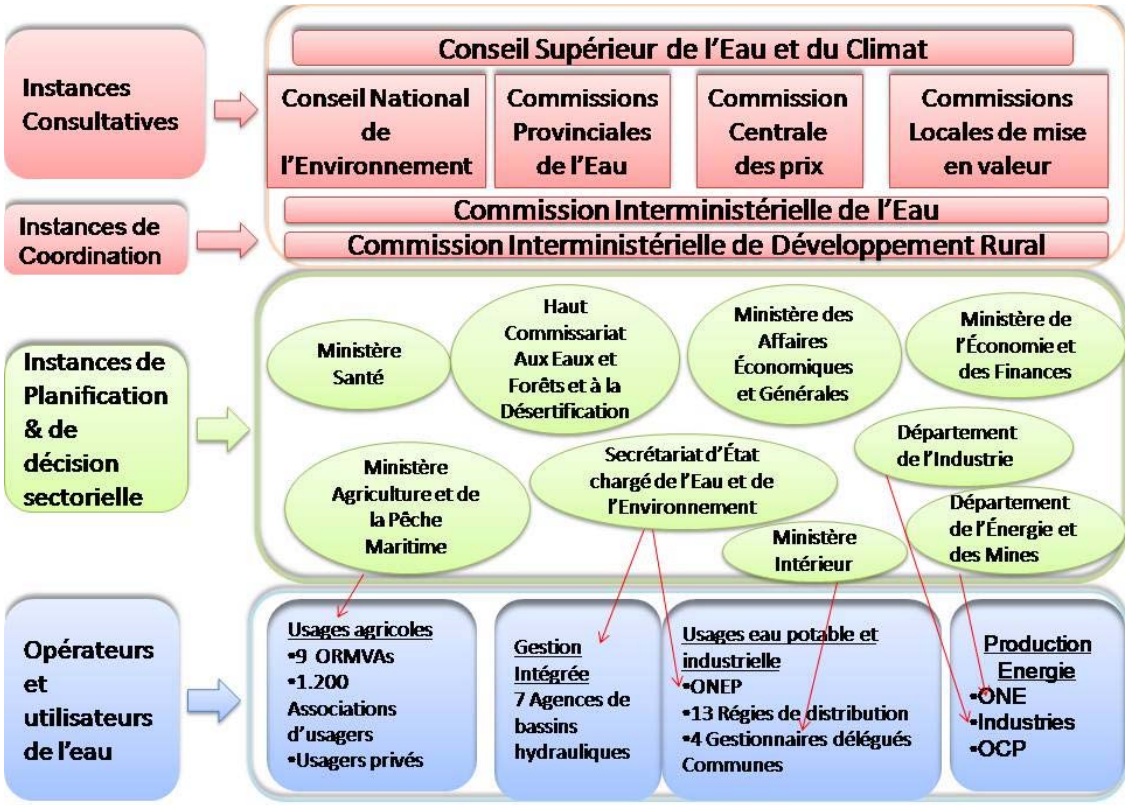
## STAKEHOLDERS

### IV.1.1 NATIONAL LEVEL STAKEHOLDERS

Nationwide, several institutions are involved in the water sector (Figure 26):

- The Consultative Bodies
- National Environment Council
- Provincial Water Commissions
- Commission Centrale des Prix
- Commission Locales de Mise en Valeur
- Coordinating Bodies
- Interministerial Commission for Water
- Interministerial Commission of Rural Development
- The Management and Planning Bodies
- Secretary of State in Charge of Water and Environment
- Ministry of Agriculture and Maritime Fishing
- High Commission for Water, Forests and Desertification
- Department of Energy and Mines
- Department of Economic and General Affairs
- Ministries of Economy and Finance
- Department of Industry
- Ministry of the Interior
- Ministry of Health
- Operators and Water Users
- Watershed Agencies
- ORMVAs
- Water Users Associations
- Private Users
- ONEP
- Régies de Distribution
- Gestionnaires Délégués des Communes
- ONE
- Industries
- OCP

**Figure 26: Institutions involved in the water sector in Morocco (Belghiti, 2008)**




### IV.1.2 LOCAL STAKEHOLDERS INVOLVED IN AGRICULTURAL WATER MANAGEMENT

**Watershed Agencies**

The watershed agency is the forum for regional consultation where stakeholders make collective decisions relating to water management. These agencies are established by decree (Decree 2-96-536 of 20 November 1996 for ABHOER and Decree 2-00-475 of 14 November 2000 for the ABHM).

The watershed agency is a public institution with legal status and financial autonomy. It plays a unifying role among all local stakeholders in the water sector within its area of intervention.

Its primary mission is to assess, plan, develop and manage water resources in the watershed, to ensure the preservation of public water resources and to anticipate risks to cope with exceptional events (water shortages, floods). It is also responsible for the protection of deep reserves and for maintaining a safety limit in the watersheds.

**Regional Offices for Agricultural Development (ORMVAS)**

The Office of Regional Agricultural Development Doukkala (ORMVAD for Doukkala, ORMVAM for Moulouya) is a public institution which manages irrigation systems. This office represents the institutional actor in charge of implementing state policy in agricultural development throughout the

irrigated perimeters. It is responsible for the development of agricultural land including irrigated hydro-agricultural land and land developments in bour, management of irrigation and drainage, and agricultural development. It is the delegate of an endowment of water for agricultural use within its area of intervention, which is bound by decree.

These institutions were officially created in 1966, bear legal status and financial autonomy. It is administered by a board of directors and assisted by a technical committee.

**Chamber of Agriculture**

The Chamber of Agriculture represents farmers in the local level interactions with agricultural development institutions. In addition, it is responsible for supporting the popularization of modern agriculture techniques.

The missions established under the Chamber's decree are important, but the Chamber's scope of intervention is limited. This is mainly due to the low representation of interests of various stakeholders involved in the agricultural sector, limited and poorly-skilled human resources, and the limited financial resources via state subsidies.

**Agricultural Water Users Association (AWUA)**

To involve water users and empower them in improving the operation and maintenance of networks, the State promulgated Law No. 02-84 on December 21, 1990, establishing the Agricultural Water Users Association (AWUA) and the attached regulations. There are 101 AWUAs and 3 ORMVAM Federations. In the case of the ORMVAD, the number of AUEA is 39.

**Farmers**

Farmers and irrigation water users are also major stakeholders. They are the end users of the irrigation cycle that must engage in responsible water use and to maximize its value. The number of farmers in ORMVAD's area of intervention of exceeds 36,000, whereas in the case of ORMVAM their number is estimated at 34,383.

Water is re-circulated through a water tower. The allocation of water per hectare granted by the Agency meets, in principle, the needs of crops grown and set forth by the Provincial Agricultural Committee under the cultural program at the beginning of the crop year.

**Other associations**

Other stakeholders include the Sugar Producers' Association under the umbrella of both the ORMVAM and the ORMVAD, and the Association of Citrus Producers, under the ORMVAM.

## ONGOING PROJECTS

### IV.1.3 THE GREEN MOROCCO PLAN

In the framework of the Green Morocco Plan, a Regional Agricultural Plan (RAP) was developed by the ORMVAD and the ORMVAM in coordination with various institutions, including regional Departments of Agricultures.

**Doukkala RAP**

The RAP for the Doukkala-Abda region is divided into four homogeneous, territorial agricultural units (TAUs), which are:

- The Sahel, extending over 300 km along the coast line. This area is intended for market gardening, poultry farming, and beekeeping.
- The plains for the development of grain farming, dairy production, red meat, vegetables, and vineyards.
- The great hydropower station which includes 96,000 ha for sugar beet, cereals, vineyards, vegetables, dairy and beef.
- The interior plateaus, which focus on improving sheep and goat production, as well as tree crops (mainly olives and capers), cumin, poultry farming, and beekeeping.

The overall objectives of the Doukkala-Abda RAP are to increase production levels of the various industries, improve production quality and marketing conditions, building increased irrigation efficiency, supporting job creation and improved incomes for the rural population.

To achieve these objectives, the RAP has selected 96 potential projects for these territorial units, including:

- 83 investment projects (Pillar I) which include the intensification of cereal production, the production of sugar beets, vegetables, table grapes (irrigation), and increased dairy production, bovine red meat, poultry meat and honey.
- 13 social nature projects (solidary agriculture, Pillar II)) which include intensifying Doukkali vineyard production via the conversion of an area of 120,000 hectares of cereals into fruit tree production including olives, capers, figs, cactus. In terms of livestock production, the focus is to increase production of sheep and goat meat, beekeeping and beldi (free-range) chicken.

The total investment for these potential projects is estimated at 10,517 million dirhams for the 2009-2020 period, of which 69% relates to the development of crop production systems and 31% to the development of animal production systems

In terms of financing, the state would bear 43% of investments through incentives through the Agricultural Development Fund (ADF), aggregators 11%, with the remaining 46% carried out by producers (aggregated).

**The Oriental's PAR**

The RAP for the Oriental region is divided into five homogeneous, territorial agricultural units (UTAs), which are:

- The great hydropower station perimeter
- Highlands and plains
- Mountains and foothills
- Oases

The overall objectives of the Oriental RAP are to increase production levels of various industries, improve the production quality and marketing conditions, improve levels of irrigation efficiency, support job creation and improve incomes for the rural population.

To achieve these objectives, the RAP has selected 60 potential projects for these territorial units, including:

- 41 investment projects (Pillar I) on citrus, vegetables, olives, red meat and dairy, and

- 13 social projects (responsible agriculture, Pillar II) targeting the conversion of cereal production into olive and almond tree production, and the development of regional products including Zegzel loquats, desert truffles, and Talsint goats.

The total investment for these potential projects is estimated at 9122 million DH for the 2009-2020 period, of which 58% target the development of vegetable production industries, 8% for the development of animal production industries and 34% to carry out the project and transverse actions.

In terms of financing, the state would bear 63% of investments through incentives through the Agricultural Development Fund (ADF) and by building the facilities provided under the PNEEI; aggregators and farmers: 37%.

### IV.1.4 SUPPORT TO THE NATIONAL SAVING IRRIGATION WATER PLAN - (PAPNEEI)

The APNEEI-1 will support the implementation of the National Program of Water Saving Irrigation (PNEEI) whose purpose is to protect water resources against the impacts of climate change and improve the living conditions of rural people through sustainable resource management.

The PNEEI thus supports the Green Morocco Plan (PMV) which aims to make agriculture an engine of national growth. The project will take place in Oum Er-BH Rbia's watershed, among others.

The project will finance the conversion of irrigation networks, the establishment of drip irrigation infrastructures, and will carry out assessments of the irrigation efficiency and capacity building of the stakeholders (ORMVA, AWUAs, etc.).

For the ORMVAD, the first installment, financed by the IBRD, will cover 5,000 hectares at a cost of MDHS 300 over five years (2010-2014). Regarding the ORMVAM, the first installments, also financed by the IBRD, will cover 14,000 ha within the Moulouya watershed, including 5,600 ha around Garet and Triffa.

### IV.1.5 OTHER ONGOING PROJECTS

**ORMVAM**

**Rural Development Project Taourirt-Tafoughalt (PDRTT):** 446.6 Million MAD (IFAD, Ministry of Agriculture, beneficiaries and OPEP).

**Rehabilitation Project of Small and Medium Great Hydropower Station** in the Northern Provinces (KfW): 194 Million DH.

**Watercourse and Livestock Development Project in the Oriental** (Phase II): 95.07 Million MAD, including 65.51 million MAD funded by IFAD.

**Semmar Project:** Support to the National Action Programme to Fight against Desertification: 13,375 Million MAD funded by the Spanish International Cooperation Agency (AECI).

**MEDA / DRI-GRN project:** 58.40 million MAD funded by the European Union.

**Moroccan Spanish Cooperation Project:** Rational use of irrigation water within the perimeters of the lower Moulouya. This is a pilot project aiming to convert the area's surface irrigation method into drip irrigation. This is a project of 99 hectares involving 4 AWUAs, or 33 beneficiaries. The cost

of the project amounts to 789,290 Euros of which about 90% comes from the AECI, 7% from the ORMVAM, and the last 3% represents the farmers' contribution.

**ORMVAD**

**GCP/MOR/O33/SPA Project:** Savings and valuation of irrigation water in the irrigated area of Doukkala (FAO; Spain; cost; 10 million DH).

**ABHOER-ORMVAD-AUEA Partnership Project:** Collective reconversion of a sprinkler irrigated area into drip irrigation on 1100 Ha.

**Climate Change Adaptation project in the Oum Er-Rbia Watershed:** Japanese donation, managed by the World Bank.

**FAO Pilot Project FAO-Spain-Morocco:** Tests of collective conversion into drip irrigation, the development of training methodology, and consulting.

**WB Project:** Launch of a study on 57,000 Ha to identify areas favorable to the conversion of 20,000 Ha to launch the 1st installment (5000 Ha)

**Bour Consolidation Project (Oulad Amrane):** Regrouping in bour in Od Amrane on an area of 27,000 Ha (cost: MAD 13 billion).

**Labkhati Agregation project:** Labkhati, Safi (6,000 ha).

# V ANALYSIS AND IDENTIFICATION OF ICT NEEDS

## DATA AND PARAMETERS

Data on surface water collected by the ABH and ORMVA can be grouped into two categories:

- Climatic data: rainfall, air temperature, humidity, wind speed, wind direction, wind force, evaporation, soil temperature.
- Hydrometric data. Water elevation at the hydrological stations and level and volume of water in dams.

The parameters for surface water quality consist of:

- A = pH, temperature, conductivity, dissolved O2, turbidity.
- B = MES, DBO5, DCO, NH4+, NTK, NO2-, NO3-, PT, PO43
- C = Na+, Cl-, K+, SO42-, Ca2+, Mg2+, HCO3-, CO32
- D = CF, SF, CT
- F = Total Iron, Phenol, HCT

For the dams:

- E = T°, PH, Conductivity, O2 dissolved, MES, SO42-, NO3-, PO43-, PT, NH4+, Chl, Iron, Mn, D.Secchi.

Sampling should be done once a year. However, it should be noted that overall, the nationally recommended sampling rate is set for each type of station:

- On a monthly or quarterly basis for primary stations;
- Semiannually for secondary stations and dam reservoirs with a campaign in wet season and another in dry season.

Sampling should be done once a year. The recommended frequency is semi-annual nationwide.

The parameters for groundwater quality consist of:

- A = pH, conductivity, temperature, dry residues
- B = MO, NO2-, NO3-, NH4+, K+, Na+, Ca2+, Mg2+, Cl-, SO42-, CO32-, HCO3-, Mn2+,Fer Total.
- C = CT, SF, CF

## ICT NEEDS / MODELING AND SIMULATION

In addition to the inventory of water resources, water quality is measured by the DRPE. Other information relating to the development and use of water resources is collected by the users/partners, namely ONEP, the Boards, drinking and industrial water distributors, ORMVAs and other Departments of Agriculture for irrigation water.

The various pieces of information are stored in the national database Badre21 and are published in daily bulletins on the hydrological situation or in the annual reports regarding the status of water quality in watersheds. Some of this information is disseminated on the Internet, such as the status of reservoirs and hydrologic situation at the level of gauging stations. A system for collecting data on the dams' reservoirs' daily water balance was also implemented in the ABHs by the PERB.

In theory, Badre21 is the core of the national information system on water. However, some difficulties regarding the daily management and status of ABHS impede its successful implementation. The data are not routinely entered into the system. Managing and using BADRE21 requires specifically trained personnel. Redeployment on an Intranet / Internet platform could help streamline operating procedures and resolve these issues.

In late 2006, the Ministry of Agriculture launched its irrigation-dedicated GIS project to unify and standardize data acquisition, harmonize and segment of various processes and the judicious use of information generated. Unfortunately in the ORMVAs this approach has not yet had a concrete impact.

The rational and optimal water use is based on efficiency throughout the chain of irrigation namely:

- Irrigation planning;
- Transport of water into the main structures;
- Distribution;
- Efficiency of water use in the plot ;
- Billing;
- Information and encouraging the efficient use of water.

This could not be done without defining relevant, quantifiable and measurable indicators in return of information available at ORMVAs.

## ICT NEEDS / MODELING AND SIMULATION

As a first step, we have listed the main business applications used by the ORMVAM, the ABHMM (Tables 17 and 18), the ABHOER, and ORMVAD (Tables 19 and 20) by identifying the name of the application, the software engine running under the application in question, its key features and possibilities of dissemination.

Table 17. Main applications used (ORMVAM)

| Application Name | Key Features | Possible dissemination |
|---|---|---|
| Partner | Computerized Maintenance Management System (CMMS) | No |
| ISAGROUPE | Analysis of agricultural data | No |
| Embryons SIG | Agricultural Information | No |

Table 18. Main applications used (ABHM)

**SIG et Base de Données élaborés dans le bassin de la Moulouya**

| | Intitulé | Zone concernée | BDD & nb enregistrement | Logiciel SIG |
|---|---|---|---|---|
| inventaires des points de prélèvements | **Inventaire** des prélèvements d'eau souterraine à partir des nappes de la Haute Moulouya et du sillon Itzer Enjil et détérmination des **assiettes des redevances** | Haute Moulouya et partie amont de la Moyenne Moulouya | Accès / 5286 | MapInfo |
| | **Inventaire** des prélèvements d'eau souterraine à partir des nappes de la Moyenne Moulouya du Bassin de Guercif et de la plaine de Kerte et détérmination des **assiettes des redevances** | Moyenne Moulouya (parties médiane et avale), Bassin de Guercif et plaine de Kerte | Accès / 5067 | ArcView 3.2 |
| | **Inventaire** des prélèvements d'eau souterraine à partir des nappes des plaines de Angad et Bouhria et détérmination des **assiettes des redevances** | Plaines des Angad et Bouhria | Accès / 2100 | MapInfo |
| | **Inventaire** des prélèvements d'eau souterraine dans la chaîne des Beni BouYahi | Chaîne des Beni BouYahi et plaine d'Azlef | Accès / 425 | ArcView 3.2 |
| | **Inventaire** des prélèvements d'eau souterraine des nappes du Couloir Taourirt - Naïma et détérmination des **assiettes des redevances** | Couloir Taourirt - Naïma et CR de Guenfouda | Accès / 890 + dBASE | ArcMap |
| Inventaire Gravières | **Inventaire** des sites d'excavation de materiaux de construction du **DPH** dans la zone d'action de Bassin Hydraulique de la Moulouya | Zone d'Action ABHM | Accès / 159 | ArcView 3.2 |
| Inventaire fil eau | **Inventaire des prélèvements au fil de l'eau** au niveau des périmètres de la PMH et détermination des assiettes de redevance | Zone d'Action ABHM | Accès / 787 | MapInfo |
| inventaires + études hydrogéol | **Inventaire** des prélèvements d'eau souterraine à partir des nappes de la plaine de Figuig et élaboration des **cartes hydrogéologiques** de gestion des nappes | Plaines de Figuig | Accès / 213 + dBASE | ArcView 3.2 |
| | Etude de **synthèse hydrogéologique** dans la Chaîne de Beni Snassen avec **enquête de points d'eau** | Chaîne des Beni Snassen - Beni BouYahi | Accès / 1198 + dBASE | MapInfo |
| | Etude **hydrogéologique** de l'Oued Sefrou - Ain Sfa / Préfecture Oujda Angad | Bassin Oued Sefrou ( Beni Snassen Sud) | Accès / 143 | MapInfo |
| | **Etude Hydrogéologique** de l'aquifère de la plaine des Triffa + **inventaire** des points d'eau (Mission 1 & 2 de l'étude de modélisation hydrogéologique de la nappe des Triffa) | Triffa | Accès / 2773 | ArcView 8.0 |
| études hydrogéol | Elaboration des **cartes hydrogéologiques** de gestion des nappes du Kert, Gareb, Bouareg, Bouhria et Angad (SIG) | Plaines de Kert, Gareb, Bouarg, Angad et Bouhria, et Jbel Hamra | Accès / 2930 | ArcGIS 8.3 |
| | Elaboration des **cartes hydrogéologiques** de gestion des nappes de la Haute Moulouya,de la Moyenne Moulouya et du Bassin de Guercif | Haute Moulouya, Moyenne Moulouya et Bassin de Guercif | dBASE | ArcView 3.2 |
| études geophys | Etude **géophysique** par sondages électriques dans les Hauts Plateaux et la plaine de Tafrata | Nord Ain Beni Mathar et Nord Tafrata | | MapInfo |
| | Etude **géophysique,** électrique et synthèse dans la Haute Moulouya et le Haut Kert | zones de Ksabi - Midar et Azlef | | ArcGIS 9.1 |

6

Inventaire des prelevements dans le Cercle de Guercif Marché n° .../09

Table 19. Key applications used (ABHOER)

| *Application Name* | *Key Features* | *Possible dissemination* |
|---|---|---|
| Sampling points Module | -Manage and use data on water samplings for irrigation purposes, drinking water supply, industry,<br>-Calculate volumes and fees based on energy, agricultural and geometric methods. | No |
| Material extraction Module | -Materialize and modelize the materials' extraction areas;<br>-Manage the areas of materials extraction to avoid potential duplication issues;<br>-File queries on the technical data regarding materials extraction. | No |
| Hydrology Module | Management and exploitation of spatial and descriptive data, hydrological data to meet the needs of the Agency in terms of spatial and textual queries, drafting reports and preparing thematic maps. | No |
| Hydrogeology Module | Management and exploitation of spatial, descriptive and hydro geological data. It includes textual and spatial queries, reporting and thematic maps creation. | No |
| Pollution sources Module | Managing and using spatial and descriptive data of pollution sources and meeting the Agency's needs in terms of spatial and textual queries, reporting and thematic maps creation. | No |

Table 20. Main applications used (ORMVAD)

| Application Name | Key Features | Possible dissemination |
|---|---|---|
| Billing (metering) | Billing (metering) (WinDev) | No |
| Irrigation network measuring | Irrigation network measuring | No |
| Embryons SIG | Agricultural Information | No |

The ABHOER is relatively more advanced in terms of information systems (Figure 27). It has developed a GIS to manage the existing information acquired or being acquired, streamline the archiving and updating of information, carry out spatial analysis and answer all decision-making issues.

The Geographic Information System in place helps managing a solution through a set of unifying themes (management of sampling points, management of material sampling, hydrology, hydrogeology, pollution sources areas, etc.) As shown in the main window as follows:

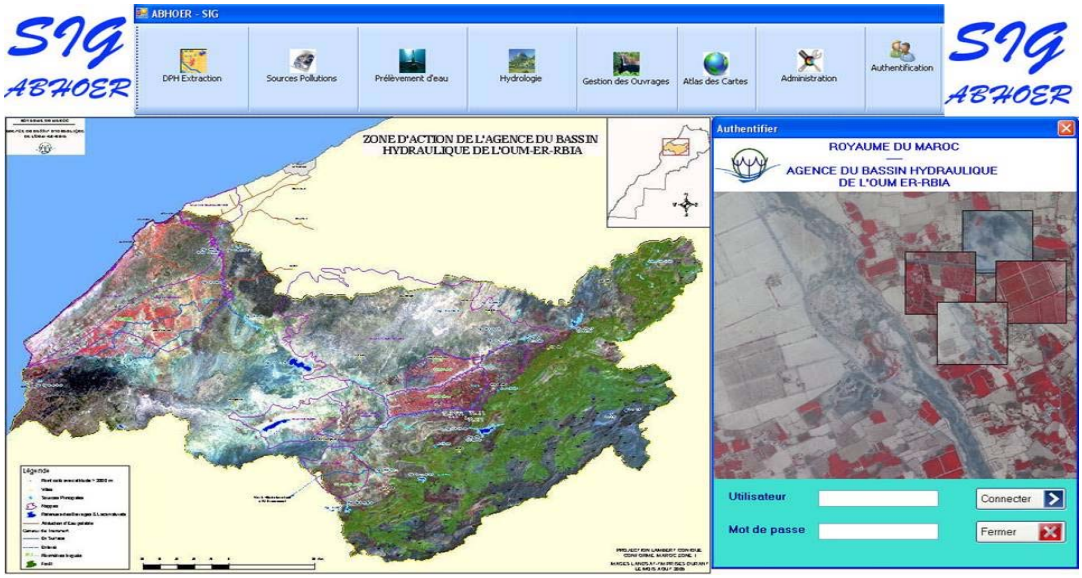



**Figure 27: ABHOER's GIS**

## NEED FOR TECHNICAL AND INSTITUTIONAL TRAINING

The institutional aspect is currently lagging. There are capacity building and technical needs of partners in training, hardware, software, and specific applications.

## TRAINING NEEDS

As part of the evolution towards an IWRM running on modern tools and earth observation partners involved need to be trained in several thematic areas such as the ICTs tools listed in Table 21. This training should be tailored according to the nature of needs, whether general or specific to a particular institution.

## SOFTWARE NEEDS

To identify skills gaps in a variety of tools, we have compiled (see tables 22 and 23) the expertise of the institutions involved (ABHOER-ORMVAD) regarding decision support tools (software or business applications), such as:

- a DBMS such as Oracle
- a GIS such as ArcGIS
- SMS best practice of flood waves propagation modelization
- GMS for table water modelization
- Data analysis tool such as SAS or SYSTAT

Table 21. Partners' training needs

| Common needs | |
|---|---|
| • Geographic information systems and their applications<br>• Practical use of GPS<br>• Modelization, optimization and systems simulation<br>• Planning and integrated management of water resources<br>• Multi Criteria Analysis | |
| **Partner** | **Specific Needs** |
| ABHM / ABHOER | • Water table modelization (hydrodynamics and quality)<br>• Salt water intrusion modelization<br>• Water tables - GMS best practice (MODFLOW)<br>• Floods - SMS best practice<br>• Dams management models<br>• Inflow forecasting models<br>• Resource allocation models and water scarcity management<br>• Watershed Management (WMS)<br>• Arc GIS Server Enterprise Edition<br>• ArcEngine<br>• Arc Hydro<br>• Arc PAD (Mobile GIS)<br>• ERDAS Imagine (satellite image processing)<br>• Tools to develop thematic maps on surface water quality in segments of Oueds of the watershed |
| ORMVAM / ORMVAD | • Water savings and efficiency<br>• Modelization of crop water needs<br>• Modelization of irrigation networks |

To identify skills gaps in a variety of tools, we have compiled (see Tables 10 and 11) the expertise of the institutions involved (ABHM-ORMVAM) regarding decision support tools (software or business applications), such as:

Table 22. ABHOR-ORMVAD and ABHM-ORMVAM Know-how / Expertise

| **Theme** | **Existing skills** | **Missing skills** |
|---|---|---|
| Computer Basics | Use: Yes; Administrative: No | |
| DBMS | Use: Yes; Administrative: No | Use; Administrative |
| GIS | Use: Yes; Lack of consistency of tools, Administrative: No | Geomatics Project Manager: Training Officer Technicians |
| Cartographic Record | GPS: No; Digitizing: Poor; Scanning: Yes | GPS; Scanning |
| Image processing | Ortho rectification: No, Mosaicking: No, DTM: No, Signa Processing: No | Ortho rectification; Mosaicking, DTM; Signa Processing |
| Acquisition of data from the field | Low | Practice and use of GPS; Instrumentation |
| **ABHOER Specifics** | | |
| Systems Modelization/Simulation | Scattered knowledge | Complete and deepen knowledge, |
| Groundwater | Modflow, Groundwater Vista | Software acquisition or update |
| Surface water | GMS; HEC-RAS | GMS full edition: SMS full edition |
| | | |
| Crops Water requirements | | Complete and deepen knowledge, |

Table 23. Map acquisition and satellite images (ABHOER-ORMVAD and ORMVAM-ABHM)

| **Maps Section** | **Existing** | **Needed** |
|---|---|---|
| Baseline data | Free of rights: acquired from central government<br>Royalties: none | Georeferenced Base maps |
| Data Produced | See business applications | Maps covering the entire watersheds over time |

## HARDWARE REQUIREMENTS

The computer equipment inventory (computers, peripherals, operation and development tools, GPS) has not been done in detail. Generally speaking, the institutions are well equipped. The identified needs are listed in Tables 24 and 25 respectively for ABHOER-ORMVAD and ABHM-ORMVAM.

Table 24. Hardware requirements (ABHOER-ORMVAD)

| **Existing** | **Needs** | |
|---|---|---|
| | Programmed | Identified |
| ABHEOR | | |
| **Equipment**<br>Servers, A0 plotter, A0 Digitizer:<br>ADSL | | 1 map server<br>5 PCs<br>An A3 color laser printer<br>10 GPS<br>Arc Pad PDA GPS: 2 |
| **Operating System**:<br>Windows Server environment<br>Windows Vista, XP, Windows 2000, Windows 98 workstations | | |
| **Development:**<br>DBMS Access, Oracle<br>Arc GIS 9.2 and ArcView 3.2: Study of the geographical system | | Arc GIS 9.3 and associated tools |

Tables 26 and 27 respectively summarize all the needs for the ABHM-ORMVAM and the ABHOER-ORMVAD.

Table 25. Hardware requirements

| Existing | Needs | |
|---|---|---|
| | Programmed | Identified |
| ABHM | | |
| **Equipment**<br>• Servers: 2<br>• PCs: 11<br>• Clone PCs: 10<br>• 16 Laser Printers<br>• 3 Color laser printers<br>• 2 A0 plotters<br>• 1 A2 plotter<br>• 2 A3 Scanner<br>• 1 A4 Scanner<br>• 1 A1 Digitizer<br>• 2 Video Projectors<br>• 2 Digital cameras<br>• ADSL: 2Mb<br>• GPS: 10 | | • 1 map server<br>• 10 PCs<br>• 12 GPS<br>• 1 A0 digitizing table<br>• 1 A0 plotter<br>• 2 A3 scanners<br>• 4 A4 scanners<br>• 2 A4 color laser printers<br>• 2 A3 inkjet printers<br>• 2 PDA GPS |
| **Operating System**:<br>• Windows 2000 Server and 2003 server<br>• Windows XP, Windows 2000, Windows 98 workstations<br>• Management Systems Database on Relational Data<br>• Microsoft Access | | |
| **Office Suite**.:<br>• Microsoft Office 97, 2000 and 2003<br>• MICROSOFT FRONT PAGE 2000 | | |
| **Development:**<br>• ArcView 3.2: Study of the geographical system<br>• MapInfo | | • Arc Gis and associated tools |

Table 26. Summary for ABHM/ORMVAM

| Needs | ABHM | ORMVAM |
|---|---|---|
| Training | • Management system database<br>• Geographic information systems and their applications<br>• Practical use of GPS<br>• Modelization, optimization and systems simulation<br>• Planning and integrated management of water resources<br>• Multi-Criteria Analysis | |
| | • Water table modelization (hydrodynamics and quality)<br>• Salt water intrusion modelization<br>• Water tables - GMS best practice (MODFLOW, ...)<br>• Floods - SMS best practice<br>• Dams management models<br>• Inflow forecasting models<br>• Resource allocation models and water scarcity management | • Water savings and efficiency<br>• Modelization of crop water needs<br>• Modelization of irrigation networks |
| Software | o a DBMS such as Oracle<br>o GIS such as ArcGIS<br>o SMS best practice of flood waves propagation modelization<br>o GMS for table water modelization<br>o Data analysis tool such as SAS or SYSTAT | o GIS such as ArcGIS |
| Maps | • Georeferenced Base maps<br>• Maps covering the entire watershed | |
| Hardware, | • 1 map server<br>• 3 PCs<br>• 2 GPS PDA<br>• 1 A0 digitizing table<br>• 1 A0 plotter | • 1 map server<br>• 3 PCs<br>• 2 GPS PDA<br>• 1 A0 digitizing table<br>• 1 A0 plotter |

Table 27. Summary for ABHOER / ORMVAD

| Needs | ABHOER | ORMVAD |
|---|---|---|
| Training | • Geographic information systems and their applications<br>• Practical use of GPS<br>• Modelization, optimization and systems simulation<br>• Planning and integrated management of water resources<br>• Multi-criteria analysis | |
| | • Water tables modelization (hydrodynamics and quality)<br>• Salt water intrusion modelization<br>• Water tables - GMS best practice (MODFLOW, ...)<br>• Watershed Management (WMS)<br>• Floods - SMS best practice<br>• Dams management models<br>• Inflow forecasting models<br>• Resource allocation models and water scarcity management | • Water savings and efficiency<br>• Modelization of crop water needs<br>• Modelization of irrigation networks |
| Software | • Arc GIS 9.3<br>• SMS best practice of flood waves propagation modelization<br>• GMS for groundwater modelization<br>• WMS for watershed modelization<br>• Data analysis tool such as SAS or SYSTAT | • Arc GIS |
| Maps | | • Georeferenced Base maps<br>• Maps covering the entire Doukkala perimeter |
| Hardware, | • One 5-client map server<br>• 5 PCs<br>• 2 GPS PDAs<br>• 1 A3 laser printer | • One 3-client map server<br>• 3 PCs<br>• 2 GPS PDAs<br>• 1 A0 digitizing table<br>• 1 A0 plotter<br>• 3 A3 scanners |

# VI SIWM PROJECT - INFORMATION TECHNOLOGY ACTIVITIES, EVALUATION AND LESSONS LEARNED

## SIWM PROJECT - FOCUS ON HARMONIZATION-RELATED ACTIVITIES USING IT

Under the project of introducing decision-making tools, the SIWM team and its experts have installed GIS stations in key partners areas of intervention. As part of this effort, software was purchased, installed and mastered as training sessions were provided. Specific missions were organized to directly assist each partner in developing specific applications and shared data platforms.

The report briefly summarizes the before-SIWM state, the SIWM achievements, the after-SIWM, conclusions and lessons learned, sustainability, and the overall SIWM outputs.

### VI.1.1 BEFORE SIWM

- Watershed stakeholders individually followed their water quality quantity parameters.
- The existing information was sparse and, generally speaking, remains uncontrolled.
- There was little or no control on the relevance of information, the spatial overlap of data, or the reliability of information.
- There was a lack of consistency in the information media (paper, layers, maps, Excel / Lotus Base files, Access, Oracle, Word, other formats).
- There was no agreement or information sharing between stakeholders.
- There was no unified database and no mechanisms to share information among users.

**Achievements under the SIWM project**

- Interactive inventory system (I3)
- Development of a tool to assess and monitor quality (OIQ)
- Developing a management tool of water attributions
- Developing a geographic database on Water and the Environment in Souss-Massa
- Groundwater management model
- ABH telemetry network
- ONEP telemetry network
- ORMVA telemetry network
- Agricultural Information System
- Water savings Tahouzint

- Management of the environment and water quality
- Harmonization of tools and methods
- Development of climate thematic maps (CD ROM).
- Various training courses on GIS, GPS and remote sensing best practices and their applications were offered.
- The partners developed several applications themselves under the supervision of the SIWM team.
- These trainings concluded on a seminar facilitated by the partners

## After-SWIM

Acquired:

- Consolidation of the various administrations (now partners) around the issue of water in a participatory manner.
- Information sharing via www.souss-eau.com and various decision making tools.
- The SIWM platform or partially integrated prototype can serve as a model for other agencies for other watershed agencies or other institutions in Morocco dealing with water issues.

It was strongly recommended to create a GIS consortium for Souss Massa, which will take over SIWM in the region with the following goals:

- Unification of the working methods (data acquisition, data processing, software tools),
- Using the same mapping media and knowledge via the SIWM project,
- The continuous development of GIS units at each respective partner, information sharing, but also data and possibly equipment.

Sustainability

- Information sharing and joint collaboration via www.souss-eau.com and various decision making tools.
- Inter partner framework agreement on providing the continuity of prior SIWM knowledge.
- Willingness of partners to bring to fruition the integrated water resource policy designed with the help of SIWM.

Conclusions and Lessons Learned

- Integrated Management is a strong and complex multidisciplinary task that requires iterative processes, consultation, field and experimental validation.
- The integration process involves many partners and stakeholders, and requires understanding, patience and courage.

## OVERALL SIWM OUTPUTS

- The SIWM model or partially integrated prototype can serve as a model for other agencies for other watershed agencies or other institutions in Morocco dealing with water issues.
- A website has been developed and can be seen at: www.souss-eau.com.
- Technology transfer was achieved through seminars, workshops, tutorials, field work in Agadir and trips to the USA.
- There are many software tools developed that enable a continuous recording of

information and simulations.
- The hardware, technical and scientific knowledge enables a continuity of work.
- Consultation regarding the possible continuation of the SIWM project in terms of integrated projects became possible.
- Adopting good practices proved its benefits. Guidance documents were produced.

## POST SIWM AND LESSONS LEARNED

Overall, the partners were all highly motivated and interested in the SIWM project. Discussions led the partners to converge unanimously on the following recommendations based on the work on the same site:

- The need to consolidate cartographic work by developing a unified digital Fund (basic maps, last administrative division),
- The importance of listing the available data by partner (cartographic and alphanumeric data)
- The need to adopt a larger scale to generate basic maps,
- The importance of mastering the basic tool (GIS) by programming additional training (basic and advanced) including map digitizing, spatial analysis and queries,
- The importance of training on statistical tools and multi-criteria search,
- The decompartmentalization of the partners through group trainings outside work sites and by avoiding individual training,
- The acquisition of additional GPS devices for some of the partners,
- The acquisition of additional IT equipment,
- The continuity of technical assistance for the supervision and monitoring of partners in achieving their objectives towards the development of their respective GIS units.

The key partners, namely the ABH and the ORMVA of Souss Massa, took advantage of the SIWM outputs, of the interest in the activities undertaken, and the pilot demo projects including agricultural warning, remote management, website, geographic databases and decision-making tools.

The ORMVA even replaced some of the telemetry components on its own budget and the application is perennial.

Unfortunately, since the end of the SIWM project, there has been no system update related to the region's integrated information system encompassing heterogeneous data from multiple partners. This is due to:

- The legal status of watershed agencies does not currently allow the recruiting of engineers and managers,
- The highly time-consuming daily tasks in heavy weather,
- The difficulty in outsourcing such tasks to a consulting firm approved by all the partners and the difficulty of joint payment by the partners involved.

In conclusion, human resources play a crucial role in the system, study or project sustainability. It is highly recommended for the MEC project to ensure a significant support in terms of human resources to ensure national ownership, sustainability and durability of the systems or achievements to be acquired.

# VII ACTION PLAN

The action plan developed to provide assistance to regional partners, ABH and ORMVA, will imply installing a information system, implementation of a GIS unit and training.

## IT SYSTEM

Morocco has undertaken a thorough reform of the water sector by creating some watershed Agencies. Moreover, the constitution of various watershed Councils, Commissions and Committees in the major watersheds, sub-watersheds and regional aquifers, allows for consultation meetings on water and its various uses. These bodies help consolidate the authority of the watershed Agencies (ABH), the Offices of Agricultural Development (ORMVA), other agencies involved in water distribution (ONEP, *Régies*) and representatives of various water users associations. These user associations are places of dialogue and action planning to address shared issues of management and resource sharing.

An Information System on Water (ISW) is necessary for these organizations to process the necessary decision making information that can be shared to the public.

The ISW will help with:

- Providing a database on the watershed's water resources;
- Collecting the documentation and information available on the watershed's groundwater and surface waters;
- Educating water users and local population.

Ad hoc missions will be organized at the Um Rbia watershed and the Moulouya to support the ABHOER/ORMVAD and ABHM/ORMVAM in modelizing and/or updating their IT systems. The missions will tackle the following tasks:

- Information system management for integrated water management by watershed, with the implementation or updating of databases, of a GIS or its potential upgrade,
- Structure of the information production needed for decision making.

## CREATION OF GIS UNITS FOR ABHs AND ORMVAs

As part of the human resources optimization, the efficiency in basic data handling, management-specific data, fast access to information, and solutions for decision making tools, it is important to establish a GIS unit or service at each organization capable of collecting and organizing data in the form of GIS layers used by all the services and departments. The operating procedures will be specified according to the partners' agendas. The GIS units are also responsible for implementing various GIS applications to be developed under the project.

Moreover, given the need to collect field data, a mobile GIS solution such that Arc Pad that is able to handle GIS and field data without having to convert it in a specific format is highly encouraged. Arc Pad lets you view vector data (parcels, perimeters, roads, networks) and raster data (aerial photographs, satellite photographs, scanned maps). Arc Pad also allows to key-in information in a specific data format.

## TECHNICAL CAPACITY BUILDING

Also in the works is a detailed program of training sessions on information technology and various other applications specific to ABHs and ORMVAs activities. As already mentioned, the training needs are crucial, the relevant themes have been identified, and other missions will further analyze the training content, structure, timing and the necessary implementation environment.

## ASSIST ABHS IN MANAGING POLLUTION SPILLS PENALTIES—APPLICATION OF THE "POLLUTER PAYS" PRINCIPLE

The integrated management of water resources policy can not be truly effective without mobilizing sustainable financing through revenue from users who pollute. Implementation of this principle in Morocco is planned for 2012. Financial participation of users is essential, based on the "user pays" principle.

Support will include analysis of successes and failures of the planned tax collection system, basic principles and application, and developing proposals to improve the organization of the system taking into account the experience accumulated in other countries.

## ASSISTING THE ABHs IN UPDATING THE DATA ON GROUNDWATER IN VIEW OF DEVELOPING WATER TABLE AGREEMENTS.

## MOULOUYA'S WATERSHED AGENCY

The ABHM considered the groundwater agreement very difficult to engage in over a four year period because of technical limitations including knowledge through geophysical, geochemical investigations on groundwater. In addition, the volumes of water involved, water users and partners were problematic. Only a preliminary study would be feasible. Only the Triffa water table, whose extraction (20000 $m^3$) could be targeted; Bouareg (highly salinized), Sabra (bour area), Taourirt (PMH).

### VII.1.1 THE OUM ER-RBIA WATERSHED

The watertable contract to implement on the Sahel and Doukkala aquifers, or at least its pre-study, will depend on the hydrogeological conclusions developed by a consulting engineer. By implementing a program of actions, the contract aims to both protect the resource quantity and quality and to define a genuine sustainable management policy for the aquifer that involves all stakeholders. This must be supported by implementing an intervention program around the following themes:

- Quantitative management including water saving solutions,
- Protection of the aquifer (seawater intrusion, pollution, improving the collection/recharge conditions, etc.)
- Facilitation and information
- Resource monitoring and further studies

# VIII CONCLUSION

In summary, the provision of technical assistance will help:

- Better define the partners' needs through harmonization of information technology and modeling;
- Define the architecture and specifications of the management system and processing of the existing information (directories, data, reference documents, material, studies, etc. in hard copy or electronic format for the entire watershed);
- Develop a regional information system on water
- Develop technical tools on managing, monitoring and modeling water resources,
- Develop content, materials, and a schedule for training to strengthen technical capacity building;
- Generate, with the help of all the producers, partnership agreements with universities, associations, and private companies.
- Develop partners' institutional capacity.

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