Managing Urban Water Scarcity in Morocco

Annexes to Section 5

NOVEMBER 2017

WORLD BANK GROUP

WATER PARTNERSHIP PROGRAM

Acknowledgement & disclaimer

1818 H Street NW, Washington, DC 20433

Telephone: 202-473-1000; Internet: www.worldbank.org

Please cite the work as follows: Dahan Stephane, 2017: Managing Urban Water Scarcity in Morocco. World Bank, Washington, DC.

Cover design: Jean Franz, Franz & Company, Inc.

CONTENTS

ANNEX VI - Institutional Framework in the Tensift basin and Marrakesh area

1. Water resources management and competitive uses in the Tensift basin

The city of Marrakech is located in the basin of the river Tensift. The Tensift Hydraulic Basin Agency (ABHT) was created in 2002. The geographic definition of the ABHT's area of action is made at the watershed scale. As a result, the development and revision of the PDAIRE and the management of water resources and needs typically involves several regions, provinces, prefectures, cities and municipalities, as well as representatives of water user associations and professional associations. It should be noted that in the new administrative division of Morocco, which was carried out in 2015 within the framework of advanced regionalization, the territory of the ABHT now belongs to a single administrative region, that of Marrakech-Safi while 'previously this territory belonged to the two administrative regions' Marrakech-Tensift Al Haouz' and 'Doukkala-Abda' with the provinces Safi and Youssoufia. This new territorial configuration implies the participation of a single actor at the regional level during the consultative meetings prior to the establishment of the PDAIRE or its revision, thus reducing the number of territorial representatives in the management of water resources. the institutional and political plan. It should be noted that the region, as well as the prefectures and provinces, are also represented at the level of the board of the ABHT by decree of January 24, 2005, article 3. However, this composition does not include representatives of the provinces of Safi, Youssoufia, Rhamna and El Kelaa des Sraghna, which also form part, wholly or partly, of the territory of the ABHT.

The Ministry of Water has established the PDNA of the Tensift hydraulic basin. This plan outlines the strategic lines of water resources management and planning as well as the objectives and actions necessary for sustainable development in the basin until 2030. However, given the updates of hydrological studies, orientations of the National Water Sector Strategy, and the more rapid development of water demand in the city of Marrakech, which alone accounts for 80% of the urban water demand of the basin, Tensift's PDAIRE was updated by the ABHT in 2010.

It should be noted that in the new Water Law 36-15, the PDAR is prepared by the ABH, in coordination with the ministerial departments, the public institutions concerned and the technical committee of the new Hydraulic Basin Council. The consultation with the Prefectural Water Commission (CPE) and the Superior Council of Water and Climate (CSEC) is no longer instituted. The PDNA is then submitted to the Basin Council for review and opinion and then to the Board of Directors of the ABH which adopts the plan and sends it to the General Secretariat of the Government for publication in the official bulletin. The new Act limited the role of EPC to participation in water management during shortages, flood prevention and awareness of resource protection. The CBSC assists in the development of the national water plan, rather than in the PDAIRE at the regional level. The regulatory texts relating to the new modalities for the preparation and revision of the PDAs, the composition of the CPE and its functioning, the composition of the Board of Directors of the ABH and the ABH Council are not yet updated or released.

The Prefectural Water Commission (CPE) is a governance body responsible for contributing to the establishment of the PDAIRE, to accompany the action of the municipalities in water saving and protection of water resources, and public awareness campaigns. It is made up of a multitude of representatives of various institutions. It is the governor who presides over the commission that holds its meetings once a quarter. In order to ensure more effective integrated management, it is necessary to rethink the CPE on an inter-municipal or regional scale rather than a prefectural or provincial scale strictly confined within the administrative boundaries. The new prerogatives of this commission according to Law 36-15, consist of water management during shortages, prevention of floods and awareness of the protection of water resources.

The ABHT is responsible for preventing the effects of extreme weather events such as floods and droughts. The DRDP includes a drought management program specifying arbitration measures to meet minimum demands. In accordance with the Water Law 36-15, a plan for the management of water shortages in the event of drought is established by the ABHT in consultation with the administration, the ONEE, the local authorities and the prefectural councils and provincial governments. The procedures for drawing up and revising this plan have not yet been laid down by the regulations. However, the ABHT has set up a system to monitor water situations through hydro-climatic indicators. As regards the floods, the ABHT establishes an atlas of flood zones. For medium or high risk areas, the agency shall draw up a flood risk prevention plan in coordination with public establishments, local authorities and the prefectural and provincial commissions concerned. The declaration of the state of shortage is made by the administration in charge of water. The Governor (Wali) plays an important role in the management of crisis situations due to water scarcity or flooding. The Governor establishes a Risk Prevention and Management Unit (CPGR), which is also responsible for setting up contingency plans in case of major crises.

2. Water resources management and competitive uses in Marrakesh

At the level of the city of Marrakech, the management of the drinking water, sanitation and wastewater treatment service is the responsibility of the municipality of Marrakech. Decisions concerning this management are taken at the level of the municipal council, whose members are elected representatives. The commune administration has a service called 'RADEEMA and ONE', which is responsible for coordinating the commune and the autonomous water and electricity distribution authority of Marrakech (RADEEMA).

RADEEMA is a communal establishment of a commercial nature under the supervision of the Ministry of the Interior, which was set up by the Municipal Council of the city of Marrakech in 1971 to take charge of water and electricity services in the city. It was not until 1998 that the authority took charge of the city's sanitation service, followed by wastewater treatment and reuse. RADEEMA was approached by other neighboring municipalities to take charge of the water and sanitation service.

RADEEMA experienced chronic fiscal difficulties, which reached their peak in 2005. It was at this point that the Ministry of the Interior initiated an action plan triggering investments of MAD 2.6 billion between 2006 and 2010 for the upgrading infrastructure and services. Today, RADEEMA is recognized as the best performing authority at national level. On the other hand, tariffs are among the highest, particularly for wastewater treatment.

At the level of integrated urban water management, the Haouz Regional Office for Agricultural Development (ORMVAH) is concerned with the re-use of wastewater treated for agricultural purposes and water saving in the framework of the Green Morocco plan to alleviate the pressure on the water resources used for the city's water supply.

The Urban Agency of Marrakech (AUM) represents the deconcentrated service of the state in urban planning. The AUM is responsible for drawing up the Marrakesh Urban Development Master Plan (SDAU), which draws spatial and strategic projections of urban planning and development options, including flood control. The Municipal Council is ultimately responsible for the execution of the installations and the hydraulic works intended for the control of the rainwater and the protection against the floods.

3. Institutional mechanisms in charge of water allocations

Through the PDAIRE, the ABHT is the main institution that manages the allocation of water resources and their allocation according to the different types of use (drinking water, industrial water, irrigation, energy production) while avoiding conflicts and 'participatory and concerted action in accordance with the Water Law 36-15. In the current management of water resources, especially multi-purpose facilities, priority is given to water supply followed by irrigation. The consultation with stakeholders in

the preparation and revision of the PDAIRE, as defined by Decree No. 2-05-1534 of November 24, 2005, allows the ABHT to take into account the needs of the different sectors. Regional or provincial representatives of public administration and public institutions involved in the water sector participate in the drafting and revision of the PDAIRE and defend their needs in consultation meetings. This participatory process should ensure that the objectives and orientations of the various sectoral plans are taken into account. However, it has not been able to prevent the city of Marrakech from developing at the expense of agricultural land and to put in place projects whose consumption of water considerably affects the water balance of the region already weakened by climate change. A closer dialogue should therefore be instituted and it seems essential that the region should be more actively and effectively involved in the management and distribution of water resources in close collaboration with ABHT, ONEE and RADEEMA. In this way, the region, in collaboration with government authorities, must ensure that a more economical management of water resources is put in place, and that water allocations and provisions for the rationalization of water resources are strictly respected. Monitoring and enforcement of strategies and regulatory frameworks need to be strengthened, for example through the establishment of groundwater contracts and the establishment of a water police.

4. Overall action plan proposed by the Plan National de l'Eau (PNE)

The PNE (2015) calls for: (i) saving and improving irrigation water, (ii) more efficient management of distribution systems and (iii) economical use of drinking water, tourism and industry, (iv) the optimization of multiple uses of water resources; and (v) consideration of the availability of water in the design and implementation of projects should be the priority axes of water policy in the years to come. The national action plan for drinking water, industrial and tourist water demand management focuses on controlling water demand, reducing water losses and improving water 'efficiency. They include all measures aimed at increasing the technical, social and economic efficiencies in the different uses of water. The action plan provides for:

- Improvements in the efficiency of drinking water distribution systems, reaching nearly 80% on the national average in 2025, through the rehabilitation of distribution networks, the improvement of metering, maintenance and maintenance networking, sectorization and restructuring, research and repair of leaks.
- Widespread access to drinking water in rural areas; the ONEE plans to achieve an access rate to rural drinking water of 96% by 2016;
- Accelerating the implementation of the environmental upgrading program for the tourism sector, including the implementation of best practices in water consumption; this program includes the reuse of wastewater for the watering of golf courses and green spaces, the introduction of good environmental practices through pilot projects of good hotel management, and the installation of water savers, watering in drip, optimizing the use of washing machines, etc.
- Strengthening the capacities of the water police by providing them with the necessary human and material resources and by providing them with the support of the administrative and judicial authorities for the control of industrial wastewater discharges.

The PNE (2015) also states that the implementation of the for drinking water, industrial and tourist water demand Action Plan requires accompanying measures that focus on:

- The introduction of provisions in water legislation to condition the granting of licenses to new projects through the adoption of best practices for water consumption, including optimization of water systems, maximization of internal water recycling, etc. ;
- The granting of subsidies and subsidized loans to help tourist and industrial units to generalize best practices and reduce their water consumption;
- Revision of the tariff system to make it incentive to reduce water consumption and improve cost recovery;
- The promotion of water consumption auditing and water-saving certification schemes;

- Standardization and incentives to use appropriate water-saving technologies and to market them at competitive prices through production subsidies;
- The development of efficiency standards for each type of equipment and construction standards that must be mandatory for any new construction or renovation;
- The generalization of the watering of golf courses and green spaces by purified wastewater;
- The introduction of water conservation practices through education, awareness and extension.

5. Options to strengthen the IUWM institutional and regulatory framework in Marrakesh

According to the 1976 Communal Charter, amended in 2002 and 2008, public services such as water, sanitation and electricity are the responsibility of municipalities. It is the municipal council which decides on the mode of water management both for the supply of drinking water and for the sanitation. The municipality is also the owner of all urban water infrastructures, including rainwater control and flood protection. As mentioned above, the municipality is also responsible for the protection of water quality, including drinking water, sewage and storm drainage and treatment ... and the fight against all forms of pollution (Article 40 of the Municipal Charter).

The municipality of Marrakech receives guidance and executes the plans and policies defined by the Provincial Water Commission, which is a link with the ABH and ONEE (water) on which the city's supply of water depends. The municipality has the assistance of a committee of vigilance of the water established by prefectoral order to face the situations of lack of water and alert on the wastes possible. Finally, this system also includes the Urban Agency of Marrakech which assists the municipality in the urban planning and the definition of investments in necessary hydraulic infrastructures.

In this system, and on the territory of the Marrakech Commune, the Autonomous Water and Electricity Distribution Authority (RADEEMA) is responsible for distributing drinking water to the people of the city. It should be noted that RADEEMA also intervenes in the supply of some communes bordering on the city of Marrakech, although this does not derive fundamentally from its legal mandate as it derives from its statutes. RADEEMA is a public institution under the authority of the municipality created in 1971 by Decree n ° 2-64-394 of September 29, 1964 relating to the Communal Authorities. Like all operators in the urban water sector, RADEEMA is under the supervision of the Ministry of the Interior. ONEE is the supplier of water and services for the construction of water storage, distribution and treatment infrastructures. RADEEMA is in charge of investments to strengthen and extend water supply networks and improve their performance, including through consumption control through the installation of meters, and the generalization of access to water. through the establishment of a common geographic information system for water and sanitation networks, as well as improved communication with all stakeholders.Pour sa gestion courante, depuis 2010, la RADEEMA bénéficie d'un allègement des contrôles qui s'exercent sur les établissements publics qui ne sont plus automatiquement préalables (« contrôle d'accompagnement »).

Since 1998, RADEEMA is also responsible for sanitation and wastewater treatment at the level of the municipal wastewater treatment plant inaugurated in 2011 to ensure the treatment of wastewater in the city of Marrakech that is being reused. The re-use of the waters treated by the WWTP is mainly intended for the irrigation of project areas reserved for the development of the golf and the palm plantation. This WWTP constitutes the first application of PPPs to the financing and realization of WWTP in Morocco. RADEEMA is a shareholder at the same time as the State and private partners, in particular developers of areas dedicated to the practice of Golf. The WWTP thus constitutes an essential instrument of the GIEU for the city of Marrakech and an example in Morocco.

The Marrakech water management system has the operational structures and the essential instruments for the success of a GIEU. However, as regards the Marrakech commune, its responsibility is important for the success of the GIEU. In this regard, the municipality of Marrakech must aim at all potential improvements at institutional, technical and financial level within the framework of its established prerogatives.

Thus, it can of itself, or in relation with the other competent institutions, ask the supervisory authorities to amend the structure of the Committee of Vigilance to make it an enlarged Committee for the monitoring of the GIEU of the city of Marrakech and to provide the Monitoring Committee with appropriate statutes to enable it to involve all stakeholders in the city in its deliberations. This GIEU Monitoring Committee will be an instrument to monitor compliance with the implementation of water policies, including conservation, the fight against waste, reinforcement of protection and safeguard actions, water and so on. Stakeholders will include citizens' organizations, trade chambers (trade, agriculture, tourism, services etc.), representatives of wholesale producers / suppliers (ABH, ONEE, STEP), whose presence will enable the Committee to assimilate issues related to water supply and supply-side services. This Committee is to be engaged on behalf of the city of Marrakech in the preparation of the basin-level (national) watershed plans and strategies when the latter will be the subject of consultation with a view to their preparation and adoption. Thus, the municipality must adopt decisions, which the laws in force authorize it to take, in order to:

i. Develop, adopt, implement and regularly update a plan for the collection and dissemination of water information. These data should be accessible to all stakeholders involved in the provision of water and sanitation services to the city of Marrakech and the conservation and protection of natural resources.
ii. Request RADEEMA to acquire a system for permanent monitoring of water losses in the distribution network and to carry out an annual audit to determine the appropriate measures to correct network failures.
iii. Establish, maintain and update an information system on all existing wells at the urban level to monitor groundwater use, including qualitatively.
iv. Formalize the intervention of RADEEMA in its mission of providing water and sanitation to the neighboring municipalities and develop the cooperation with the neighboring municipalities in the framework of a contract of agglomeration or other.
v. Adopt a regulation on requirements for collection and conditions of use of rainwater in consultation with the urban agency.
vi. As part of the strengthening of the Marrakech GIEU, the municipality and the provincial / regional authorities must adopt a policy whereby all industrial water users must initiate the necessary procedures with RADEEMA to process and reuse their waste water in the existing incentives or to be put in place. RADEEMA must undertake and make public an independent study of the wastewater reuse contracts of the WWTP in order to improve its performance on a regular basis.
vii. Ensure that RADEEMA and WWTP are stakeholders involved in any water management contract (underground or other) of the ABH whose supplies depend on it.
viii. Ensure that environmental impact assessments for investment projects affecting the municipality of Marrakech include a water and sanitation component to be reviewed by the GIEU Committee and RADEEMA before the issuance of any environmental compliance certificate.
ix. Adopt a policy of education and public awareness of the problems of water management, protection and conservation. This policy must be implemented and supported by all modern and traditional means of communication: school curriculum, poster campaign, use of the Internet and social networks and heavy media.

ANNEX VII - Water resources at basin level: current situation and projections

1. Surface water

Surface water resources, at the scale of the ABHT master plan area, are very irregular and unevenly distributed. The region can be broken down into three planning units, with unequally distributed surface water resources:

- The High Tensift Unit (11,900 km2);
- The Bas Tensift unit (7,900 km2);
- The Ksob-Igouzoulen unit (5,000 km2).

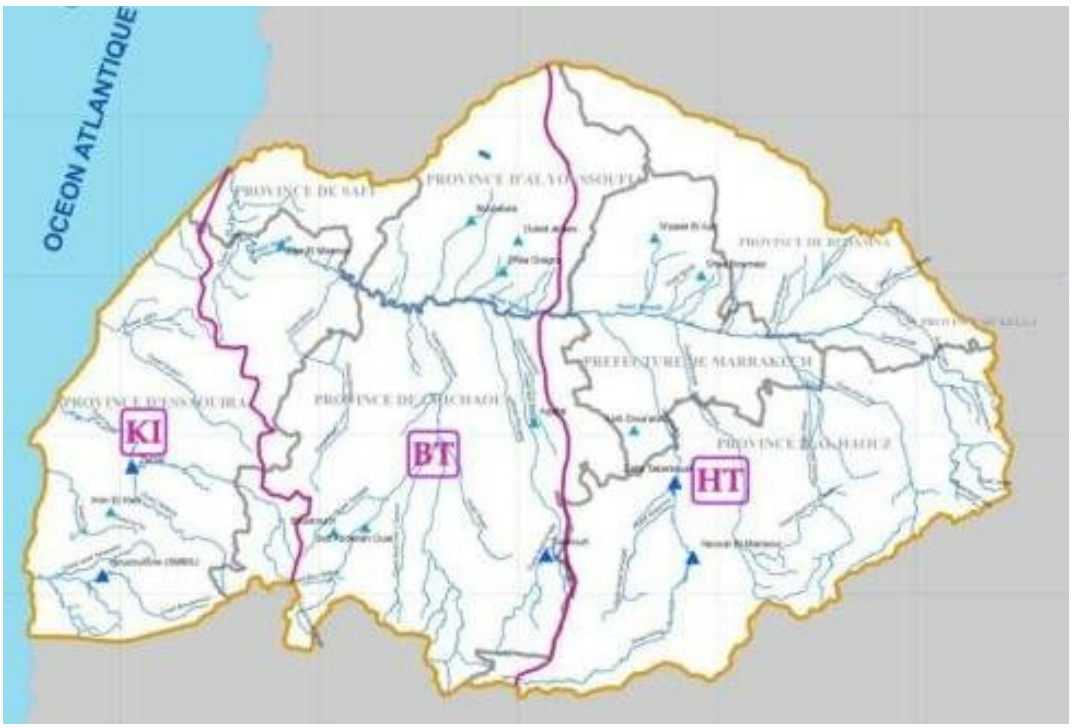

Figure VII-1: *ABHT planning (PDAIRE ABHT)*

The updated annual contributions per planning unit are as follows.

- High Tensift: 860 Mm3, ie 72 mm / year (222 Mm3 corresponding to the upstream withdrawals from the hydrological stations and 638 Mm3 corresponding to the average inflow measured at these stations). The average annual rainfall is around 350 mm and the annual average runoff is therefore estimated at 20%.
- Lower Tensift: 220 Mm3, ie 28 mm / year (58 Mm3 corresponding to the upstream hydrological stations and 162 Mm3 corresponding to the average inflow measured at these stations). The average annual rainfall is about 200 mm and the average annual runoff coefficient is estimated at 14%
- Ksob - Igouzoulen: 62 Mm3, that is to say 12 mm / year (16 Mm3 corresponding to the upstream withdrawals of the hydrological stations and 46 Mm3 corresponding to the average contribution measured at these stations). The average annual rainfall is about 250 mm and the average annual runoff is therefore estimated at 5%

In addition, the region benefits from a transfer of water from the Oum Er Rbia basin via the Canal de Rocade with an expected average flow of 300 Mm3 according to the PDAIRE, but already much lower

at present order of 180 Mm3 for the supply of drinking water to the city of Marrakech and for irrigation in the central Haouz.

2. Groundwater

The region is characterized by the presence of very diverse geological structures which are at the origin of the uneven geographical distribution of groundwater. Hydrogeological units of noteworthy extension are included in the sedimentary cover that forms the basement of plains and plateaus. The main slicks are:

- the Haouz-Mejjate aquifer: at the foot of the Atlas, the Haouz-Mejjate plain, with an area of 6'860 km², is a vast depression filled by the dismantling products of the Atlasic chain. It contains the water table of Haouz-Mejjate and its western edge known as the water table of the Mejjate. It is the most productive aquifer in the region, but also the most exploited;
- the aquifers of the basin of Essaouira-Chichaoua which have several aquifer levels, the importance of which varies according to the nature of the geological formations and the extension of their impluvium. The main aquifers of this region are:
  - the coastal water table,
  - the Meskala-Kurimate aquifer,
  - the Ouled Bou Sbâa aquifer,
- the aquifer of the Bahira more to the north beyond the Jbilet and which contains a water table whose increasingly intense exploitation has favored the development of the particularly arid zone of Ben Guéris;

The annually renewable volume of groundwater is globally estimated at 554 Mm3 / year, 80% of which is covered by the Haouz-Mejjate and Bahira aquifers. The table below summarizes the balance of the aquifers in the plan area, the total volume of which can be exploited in a sustainable manner and does not exceed 506 Mm3 / year.

Aquifer	HAOUZ-MEJJATE	BAHIRA	BOUSBAA	MESKALA	COTIERE ESSAOUIRA	TOTAL
Total inflow	**396**	**63**	**58**	**39**	**46**	**602**
Total outflow	**572**	**103**	**60**	**39**	**46**	**820**
Total aquifer	**-176**	**-40**	**-2**	**0**	**0**	**-218**

Table VII-1: Overview of aquifers (en Mm^3 / year)

3. Interannual variability

Analysis of annual height data for a few stations covering the Haouz and Marrakech basins, including the Marrakech (plain), Lalla Takerkoust (Lalla Takerkoust Dam), Nkouris (upstream Yaakoub Al Mansour) and the Aghbalou, Tahannaout and Imi Hammam dominating the relief of the High Atlas upstream of the Haouz, shows a high interannual variability of rainfall. This variability is represented by coefficients of variation (CV) between 30 and 45%, indicating a strong irregularity of precipitation compared to an average year. Moreover, the statistical adjustment of the annual cumulative precipitation at the level of the studied stations allowed us to translate this variability into the probability of occurrence associated with percentiles. Thus, in general, 80% of the annual precipitation quantities received on the basins (decile of 20%) constitute only 70% of the interannual average.

Hydrological variabiliy at Lalla Takerkoust reservoir

The analysis of the flows based on the annual records at the Lalla Takerkoust dam, with a surface area of 1,707 km², also shows a high inter-annual variability of wadis flows, reflecting an expanded response and greater variability than the already significant variability observed in the precipitation series. The Coefficient of Variation CV of annual flows is CV_Q = 0.78, compared to CVP = 0.33 for precipitation; so the elasticity of runoff[1] to precipitation is about CV_Q / CV_P = 2.4.

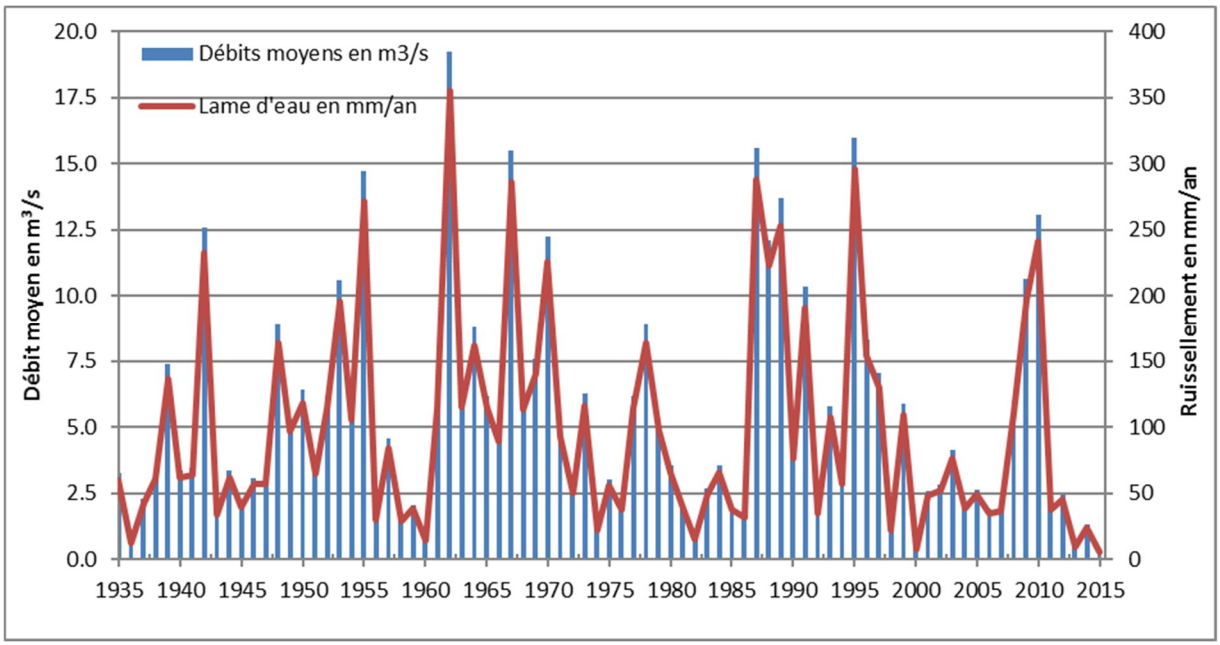

Figure VII-2: Evolution of inflow to Lalla Takerkoust reservoir

The correlation between annual rainfall (Lalla Takerkoust and Nkouris stations) and annual runoff at Lalla Takerkoust dam is only moderate (about R = 0.8, Figure 2) and does not provide a solid guide for estimating the coefficient of elasticity of runoff for precipitation (the power coefficient in FIG. 12 is about 2.06, whereas the elasticity according to the CV_Q / CV_P estimate is of the order of 2.4, an approximate value close to the values found for the basin of the Oum Er Rbia. This coefficient reflects the relationship between a rainfall variation P / P and the corresponding variation of runoff Q / Q (see right panel in the figure below).

The statistical adjustment of annual flows allowed us to translate this variability into the probability of occurrence associated with percentiles. Thus, in general, 80% of the inputs (decile of 20%, or approximately 57 Mm3 / year) constitute only 31% of the interannual average (186 Mm3 / year). Note that theoretically according to the normal probability distribution, the decile of 20% is equivalent to (1 - 0.842 CV_Q) * average, so 34% of the average.

[1] The elasticity of the flow to precipitation and temperature defines the reaction of the flow to changes in rainfall and temperature (due to changes in evapotranspiration). A precipitation elasticity of 2.4 suggests that a 10% decrease in rainfall leads to a 24% reduction in runoff. A sensitivity at -4% per ° C suggests that a 2.5oC increase in temperature results in a 10% decrease in flow.

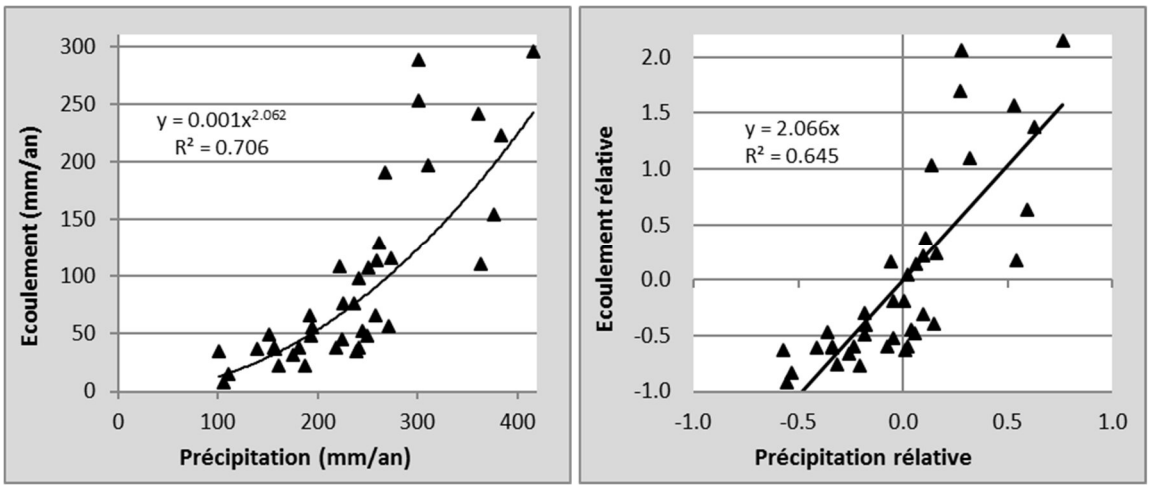

Figure VII-3: Correlation between the inputs to the Lalla Takerkoust dam and the average precipitation of the basin, derived from the Lalla Takerkoust and Nkouris stations for the period 1973 to 2012; left panel: absolute values; right panel: changes from the average

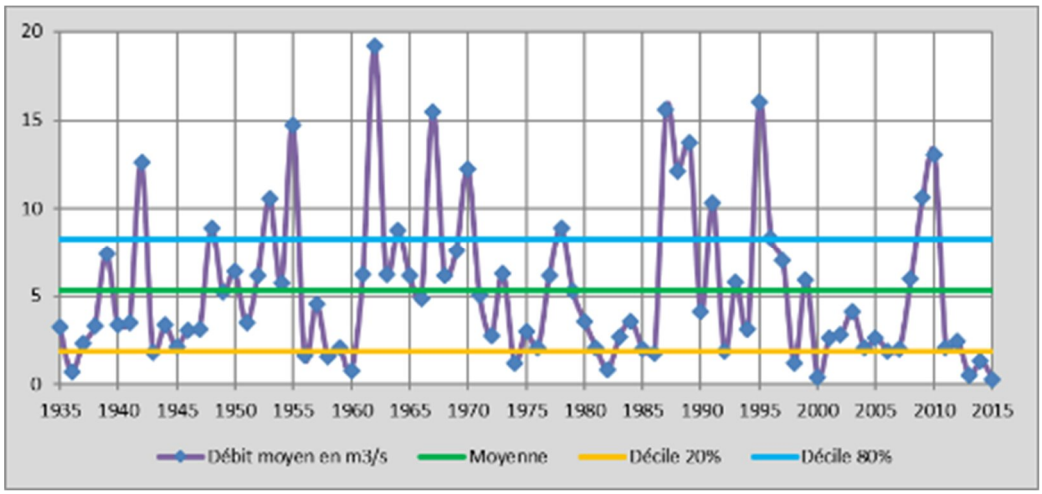

Figure VII-4: Evolution of inflows to Lalla Takerkoust (with averages and centiles)

Year type	Deciles	Lalla Takerkoust dam	
		Flow (m^3/s)	Inflow (Mm^3/year)
	10%	1.1	33.6
Dry	20%	1.8	57.3
	30%		80.7
Medium	40%	3.3	105.6
	50%	4.2	133.2
	60%	5.2	165.4
Wet	70%	6.5	205.3
	80%	8.2	259.3
	90%	11.0	348.2

Table VII-2 : Year inflows at the inlet of Lalla Takerkoust reservoir

In addition to the interannual cyclical variability, a series of alternations between wet episodes and dry episodes, the analysis of the inflow series also shows a multi-decadal trend towards a reduction in

these inflows. This long-term downward trend was analyzed by calculating averages over 30-year periods lagged 10 years. This calculation makes it possible to demonstrate a succession of "normal climatologies" with a decrease in stairs since 1940. Thus, between 1941 and 1951-1980 and the period 1981-2010, the significant decrease in inflow reached 25 Mm3 / year, ie 12.5%, or 200-175 Mm3 / year.

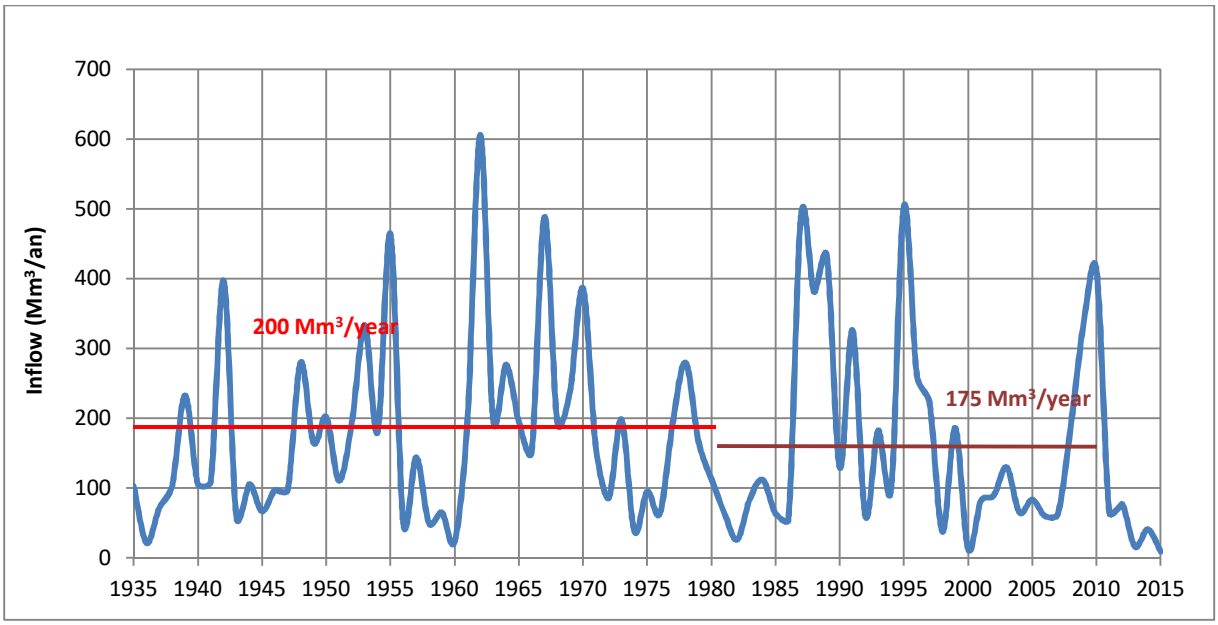

Figure VII-5: Evolution of inflows to Lalla Takerkoust dam – comparison between 30-year averages 1940 - 1980 and 1981 – 2010

Hydrological variability at Hassan 1er dam complex

The analysis of the flows based on annual records at the Hassan I dam also shows a high inter-annual variability of the wadis flows, reflecting a logical response of the same variability observed on the precipitation series. The statistical adjustment of annual flows allowed us to translate this variability into the probability of occurrence associated with percentiles. Thus, in general, 80% of the inputs (decile of 20%, ie approximately 149 Mm3 / year) constitute only 57% of the interannual average (260 Mm3 / year);. Note that according to the normal probability distribution, the decile of 20% is equivalent to (1 - 0.842 CV_Q) * average, so for CV_Q = 54% (for Hassan 1er) 55% of the mean is found. Thus, for Hassan 1st, the CV_Q / CV_P ratio is 54% / 24% = 2.25 (elasticity of runoff for precipitation upstream of the Hassan I dam).

Year type	Deciles	Hassan 1er	
		Flows en m³/s	Inflow in Mm³/year
	10%	3.6	112.8
Dry	20%	4.7	148.9
	30%	5.7	179.4
Average	40%	6.6	208.8
	50%	7.6	239.0
	60%	8.6	272.0
Wet	70%	9.8	310.6
	80%	11.4	360.1
	90%	13.9	436.8

Table VII-3 : Year inflows at the inlet of Hassan 1er dam complex

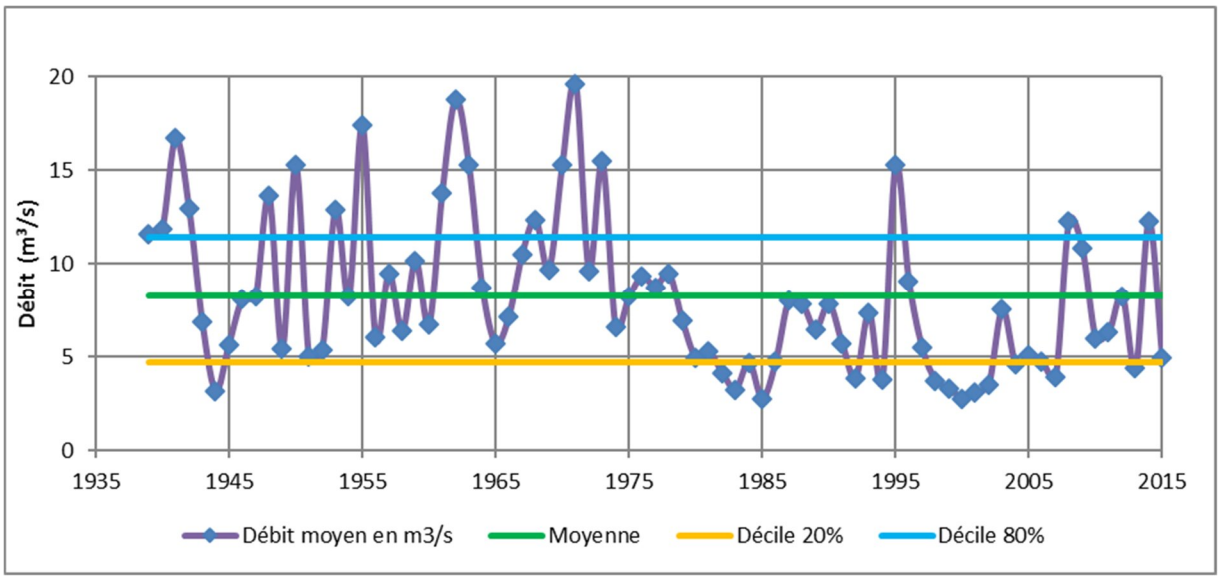

Figure VII-6: Evolution of inflows to Hassan 1er (with averages and centiles)

In addition to the inter-annual cyclical variability, reflecting a succession of alternating wet episodes and dry episodes, the analysis of the inflow series also indicates a multi-decadal trend towards a reduction in these inputs, particularly an abrupt decline from 1980 onwards. This abrupt and long-term decline was analyzed by calculating averages over 30-year periods lagged by 10 years. This calculation makes it possible to highlight a succession of "normal climatologies" with a decrease in stairs since 1940.

Thus, between the period before 1980 and the period after 1980, the significant decline in inflows reached 134 Mm3 / year, ie 42% (compared to 12.5% for the Lalla Takerkoust dam), ie 320 to 186 Mm3 / yearr, caused by a decrease of approximately 17% in the upstream precipitation of the dam, a ratio of 2.46.

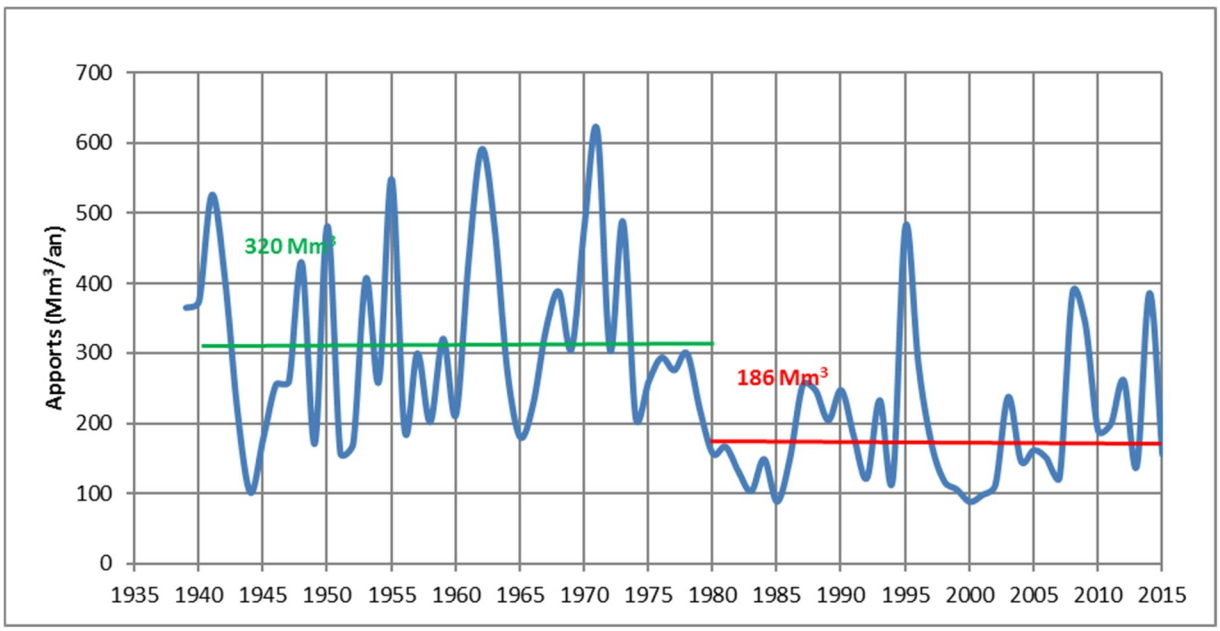

Figure VII-7: Evolution of inflows to Hassan 1er dam complex – comparison between 30-year averages 1940 - 1980 and 1981 – 2010

Conclusion on hydrological variability

- Rainfall in the Tensift Basin is characterized by high inter-annual variability with coefficients of variation of the order of 30%, even in the OER Basin.
- This rainfall variability is reflected in the hydrological response by a significant variability of the flows and surface inputs (approximately 60% in the OER basin), in particular those regulated by dams. The coefficients of variation of the inflows calculated for the Lalla Takerkoust dam are 78%, reflecting this high variability.
- Water balances have been calculated in all planning evaluations by adopting an average year, but the effect of drought episodes (especially episodes of 2 or more consecutive years) is a real the low inter-annual storage capacity of the structures.
- By adopting a dry year threshold corresponding to the decile of 20%, the dry year inputs constitute respectively 57% and 35% of the average of the contributions for the Hassan 1 dam and for the Lalla Takerkoust dam.

4. Potential climate change impacts on water availability

Long-term downward trends in precipitation at the study area level were highlighted by, inter alia, inflows to dams (see above). This trend may be due to climate change and is consistent with several climatological studies that have revealed similar trends on precipitation.

The vulnerability study presented in the report of Morocco's Third National Communication (MCN) to the United Nations Framework Convention on Climate Change (April 2016) provides some assessments of the future impact of climate change by 2100 Climate projections include annual precipitation and average annual temperatures for two IPCC scenarios, RCP 2.6 and RCP 8.5 and for the IPCC deadlines in its 5th report. For all time horizons, the report shows a downward trend in annual cumulative precipitation ranging from 10 to 20%, reaching 30% in the Saharan provinces by 2100. For average annual temperatures, upward trend of 0.5 to 1 ° C is projected to 2020 and at least 2 to 2.5 ° C by 2050 and 3 to 3.5 0C by 2080, for the entire country. The report concludes that these impacts will result in reductions in reservoir inputs in the range of -7% to -40% depending on the scenario by 2080.

Assessment of climate risks for the Oum Er Rbia basin

A World Bank (2017) Climate Risk Assessment (ERC) study was conducted using a set of general circulation models (GCMs) and stressed the importance of not to favor certain models to the detriment of others. This multi-model assembly approach was considered the most appropriate for assessing the impacts of climate change on the basin's water resources. This helps to reduce the effects of model errors in a particular model and the natural variability in a particular cycle. The main conclusions of this evaluation are as follows:

- Future projections of precipitation and temperature vary widely for the Oum Er Rbia basin following several GCM models. The basin and Morocco expect a much drier future. Almost all projected future flow changes are negative.
- The elasticity of rainfall runoff is estimated to be 2.0 for the runoff part of the OER basin. For this region, the temperature sensitivity of runoff is estimated to be about -4% per 0C.
- Differences between individual precipitation projections are significant, with a standard deviation of 10% by 2050. Most CMIP5 projections range between -40% and 0% rainfall variation. The wide range of precipitation projections in multiple CWMs justifies a simplified analysis based on climatic elasticities of runoff.
- In 2050, precipitation is expected to decrease by about 20% and the expected increase in temperature is around 2.5 ° C, which on average gives a reduction of runoff of about 50%.

- Projections of climate change have not changed much between A1B and A2 (CMIP3) and the Representative Concentration Pathways (RCP) scenarios 4.5 and 8.5 (CMIP5), although projected rainfall decreases slightly less for CMIP5 compared with CMIP3.
- The GCMs that best reproduce the past climate are not surely the best performers for climate predictions of the 21st century and the significant uncertainty in the GCMs individually prompts us to use a set of models for a better assessment of future climate change.

The study by Khomsi et al. (2016) on the regional impacts of global climate change and their seasonal trends (extreme precipitation, temperature runoff) was carried out on two contrasting regions of Morocco (Bouregreg and Tensift). It was conducted in a statistical way using the climatological and hydrological data of the 2 basins on a relatively long series. For all gauging stations studied, outside the Tahanaout station where a change was detected in the spring of 1996, no significant change points were detected. During most of the four seasons, most trends in runoff are low. None of the seasonal trends are statistically significant.

In the winter, some declining trends appear in the Tensift watershed. In the spring, and for the Tensift Basin, bearish trends are observed at stations near the mountains. This downward trend in runoff in the Tensift Basin has been attributed to the decrease in snowfall in high areas.

Although data on future predictions of the effects of climate change remain subject to many uncertainties, inherent in the nature of the climate process itself and its complexity, and difficult to capture precisely by GCMs, it is likely that these changes, which have already occurred in the past, continue with greater intensity. An order of magnitude of these changes remains a major scientific challenge, but by cross-checking all available data from various evaluations, we are justified in assuming the following impacts:

Indicator	**Impacts**
Average annual precipitation	The general annual decrease in precipitation by 2050 in the proportions given in the CGM climate projections is at least in the range of -10% to -30%.
Average annual flows	The annual general decline in precipitation and the increase in temperature, and consequently the increase in evapotranspiration, will adversely affect flows and inputs; the changes are at least between -20% and -50% by 2050.
Extreme drought events	The significant extension of the maximum drought period on an annual basis will result in disruption of groundwater levels and a weakening of the capacity to rebuild reserves.
Mean temperature	Warming in all seasons combined with an increase in average temperature from 1 ° C to 3 ° C will in particular impact water demand by exacerbating evaporation and evapotranspiration, and may also cause a decrease in intakes of the order of 10% by 2050. This warming is more pronounced in summer than in winter, demand for drinking and agricultural water will be subject to additional pressure that may create seasonal imbalances requiring more adapted mobilization and distribution structures .

Table VII-4: *Impacts of climate change on drought inputs and events*

Future water balance in the Tensift bassin

The combined effect of climate variability (CV) and climate change (CC) will be felt in the long term, presumably with a resonance due to the likely exacerbation of climate variability by climate change. These scenarios are combined in the following table:

Type of drought (CV)		Reduction of inflow due to climate change (CC)		
		0%	25%	50%
Very dry year (10th decile)	60%-80%	70%	77.5%	85%
Dry year (60th decile)	40%-60%	50%	62.5%	75%
Average year	0%	0%	25%	50%

Table VII-5: Combined climate variability and climate change scenarios for Marrakech

Using the combined effect of climate variability (VC) and climate change (CC), scenarios were constructed as follows:

- Climatic variability (CV) was assumed to have no significant effect on the Al Massira adduction given the large capacity of the dam reservoir (2,760 Mm3) to regulate multi-annual flood waters. This hypothesis is realistic today but assumes that the climate variability in the future would be the same as today, which is not demonstrated. It is even likely that this variability will be accentuated by climate change. For transfers to the Al Massira reservoir, the effect of CCs on the volumes available for transfer remains more attenuated than on volumes lost to the ocean.
- For Al Massira, climate change would take place on both the own and the import side in the event of a transfer from the North. Climate change is therefore a realistic scenario that must be integrated into the long-term vision of the Massira-Marrakech transfer.
- For the Lalla Takerkoust and Hassan 1st dams, the effects of CV and CC are inevitably combined. The assumptions made allow us to see the combined effect of inter-annual drought and climate change.
- For water withdrawals from wadis, the effects of the CV are already being felt because in general irrigation is not perennial and follows the wadi regime. In the future, CCs also inevitably combine with this CV. The assumptions made allow us to see the combined effect of inter-annual drought and climate change.

The results of this evaluation are summarized in the following tables, from which the following observations can be made:

- In the medium year, climate change would impact the water balance of the Marrakech area by a deficit widening to 324 Mm3 / year by 2050 for a realistic projection, worsening to 650 Mm3 / year by 2050 for a pessimistic projection
- In the dry year, climate change would affect the water balance of the Marrakech area by a deficit increase of 700 to 900 Mm3 / year by 2050.
- The most catastrophic scenario, associating the occurrence of a very dry episode in a CC context, would correspond to a deficit of more than 1 000 Mm3 / year.
- The impacts of the combined scenarios of variability and climate change on the water balance of the groundwater (El Haouz water table) in the Marrakech region (2050) are estimated in the following tables.

The combined effect of climate change and climate variability would result in a balance deficit of up to 1,300 Mm3 / year in the most catastrophic scenario in the future by 2050. This deficit due to climatic risks would be added to the deficit already observed, which has been documented in the previous parts of this report, namely in particular the groundwater deficit, now reaching 176 Mm3 / year. The surface water deficit, which is already at the current level of 74 Mm3 / year (see 2.3 above), should be offset by a transfer of water from the Al Massira dam, but this should also be offset by a transfer from the North, which should also experience similar reductions in precipitation and flow.

Table VII-6: Impacts of the combined scenarios of hydrological variability and projected climate change on the water balance of the Marrakech region (2050 horizon)

				Réduction des apports	0%	25%	50%	50%	62.5%	70%	75%	77.5%	85%
				Climate change	optimistic	realistic	pessimistic	optimistic	realistic	pessimistic	optimistic	realistic	pessimistic
				Climate variability	Average year	Average year	Average year	Dry year	Dry year	Dry year	Very dry year	Dry year	Very dry year
Sector	**Demand in 2050 Mm³/yr (*)**	**Surface water resources**	**Total volumes – baseline situation**	**Surface water volumes – baseline situation**	**Expected reductions in water availability Mm3/year**								
Municipal water	189	Massira Conveyance	132	132	-	17	33		17		33	17	33
Municipal water		Canal Rocade + Lalla Takerkoust	57	365	-	91	183	183	230	256	274	283	310
Large irrigation	308		308										
Small irrigation	565	Lalla Takerkoust	565	565	-	141	283	283	356	396	424	438	480
Private irrigation Privée	259	Aquifer	259										
Seguias from river	300	Oueds	300	300	-	75	150	150	189	210	225	233	255
Seguias from groundwater	65	Aquifer	65										
Total	1 686		1 686	1 362	-	324	648	615	791	861	956	970	1 079

(*) – Source : see related Annex

Table VII-7: Impacts of the combined scenarios of hydrological variability and climate change on the water balance of the groundwater of the El Haouz aquifer (2050)

	Groundwater – baseline situation	0%	25%	50%	50%	63%	70%	75%	77.5%	85%
		optimistic	realistic	pessimistic	optimistic	realistic	pessimistic	optimistic	realistic	pessimistic
		Average year	Average year	Average year	Dry year	Dry year	Dry year	Very dry year	Dry year	Very dry year
Type of inflow	**Inflows (Mm³/year)**	**Expected reuduction in the combined CC and CV scenarios**								
Rainwater infiltrations (*)	144	0	14	29	29	36	40	43	45	49
Infiltrations from oueds riverbeds	37	0	9	19	19	23	26	28	29	31
Irrigation backflow	166	0	42	83	83	105	116	125	129	141
Séguias backflow	38	0	10	19	19	24	27	29	29	32
Lateral inflow Southern piedmont	11	0	1	2	2	3	3	3	3	4
TOTAL	396	0	76	152	152	191	212	227	235	258

(*) The reduction in rainwater infiltrated was calculated by taking into account an elasticity coefficient of 2.5 between runoff and precipitation

Table VII-8: Synthesis of the impacts of hydrological variability and climate change on the water balance of the Marrakech region (2050)

	0%	25%	50%	50%	63%	70%	75%	77.5%	85%
	optimistic	realistic	pessimistic	optimistic	realistic	pessimistic	optimistic	realistic	pessimistic
	Average year	Average year	Average year	Dry year	Dry year	Dry year	Very dry year	Dry year	Very dry year
Type of deficit	**Expected reuduction in the combined CC and CV scenarios**								
Surface water	0	324	648	615	791	861	956	970	1,079
Groundwater	0	76	152	152	191	212	227	235	258
Total	0	400	800	767	982	1,073	1,183	1,205	1,336

ANNEX VIII - Current water supply sources for the city of Marrakesh

1. Canal de Rocade

The Rocade Canal was designed and put into operation following a decision to transfer all the inputs from Wadi Lakhdar to Tensift, with the exception of the water rights recognized downstream of Sidi Driss (estimated at 10 million m3 / year). With the construction of the Hassan 1st complex - Sidi Driss and the Canal de Rocade, the region of Marrakech has since 1985 benefited from a transfer of water from the Oued Oum Er Rbia basin. The Rocade Canal carries raw water on a 118 km line and has a transit capacity of 20 m3 / s. In the middle year, the canal should carry a volume of around 300 Mm3 / year, including 50 Mm3 / year to supply the town of Marrakech with drinking water and 250 Mm3 / year for the irrigation of the N'fis perimeter (34,000 ha) in the central Haouz area.

Successive droughts over the past 35 years have significantly reduced the inputs to dams, resulting in low fill rates of dams, especially during drought years. For the Hassan 1st dam, the mean filling over the period from 1981 to 2015 is for example 42% lower than in the period from 1941 to 1980. For this reason, the flows transferred rarely exceed 200 Mm3 / year; for example, from 2009 to 2015 the average throughput of the canal was 196 Mm3 / year, of which 64 Mm3 / year for the Marrakech municipal water supply and 132 Mm3 / year for irrigation. This reduction is therefore deferred to the agricultural subsidies which are still subject to the reductions due to climatic fluctuations, municipal water remaining untouched. The reality is that recently allocation to municipal water often exceeds 60 Mm3 / year to the detriment of irrigation. In a future marked by the effects of climate change, there is every reason to believe that the rules governing the operation of the canal will always remain the same, with the result that the agricultural allocations will be reduced drastically.

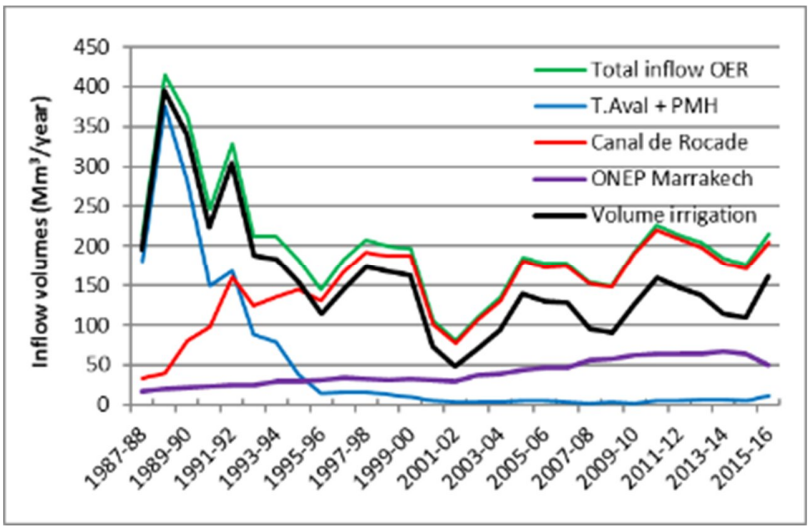

Figure VIII-1: Transfer of water from the OER basin to the Tensift basin and the distribution between the municipal water of Marrakech and the irrigation of the N'fis perimeter

2. Barrage de Lalla Takerkoust

The construction of modern hydraulic structures in the Tensift basin began in the 1930s with the construction of the Lalla Takerkoust dam on Oued N'fis for irrigation of the N'fis perimeter. The Yacoub - Al Manssour - Lalla Takerkoust Complex was constructed to provide an annual volume of nearly 107 Mm3,

including 90 Mm3 (84%) for irrigation of N'fis and 17 Mm3 (16%) for feeding drinking and industrial water in the city of Marrakech. Although the latter is given priority over the N'fis perimeter, its guarantee is not ensured because the frequency and intensity of droughts could increase and the storage volume could decrease due to siltation of the Lalla Takerkoust complex. The Lalla Takerkoust dam was raised by 9 meters in the early 1980s and was reinforced by the construction of the Ouirgane dam.

The figure below shows the current releases from the Lalla Takerkoust reservoir for irrigation of the N'fis perimeter and AEP for Marrakech. Successive droughts after 1980 have significantly reduced inputs to the Lalla Takerkoust dam reservoir (the average for the period 1981-2008 is 46% lower than in 1941-1980), resulting in low the rate of filling of the reservoir during the drought years. That is why, in reality, the contribution for the Marrakech water supply has been much less than 17 Mm3 / year in recent years.

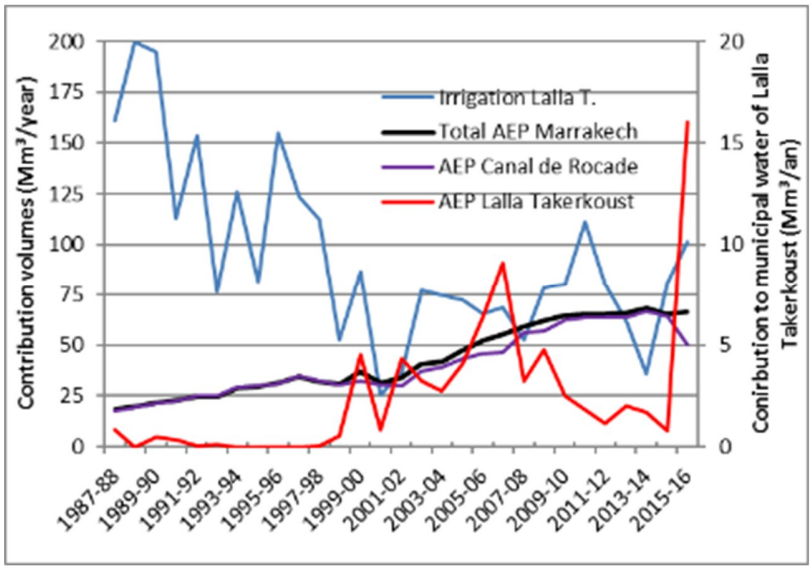

Figure VIII-2: Distribution of water resources from Lalla Takerkoust dam between municipal water and irrigation.

The supply for AEP of Marrakech from Lalla Takerkoust. In reality, it varies most of the time between 1 and 4 Mm3 / year. The total municipal water supply for Marrakech, including the supply of the Rocade Canal has been nearly constant since 2010 at 66 Mm3 / year.

The combined effect of the negative impacts of climate change and the silting capacity loss of Yacoub-Al Mansour and Lalla Takerkoust reservoirs would result in a substantial reduction in water resources mobilized at of the branch of N'fis. As a result, it is planned that the contribution of the Lalla Takerkoust complex would be zero from 2030.

3. Potable water conveyance from Al Massira dam to Marrakesh

The National Water Plan has planned a major water transfer project from the Oued Laou, Loukous and Sebou basins via the Al Massira dam, with the aim of strengthening the water resources of basins of Bouregreg, Oum Er Rbia and Tensift. This transfer was devoted as a scenario in the PDARs of the basins concerned. The North-South transfer, staggered by phasing, provides for a first phase transfer of 300 Mm3 / year from the Sidi Mohammed Ben Abdellah dam on the Oued Bouregreg to the Al Massira dam (gallery with flow of 10 m3 / s). During phase I, the transfer is not intended to cover the chronic deficit of the Oum Er Rbia but only to offset the water exports for AEP to Casablanca and Marrakech (440 Mm3 / year).

The Al Massira - Tensift transfer, with a gross volume of 100 Mm3 / year (net 95 Mm3 / year), which was logically conditioned by the upstream transfers, will actually be carried out before these transfers. The impact of this transfer without compensation for the Al Massira dam will result in a widening of the deficit at the level of the Oum Er Rbia which will be passed on to the agricultural water endowments of the Doukkala perimeters. These impacts are already visible in years of drought.

Figure VIII-3: Schematic of the planned drinking water supply infrastructure through the "North-South Transfer" via the Al Massira Dam (source ONEE)

There is currently no formal decision on the scheduling of these transfers and the scenarios of the national water strategy are not rigorously applied. This case was handled urgently to avoid a water shortage at the level of Benguéris and Marrakech. Since drinking water always has priority over agricultural water, any deficit, whether due to climate variability, climate change or the reduction of water available in the reservoir due to an off-shore transfer basin, automatically reverts to irrigation.

Work on the first tranche of this transfer is underway. The start date of the first phase of this project, currently being implemented by ONEE with funding from the African Development Bank (AfDB) and the Office Chérifien de Phosphate (OCP), is scheduled for 2018. Phase I of the project for the supply of drinking water under construction is designed to produce in 2030 a drinking water volume of 78 million m3 / year for the municipal water supply of the city of Marrakech and the urban center of Tamensourt. The water balance is used "en route" for the Benguéris municipal water supply and other centers and projects.

The first phase of the project includes components related to production, storage and water supply, as follows:

Construction of a raw water intake from the Al Massira dam (7 m3 / s, including phases Ii and III)

Installation of a raw water supply line (diameter 2'000 mm, linear about 3 km)

Construction of a clearing station (3.5 m3 / s)

Laying of a drainage pipe (diameter of 1,600 to 2,000 mm, linear of approximately 45 km)

Construction of 2 tanks (R1, RMC1)

Construction of 2 pumping stations (SR1: HMT 182m and SR2: HMT 182m)

Construction of a treatment plant (capacity = 2.5 m3 / s = 79 Mm3 / year)

Installation of a pipe for the supply of treated water (diameter of 1,300 to 1,800 mm, linear of approximately 65 km) from the treatment plant to Marrakech

Construction of 3 reservoirs (R2, RMC2 and North reservoir)

Construction of a pumping station SR3 (HMT of the order of 100m)

The analysis of the water balances in makes it possible to draw the following conclusions:

Despite the realization of the drinking water supply from the Al Massira dam, the drinking water supply of the great Marrakech will remain fragile especially on the side of the ring road; this supply is assured to the detriment of irrigation of the perimeter of the Haouz Central;

Supply capacities are sufficient to ensure safe drinking water supply in good conditions beyond 2030;

In the absence of the necessary structures to effect the interconnection between the existing water reservoirs of RADEEMA and the reservoirs for the water supply from the Al Massira dam, the water withdrawals operated to meet drinking water requirements are higher than the allocation allocated to drinking water at the level of the adductions from the bypass channel and less than the allocation allocated to drinking water at the level of the Al Massira conveyance.

The construction of the interconnection structures between the different reservoirs is necessary to secure and diversify the drinking water supply in the greater Marrakech;

With the use of drinking water supply from the Al Massira dam and the bypass channel, the challenges of energy management are clearly linked to problems of technical and economic optimization and rationalization of management; water-energy-food interactions therefore represent a stake in technical and economic development and optimization and management rationality.

The construction of the interconnection works would result in an improvement in the safeguarding of the drinking water supply in the greater Marrakesh and the provinces of Benguerire, El Kelaa Sraghna and Azilal and reduced pressure on perimeter irrigation the Haouz Central and N'fis. The analysis of the water balance adjusted to take into account the construction of the interconnection structures allowing a transfer of 50 to 60 Mm3 / year between the two water sources, makes it possible to draw the following conclusions:

The water supplies from the Hassan 1 - Sidi Driss and Al Massira dams correspond to those allocated under the UAR Er Rbia and Tensift PDAR projects;

The allocation to be taken from the Hassan 1er - Sidi Driss complex is considerably less than the capacity of the existing treatment plant (3.1 m3 / s = 98 Mm3 / year); this allocation remains high to be secured during the drought years.

The water supply from the Al Massira dam would be exploited in full capacity, which would affect the operation of the drinking water distribution networks and enriched the energy costs;

Taking into account the water supply reserved for OCP (18 Mm3 / year) and the cities of Casablanca, El Jadida, Safi and Marrakech, drinking water withdrawals from the Al Massira dam would be around 450 million m3 / year. During a period of drought, equivalent to that observed from 2000 to 2007, irrigation cessation would be necessary to avoid a rupture of the water stock at the Al Massira dam;

Solutions to reduce the supply of drinking water from the Hassan 1 - Sidi Driss complex and the Al Massira dam and to reinforce the water resources at the level of these structures would be necessary to secure and strengthen the diversification of the drinking water supply of the great Marrakech.

The current project is not taken into account in the financial and economic analysis in this report as it is the infrastructure already existing soon. On the other hand, the costs of Phases II and III of the supply of drinking water from Al Massira to Marrakech are taken into account. The aim of Phase II will be to complete Phase I by constructing the interconnection structures between the RADEEMA reservoirs to ensure that during periods of drought the city of Marrakech can rely solely on the water resources of the Al complex Massira.

The Hassan 1 - Sidi Driss complex could not provide both the supply of drinking water to the city of Marrakech and the minimum water supply for the Haouz perimeter, which was adopted as part of the Oum Er Rbia and Tensift PDAIRE, especially during periods of drought, similar to that observed in the post-1980 period. The third phase of the project should therefore be carried out by doubling the works of the first phase, including a new treatment plant the same capacity of 79 Mm3 / year), with the exception of the intake. The third phase of the project should be carried out from 2025.

4. Haouz aquifer

The exploitation of groundwater for the supply of drinking water to the Grand Marrakech is largely affected by the overexploitation of the Haouz groundwater. Until 1963, the exploitation of the Haouz aquifer for the purposes of the water supply of the city of Marrakech was done solely by natural drainage. From 1984, the date of commissioning of the supply from the Canal de Rocade, pressure on groundwater resources decreased and drinking water abstractions from the various catchments were reduced. From the year 2000, and following the significant declines in the groundwater level due to overexploitation for irrigation, ONEE began to strengthen the city's drinking water from surface water. Tensift's PDAIRE allocated groundwater resources exclusively to irrigation, and the supply of potable water to Marrakech from the groundwater was therefore reduced to almost zero. The graph below shows the evolution of groundwater production in the city of Marrakech. Currently a small amount of groundwater is still used by some golf courses (2 Mm3 / year).

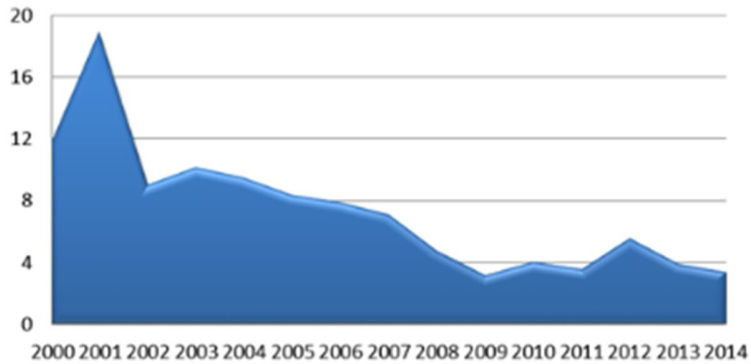

Figure VIII-4: *Evolution of groundwater production (Mm3 / year) in the Marrakech city perimeter (source: ONEE)*

Historically, this area is dependent on groundwater as the main water resource, but the pressure on groundwater is increasing from year to year, largely due to the development of large-scale irrigation, tourism and population growth. This increase in demand is currently leading to a decline in the groundwater level in some sectors: the average water level declines observed over the past 20 years are in the order of 0.8 to 1.6 m / sectors of N'fis and Central Haouz and 0.2 to 0.5 m / year in the eastern sector (CBSC, 2001).

We present below the main conclusions of the last study to update the balance of the Haouz aquifer (GIZ, 2016). The report on the study of the integrated water resources management plan in the plain of Haouz (JICA, 2008) and the website of the ABHT were also used to present this synthetic section on the Haouz water table.

Characteristics: The Haouz aquifer covers an area of 6,859 km², between Wadi Chichaoua in the west, Wadi Tessaout in the east, Wadi Tensift in the north and the Upper Atlas range in South. Groundwater flows into plio-quaternary formations (clay sands, lacustrine limestones, pebbles and gravels with a sandy clay matrix), whose overall power varies between 50 and 80 m and can reach locally 120 m. These formations are deposited on the substratum of the Miocene marls or of the Viséen schists. The surface area of the groundwater is about 30 m below ground level, but is between 5 and 10 m along the Wadi Tensift and can extend up to 80 m along the foothills of the ground, Atlas. In areas where groundwater is intensively exploited, it is about 40 to 50 m. The productivity of the water table is generally good. They are a few liters per second and can reach 50 l / s in places; but as they move closer to the Piedmont area, they are becoming weaker. These productivities, which reflect very variable hydrodynamic characteristics of the water table (permeability and transmissivity), are due to the heterogeneity of the aquifer. Water reserves are estimated at between 7 and 9 billion m3 of water (Sinan, 2003) for an average annual recharge (2001-2013) estimated at around 400 Mm3 (GIZ, 2016).Natural feeding sources :

The natural feeding of the Haouz aquifer is made by:

- Direct infiltration of rainwater into the plain and the Eocene and Cretaceous formations of the Central High Atlas between 1300 and 1900 m and on the limestone and limestone limestones of the eastern Haouz between 1,200 and 1,600 m more of the infiltration of the waters of the wadis into the foothills of the Atlas.
- Infiltration of excess irrigation water (whether from groundwater or surface water)
- Preferential infiltration along the minor beds of the wadis and along the traditional séguias network
- The lateral contributions from the geological formations of the Atlas Mountains

- Upward drainage from the eo-Cretaceous aquifer formations which form, in some places, the substratum of the plio-quaternary series of the aquifer of the Haouz plain. This term is not considered in the GIZ (2016) balance sheet presented below. A study has just been launched by the ABHT to characterize this water table.
- Infiltration of rainfall on the plains contributes very little to the recharge of the groundwater due to the existence of a silt cover which limits the infiltration rate to 4% (GIZ, 2016). The piezometric monitoring of the water table shows that the water table does not react quickly during the rainy years.

Haouz aquifer - 2001-2013 overview: An analysis of the history of the water tables for the period 2001-2013 shows that the return of irrigation water to the groundwater is the most important part of the water supply (42% of the diet overall); followed by the infiltration of rainwater at the level of the plain and the right of the High Atlas (combined in the graph below to form 36%, the majority of which comes from infiltration at altitude). Infiltration of runoff contributes about 20%. The annual rainfall of 220 mm / yr is estimated to be at least 12% of the annual precipitation of 220 mm / yr.

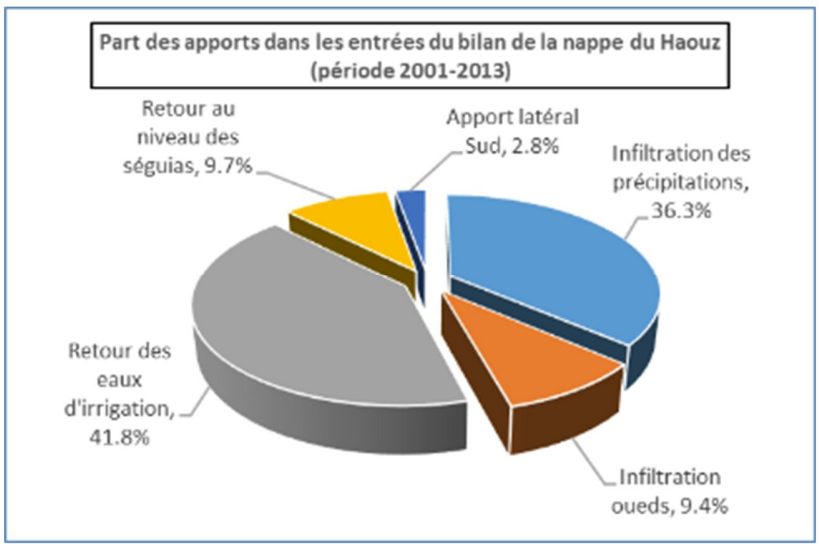

Figure VIII-5 : Inputs into the water balance of Haouz aquifer

	Inflow (Mm³)						Outflow (Mm³)				Total (Mm³)
Years	Infiltration from precipitations	Infiltration from oueds	Backflow from irrigation	Backflow from seguias	Lateral inflow - South	Total inflow	Agriculture	Pumping ONEE	Drainage Tensift	Total outflow	
2001-2002	117	18	160	26	11	331	663	84	2	749	-417
2002-2003	139	24	163	35	11	372	564	25	2	590	-219
2003-2004	175	44	159	40	11	430	457	25	2	484	-54
2004-2005	89	27	178	27	11	332	707	26	2	734	-402
2005-2006	180	37	148	42	11	419	392	21	2	415	4
2006-2007	107	34	162	36	11	350	552	22	2	575	-225
2007-2008	92	24	160	33	11	320	597	22	2	620	-300
2008-2009	222	68	173	70	11	544	255	22	2	278	266
2009-2010	177	69	158	53	11	467	385	22	2	408	58
2010-2011	175	37	181	46	11	449	555	22	2	579	-130
2011-2012	119	33	183	26	11	372	753	23	2	777	-405
2012-2013	137	32	164	27	11	371	635	24	2	660	-289
Average	**144**	**37**	**166**[2]	**38**	**11**	**396**	**543**	**28**	**2**	**572**	**-176**
Percentage	36%	9%	42%	10%	3%	100%	95%	5%	0%	100%	-44%

Table VIII-1: Balance of the Haouz aquifer - period 2001/2013 (Source: GIZ, 2016)

Nappe du Haouz - Piezometric history: Period 1970-2000

The analysis of the piezometric histories shows that the irrigation schemes (gravity irrigation) have had a definite influence on the water table:

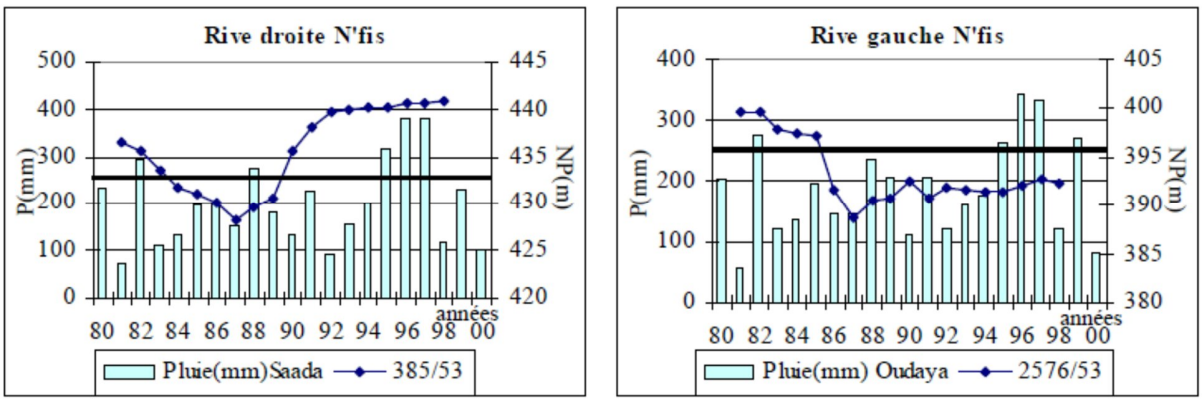

Figure VIII-6: Piezometric histories for the right and left bank of the N'fis river

The decline in the level observed before the irrigation schemes were achieved was mitigated by the return of irrigation water despite the increase in the number of wells and boreholes that were estimated at 25 000 in 2014 (ABHT, 2014). Most of the Haouz observation points show a decline in the groundwater level between 1981 and 1987. After 1987, various sectors experienced a piezometric rise of variable magnitude due to the decrease in the volumes of water pumped as a result of impoundment of irrigated perimeters from dams (Razoki, 2001). The Abourida analysis (2007) has been reproduced, which characterizes the behavior of the water table by sector during the period 1970-2000.

[2] Selon GIZ (2016) le 2/3ème de l'irrigation provient des eaux souterraines et le 1/3ème provient des eaux de surface.

At the N'fis sector, the 385/53 piezometer located on the right bank shows a decrease of 8 m between 1981 and 1987, ie more than 1 meter per year. From 1989 to 1992, an important upturn of about 9 m was recorded, related to the impoundment of the N'fis irrigation sector. After this date, the piezometric level underwent only slight variations despite relatively high precipitation in 1994, 1995 and 1996. This indicates that direct infiltration of precipitation has a lesser effect on groundwater feeding. At the left bank of the N'fis sector, the piezometer 2576/53 shows a decrease of 10 m between 1981 and 1987, followed by a rise of about 5 m between 1987 and 1990 due to the water supply of irrigation derived from the floods of the Oued N'fis occurred during these years.

Outside irrigated perimeters in the central Haouz, the relationship between rainfall infiltration and piezometric variation is not evident, runoff concentrated in the hydrographic network seems more important than the diffuse infiltration of rainfall. Thus, the piezometer located near the Wadi Tensift shows an erratic evolution, testifying to the important contribution of floods to the recharge of the groundwater.

On the contrary, other zones show a continuous decrease due to local overexploitation of the groundwater. In the upper Tessaout perimeter, the decline in the piezometric level between 1980 and 1987 ranges from 2 m to the north of the perimeter to 6 m in the west. This reflects an exploitation of the water of the groundwater, following the rainfall deficit during these years. After 1987, a slight rise of one meter is observed to the north of the area following the decrease in the volumes of water pumped from the groundwater, which is linked to the supply of surface water from the dams and to the increase of precipitation during 1988 and 1990.

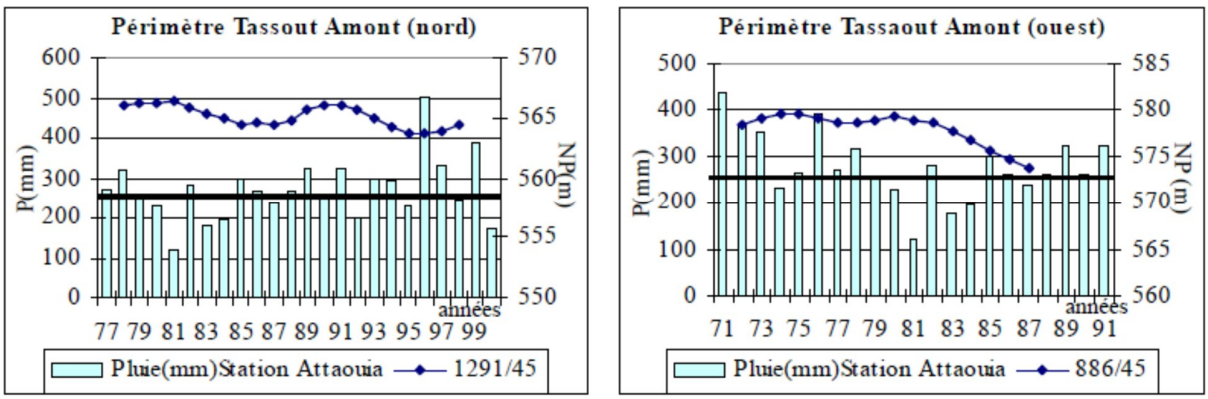

Figure VIII-7: *Piezometric history for the perimeter of Tessaout*

Haouz aquifer - Piezometric history: Period 2006-2014

Below is a presentation of the analysis of the GIZ report (2016) which characterizes the behavior of the water table by sector during the period 2006-2014:

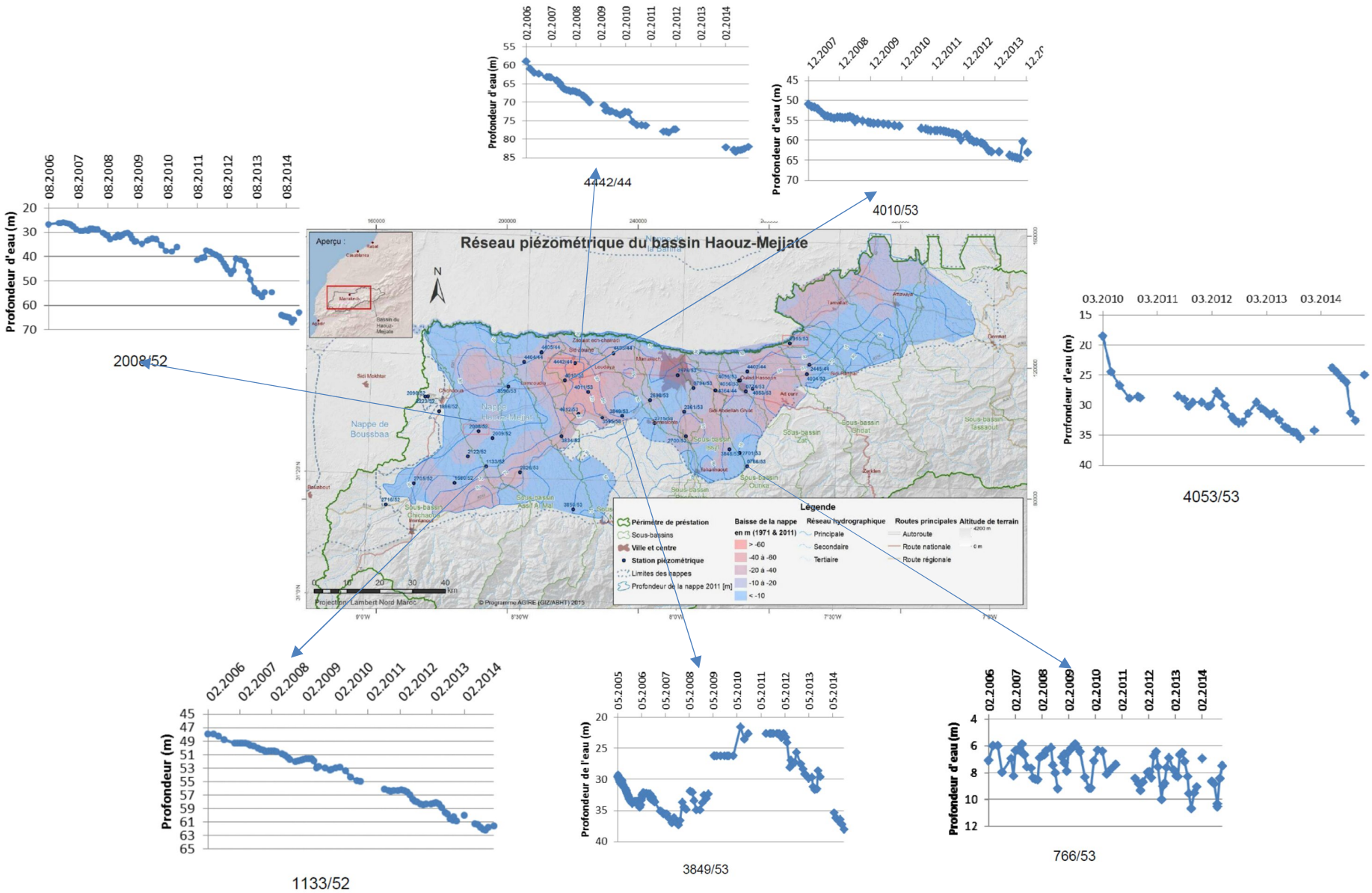

Figure VIII-8: Behaviour of the Haouz-Mejjate aquifer by sector

The effect of pumping caused total water table declines on the order of 20 meters on average and reaching 60 meters at the agricultural perimeters of N'Fis and Haouz Oriental. On the left bank in the upstream part of the N'Fis perimeter (Piézomètre n ° 3849/53) from May 2005 to January 2015, there is a succession of falls and risings corresponding to the succession of dry periods when pumping up and at wet periods when irrigation by regularized surface waters is relatively developed.

In the areas of Sidi Zouine (piezometer N ° 4442/44) and Loudaya (piezometers n ° 4010/53), there is a continuous decrease of 2.5 m / year and 2 m / year on average, respectively. These declines are caused by excessive pumping that compensates for the shortfall in surface water supplies from groundwater withdrawals.

In the wadi feeding zone (Oued Ourika, piezometer no. 766/53), the piezometric level fluctuates between 5 and 10 meters in depth depending on the extent of the wadi flow. In the Mejjate plain, a continuous decline ranges from 1.50 m / year (piezometer 1133/52) to 3.50 m / year (piezometer 2008/52).

At the level of the recharge thresholds on the wadi Imin zat (piezometer no. 4053/53), there is a succession of falls and risings of the static level, the mean piezometric level stabilizing at 25 m depth, probably due to the joint action of the spreading of flood waters downstream of the thresholds and irrigation using run-off samples by séguias in soil upstream of the thresholds which compensate for the water withdrawals by pumping. This behavior of the Haouz aquifer shows the dependence of its balance on returns of irrigation water and rainfall at the level of the High Atlas.

Impacts of the National Water Saving Plan for Irrigation (PNEEI): In the case of the Haouz basin, the implementation of the National Plan for the Saving of Water in Irrigation (PNEEI) reconversion of the irrigation of 80,600 hectares of large hydroelectricity (GH perimeters of N'Fis in the central Haouz and Tessaout upstream in the eastern Haouz) to localized irrigation (drip irrigation). This conversion of irrigation is one of the key measures to mitigate the impacts of water withdrawals on the Haouz aquifer. Indeed, among the expected effects of the PNEEI is the saving of irrigation water from about 20% to 50% (Belghiti, 2009). It is also expected that agricultural pumping would be significantly reduced, as the drip technique makes it possible to make significant savings on surface water and thus make this resource available over a longer period of the year and s partially free from pumping which occurrent in summer. With gravity irrigation, the surface water volumes used were such that surface water supplies were insufficient to cover the needs of summer cropping. During long periods of drought, even the winter water requirements of the perimeters are not fully satisfied.

Moreover, the saving of surface water through localized irrigation would lead to a reduction in the recharge of the water table by reducing the return of irrigation water. The latter are currently estimated at 166 Mm3 / year on average over the period 2001-2013 (GIZ, 2016). Considering that the share of surface water contributes about 202 million m3 / year (27%) of irrigation water and groundwater to 543 million m3 / year (73% 6.14), a recharge volume of 45 Mm3 / year originates from surface water and 121 Mm3 / year originates from groundwater, totaling 22.3% of the water supply for gravity irrigation. Thus, localized irrigation from surface water would result in a decrease of 25-45 Mm3 / year in irrigation surface water returns, - considering that due to potential agricultural intensification the recharge will much more affected than evaporation and sweating, and could even be completely eliminated.

The PNEEI does not advance an estimate of expected savings in groundwater withdrawals. These agricultural pumping currently amount to approximately 543 Mm3 / year and are mainly concerned with irrigated perimeters (see map of water table drops). Considering that the impact of localized irrigation is the same for surface water (20% to 50% reduction in water demand) and for groundwater, and that pumping will also be reduced by 20 % to 50%, drip irrigation would easily lead to a 50% to 100% reduction in the recharge of groundwater irrigation. Consequently, the net water balance of the aquifer could

improve with 25 to 100 Mm3 / year. However, there are many reports that drip irrigation often occurs with intensification of agriculture, resulting in unchanged losses for evaporation and transpiration, and complete elimination of recharge of the plant. aquifer. In this case, the net water balance of the aquifer would remain unchanged under drip irrigation. Thus, drip irrigation would slightly improve the net balance of groundwater or leave the same unchanged.

Climate change: The negative effects of climate change in 2050 (average scenario) would result in a reduction in rainfall of about 20% and a reduction in water intakes of about 50 %. These decreases would lead to increased pressure on groundwater by farmers to meet crop rotation water requirements. The table below shows the mean balance of the Haouz aquifer corresponding to the current period (2001-2013) and the projected aquifer balance by 2050.

Scenario	Infiltration des précipitations	Infiltration oueds	Retour des eaux d'irrigation	Retour des séguias	Apport latéral Sud	Total entrées
Actuel	144	37	166	38	11	396
Impact CC	– 20%	– 50%	- 45 (eau de surface)	- 50%	– 20%	-114
Avec CC - moyen	115	18	121	19	9	282

Table VIII-2 : Average balance of the Haouz aquifer - current and with the impact of the average climate change scenario (in Mm3 / year)

For example, a 20% decrease in rainfall and 50% in runoff, with the same net water withdrawal and groundwater return (recharge) but with a decrease in surface water recharge, would result in an increase in the net water deficit of 114 Mm3 / year in addition to the existing deficit (176 Mm3 / year), ie a deficit of 290 Mm3 / year.

On the other hand, the years when the balance sheet of the aquifer is deficit would be more frequent than at present, which would aggravate the overexploitation of the aquifer already observed in certain sectors of the aquifer. These additional deficits would result in a decrease in the non-renewable reserves of the aquifer and a decrease in the productivity of the catchments. To compensate for groundwater losses due to the decline in returns from irrigation water, either artificial recharge in irrigated areas should be provided or the volumes of water withdrawals from the water table should be reduced by pumping. The latter option involves a reduction in irrigated areas and / or the replacement of high-consumption crops by those who consume less per hectare per year.

Conclusion

The piezometric observations of the Haouz aquifer show the extent to which the latter is solicited by agricultural samples, as well as its dependence on returns of irrigation water to ensure its recharge.

Figure VIII-8 shows the map of decreases in the piezometric levels between 1971 and 2011. The areas with the biggest declines are located in the N'fis and Tessaout irrigated perimeters upstream. The current and planned artificial recharge operations in the Haouz basin will improve the productivity of catchments (municipal, industrial and agricultural water demand). On the other hand, if the decline in groundwater piezometric levels continues or worsens in the context of climate change, then the risk of depletion of reserves may persist.

5. Treated wastewater reuse

The reuse of wastewater and purified waste under the National Sanitation Program (NAP) will have to ensure up to 60 Mm3 / year in 2030, but according to the projections presented in the water demand section, it is more likely that the volume of waste and purified water available from the RADEEMA area of

action is only in the order of 40 Mm3 / year in 2030 and 50 Mm3 / year in 2050. The Tensift Basin PDO has provided these purified waters to irrigate the green spaces and the golf courses of Marrakech, both to recharge the groundwater table of Haouz by direct or indirect infiltration. This unconventional source will eliminate all harvesting from the Haouz water table for the supply of water to golf courses and green spaces. The current conditions of wastewater treatment in Marrakech are discussed in some detail below

The area served by the RADEEMA liquid sanitation network includes the agglomeration of Marrakech. This area of action covers an area of 23.8 km2 with a population of about 1 million inhabitants. of service is about 90% and the linear network is 2,740 kilometers.

The collection and transport of wastewater is generally ensured by a gravity pipeline. However, some areas are equipped with pumping stations (16 stations were in operation by the end of 2015). According to the places and the years of construction, the sanitation network of the city of Marrakech is realized as a unitary system (old districts of the city), separative system (industrial zone Sidi Ghanem, tourist zones) or pseudo-separative system M'hamid zone Targa). Urban sanitation planning is based on the Master Plan, which defines, among other things, investment projects. According to information from RADEEMA, the Master Plan prescribes for the construction of large residential, tourist or industrial complexes of sewer pipes and retention and infiltration ponds.

The Wastewater Treatment Plant (WWTP) was carried out in two phases: the first phase consists of a primary treatment by an activated sludge process. This phase has been operational since 2009. The second phase consists of the extension of the treatment to the tertiary level and allows us to have treated water usable for watering golf courses and green spaces in Marrakech. This phase has been operational since December 2011. The station's processing capacity is 1.3 million inhabitants, with a nominal flow rate of 118,000 m³ per day (43 Mm3 / year). The treated water is stored in a basin with a capacity of 9 000 m³, before passing through a circuit of the treated water distribution network, which extends over a line of 80 km of pipes with diameters between 250 mm and 1 100 mm feeding golf courses through five pumping stations.

The WWTP treats almost all of the urban waste water of the city of Marrakech and offers non-conventional water resources (purified waste water) with a capacity of around 33 Mm³ per year. This is about 25%, the supply of 66 Mm3 / year yields about 50 Mm3 / year, of which about 80% is collected as wastewater (40 Mm3 / year); in turn 83% of this amount is treated, yielding potentially 33 Mm3 / year for reuse. Within the treatment process, methane gas from the fermentation of sludge is used to generate electricity, generating daily 30MWh electricity. This fulfills nearly 50% of the total electricity need of the wastewater treatment plant. The tertiary treatment and distribution system ensures the irrigation water requirements of the golf courses whose average needs are estimated at about 1 Mm³ per year and golf course. Of the 19 projects planned at the Marrakech level, 11 are currently operational, 3 are under construction and 5 are on stand-by. Of the 11 functional golf courses, 8 are served by the WWTP with a volume of treated wastewater of about 6 Mm³ per year (2015).

Treated wastewater that cannot be used for golf irrigation (about 27 Mm3 per year in 2015) is evacuated (after treatment at level 2) into the Tensift River, where it can be used for downstream riparians, or recharge the Haouz aquifer from the river bed. It should be noted that the reuse of treated wastewater for golf courses and green spaces results in a reduction in the volumes available for the informal irrigation sector. Once all 20 planned golf courses are running, they will all require about 20 Mm3 / year. The Palmeraie de Marrakech, part of the UNESCO World Heritage Site. In a first phase, 390 ha of palm grove with about 200,000 palm trees are already irrigated with 0.75 Mm3 per year of treated wastewater. In the near future, the entire Palmeraie which stretches over 810 h will be supplied by the WWTP with 1.5 Mm3 per year.

The water supply of each golf course, as well as the conditions of supply and financial contribution are governed by an agreement between RADEEMA and the promoters. According to RADEEMA, 17 golf courses have signed a convention and at least two of them continue to source exclusively from the aquifer and the Canal de Rocade and extract about 2.5 Mm3 per year. Under the terms of the agreement, promoters are required to cover at least 80% of the golf course's requirements for treated water; the difference is pumped from the aquifer because the m³ pumped costs less (about 0.5-1.5 MAD / m3 including the abstraction fee of 0.04 MAD / m3) than the m³ cleaned (2.5 MAD / m3). The cost of tertiary treatment, pumping and transport to the golf courses is 3.6 MAD / m3. (2.2 MAD / m3), which is mandatory for releasing the effluent in the Tensift River when there is no reuse of wastewater.

According to information from RADEEMA and environmental studies, the hydraulic capacity of primary, secondary and tertiary treatments will be saturated by 2020. RADEEMA has therefore initiated planning for the extension of the WWTP or the construction of a second WWTP. For the moment, the extension of the existing WWTP is prioritized. Considering water-saving measurements (eg drip irrigation, automated watering of golf courses according to current needs measured continuously, replacement of turf in green areas by plants that are more economical in consumption of d water), irrigation needs per hectare should stabilize and decrease over the long term. By 2030, the demand for irrigation water for Marrakech is estimated at about 35 million m3 / year.

6. Reuse of grey water in hotels

The consumption of drinking water in Marrakech hotels and accommodation is considerable. Assuming a current capacity of about 80,000 beds, a specific moderate consumption of 300 liters per night, and an average occupancy rate of 40%, the annual consumption is estimated at present at about 3.5 Mm3 per year. This figure is higher than RADEEMA sales to tourism customers specified for 2015 at 2.7 Mm3 / yr.

In Marrakech, hotels have various water sources. Drinking water is supplied mainly by RADEEMA. For other uses, facilities often have alternative resources to reduce water bills and have flexibility in water supply.

The National Plan for the Development of Tourism Activities designed in 2010 aims to impose Morocco as a tourist model combining sustained growth with responsible management of the environment and respect for the cultural authenticity of Morocco. Considering that drinking water consumption in the tourism sector is expected to increase further and could reach a demand of 5 to 10 Mm3 per year from 2050 onwards, the potential for savings is considerable. The realization of water savings in luxury establishments is a challenge, water recycling measures or the re-use of relatively unpolluted gray water from showers, laundries and swimming pools are a relevant option with potential for several million m3 per year. Indeed, in tourist establishments, more than 50% of drinking water consumption corresponds to gray water that is less polluted and relatively easy to process and reuse. According to pilot studies in Jordan the potential for saving gray water reuse is in the order of 15 to 20 m3 per hotel room per year. A capacity increase of 20,000 beds or 10,000 rooms thus represents a savings potential of approximately 150,000 to 200,000 m3 per year without compromising the quality of services or sanitary conditions.

ANNEX IX - Water demand of the Greater Marrakesh

1. At the level of the Tensift water basin

According to the PDAIRE, the current needs for drinking and industrial water are 128 Mm3 of which 106 Mm3 for the High Tensift. A more up-to-date assessment shows that these needs are underestimated because for the Marrakech region alone, these needs are estimated at 126 Mm3 / year, including the demand for water from El Kelaa and Azilal. The irrigation water requirements amount to 1,625 Mm3 distributed as follows:

- 348 Mm3 for the Large Hydraulic schemes (LG)
- 562 Mm3 for Small and Medium Hydraulic Schemes (SMG) - DPA zone
- 444 Mm3 for the Small and Medium Hydraulic (PMH) - zone ORMVA
- 271 Mm3 for private irrigation

Sector	Total demand (2010) Mm^3/year	Resources currently mobilized (Mm^3/year)				Déficit
		Surface water (reservoirs)	Groundwater	Direct intake from rivers	Total resources	
Municipal and industrial demand	128	82	46		128	0
Agriculture irriguée	1 625	243	438	645	1 326	-299
Espaces verts et golfs	22		22		22	0
Totaux	1 775	325	506	645	1 476	-299

Table IX-1: Structure of the current demand in the Tensift according to the ABHT PDAIRE

Thus, the deficit in the "normal" or average year is about 300 Mm3 / year for the entire Tensift basin. In the dry year, corresponding to a decile of 20%, the decrease in contributions is about 40% compared to the average value. This decrease will directly affect the volumes stored in the works and indirectly the renewal of groundwater.

Given the limited interannual regularization capacity of the dams in the area, it can be assumed that a succession of 2 or 3 dry years would result in a dramatic drop in the resource mobilized by the same magnitude of the reduction in inputs of 40%. This would then correspond to an overall deficit of almost 900 Mm3 / year, which will directly impact agricultural allocations

2. .At the level of Marrakech area

The Greater Marrakech includes a spatial extent that extends well beyond the administrative urban perimeter. This area includes:

- The RADEEMA zone of action, comprising the urban communes of the city of Marrakech, Ouahat Sidi Brahim, the town of Tamansourt (Harbil commune, Mord) and the center of Tassoultante (Tassoultante commune, located in the South)
- The peri-urban and rural centers fed by the ONEE, grouping together several communes around Marrakech, coming from the provinces of Marrakech, Haouz and Rhamna (M'Nabha, Loudaya, Sid Zouine, Ait Ourir, Amizmiz, Tahannaout, Ghmate, Sidi Abdellah Ghiat, Lalla

-

Municipal and industrial water supply

Zone	Canal de Rocade & Lalla Takerkoust	Groundwater	Total
RADEEMA - Marrakech	66.0		66.0
Demand of other urban centers	11.7	7.9	19.6
Demand Haouz province	14.6	4.5	19.1
Demand Rehamna province	3.7	3.0	6.7
Demand El Kelaa et Azilal	15.0		15.0
Total demand	111.0	15.4	126.4
Allocation to municipal water	70.7	15.4	86.1
Potable water balance	-40.3	0	-40.3

Table IX-2: Water allocations in the Greated Marrakech in 2015 (Mm^3/an)

Agriculture

The current demand for agricultural water has been estimated from the PDAIRE. This demand includes all the irrigated perimeters of the Large Hydraulic schemes (GH), the Small and Medium Hydraulic schemes (PMH) and the private or traditional irrigation. The management of agricultural water is entrusted to ORMVA, DPAs or associations of agricultural water users or private investors depending on the nature of the perimeter. The resource allocated comes from Nfis inputs, regulated or not by the Lalla Takerkoust and Yacoub al Mansour (Wirgane) dams, the Rocade canal or the Haouz nappe.

Sector	Superficie (Ha)	Besoins actuels en tête de périmètre (Mm^3/an)
NFIS RD sector irrigated from canal de Rocade	17 400	141
HAOUZ CENTRAL sector irrigated from canal de Rocade	14 300	125
NFIS RD sector irrigated from Lalla Takerkoust reservoir	4 000	83
PMH Haouz aquifer		110
Private irrigation from Haouz aquifer	84 750	241
Total		**700**

Table 1 : Structure de la demande agricole actuelle dans la zone de Marrakech

Overview of current water demand

Zone	Current water demand (2016) in Mm^3/an by supply source			
	Total	Canal de Rocade	Barrages LT et YM	Nappe Haouz
Municipal water demand - Zone RADEEMA	66	64	2	0
Municipal water demand – Greated Marrakech	19.6	11.7		7.9
Municipal water demand - Haouz	19.1	14.6		4.5
Total Municipal water	104.7	90.3	2	12.4
Total Irrigation	700	266	83	351
Totaux	**805**	**356**	**85**	**363**

Table IX-3: Total current water demand in the Greater Marrakech

Flows at canal de Rocade

The series of flows supplied at the Rocade canal averaged 271 Mm3 / year, consisting of the contribution of the Lalla Takerkoust dam (72 Mm3 / year) and the Hassan I dam (199 Mm3 / year). The supplies of the canal are distributed according to the allocations described below:

Restitutions en Mm³/an (Moyennes récentes)	***AEP Marrakech***	***Irrigation***	***Total***
Lalla Takerkoust	4	68	72
Hassan 1er	65	134	199
Total Canal de Rocade	**69**	**202**	**271**

Table IX-4: Current average allocations for dam renditions Lalla Takerkoust and Hassan 1er for the Greater Marrakech

The supply series show a sustained increase in the municipal and industrial water allocation to the detriment of the agricultural allocation, which has increased from 35 Mm3 / year in 2000 to almost 70 Mm3 / year in 2015. Fluctuations in annual inputs and refunds 2 sources of supply (Lalla Takerkoust and Hassan I) are given in following figures and table. These fluctuations show the low capacity to regulate the floods of these two reservoirs.

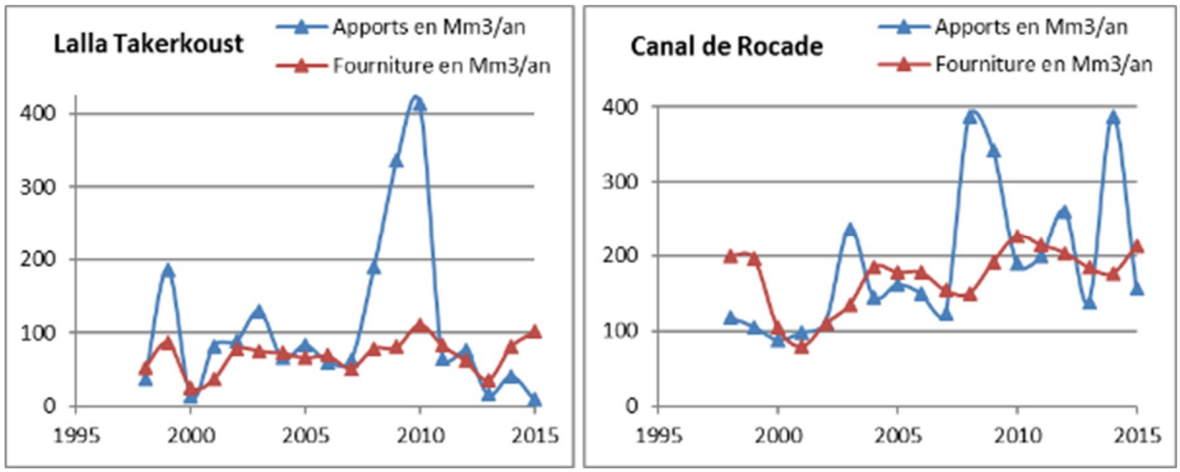

Figure IX-1: Évolution of inflows and backflows at Lalla Takerkoust (left) and Hassan 1er via canal de Rocade (right)

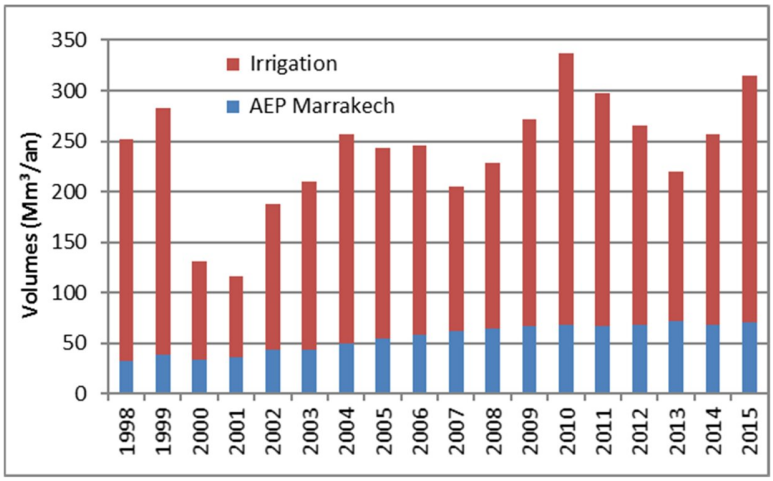

Figure IX-2: *Evolution of cumulated supplies from Lalla Takerkoust and Hassan 1er via Canal de Rocade*

	Fournitures en Mm³/an cumulées (canal de Rocade + barrage Lalla Takerkoust		
Année	***AEP Marrakech***	***Irrigation***	***Total fournitures Canal de Rocade***
1998	32.8	219.5	252.3
1999	38.5	244.7	283.2
2000	33.2	97.5	130.7
2001	36.0	80.5	116.5
2002	43.2	144.5	187.7
2003	44.1	165.8	209.9
2004	50.1	207.1	257.3
2005	55.1	188.5	243.6
2006	58.3	187.9	246.3
2007	62.2	143.2	205.4
2008	64.5	164.2	228.8
2009	67.4	204.6	272.0
2010	67.9	269.5	337.4
2011	67.7	229.4	297.1
2012	68.4	197.3	265.7
2013	71.7	148.7	220.5
2014	68.4	189.1	257.5
2015	70.4	244.2	314.6
Moyenne étendue	**55.6**	**184.8**	**240.4**
Moyenne 10 ans (*)	**66.7**	**197.8**	**264.5**
Moyenne 5 ans (**)	**69.3**	**201.7**	**271.0**

(*) Sur les 10 dernières années ; (**) sur les 5 dernières années

Table IX-5: Cumulated supplies from Lalla Takerkoust and Hassan 1er via Canal de Rocade for the Greater Marrakech

3. Conclusions

Based on these data, the following observations can be made:

1. Demand for drinking water is rising sharply, it currently totals 85.6 Mm3 / year for the RADEEMA zone of action and the contours of the city of Marrakech. If one adds the urban centers of Haouz, it amounts to 105 Mm3 / year.

2. This demand is partly covered by the Haouz groundwater (12.4 Mm3 / year), the remainder is supplied by the Rocade canal (92.3 Mm3 / year).

3. The demand for agricultural water amounts to 700 Mm3 / year, of which 266 Mm3 / year are allocated from the Rocade canal, 351 Mm3 / year from ground water and 83 Mm3 / year from the Lalla complex Takerkoust / Yacoub al Mansour.

4. In the normal year, the total deficit at the Rocade canal is 356 + 85 [total demand] - 271 [average channel flow] = 170 Mm3 / year.

5. The deficit, as well as any adjustment of allocations in the event of shortage, are deferred to the agricultural allowances, with drinking water always a priority and contributing to an overexploitation of the groundwater of the Haouz aquifer, reported as 176 Mm3 / year.

On the other hand, assuming a dry year or a dry period of 2 or 3 years, the intakes will be reduced by about 40% (percentile 20%). This decrease will likely affect the volumes available for the Lalla Takerkoust and Hassan I dams, and consequently the supplies returned to the Rocade Canal. This decrease is at least of the order of 108 Mm3 / year (40% of the average refunds of 271 Mm3 / year in the Rocade canal), increasing the deficit to 278 Mm3 / year, always to the detriment of water agricultural.

ANNEX X - Water demand and supply system for the city of Marrakesh

1. Background

For this case study focusing on integrated urban water management, the RADEEMA area of action was selected as the scope of the project. RADEEMA's area of operation includes the entire territory of the city of Marrakech with its five districts (Marrakech-Medina, Menara, Gueliz, Sidi Youssef Ben Ali and Annakhil), the municipality Mechouar-Kasba, part of the rural communes of Al Ouidane, Ouahat Sidi Brahim, Saâda and Tassoultante and also part of the commune of Tamesloht, where some important tourist projects are implemented and which is part of the province of Haouz.

The "Grand Marrakech" corresponds to the area that is supplied with drinking water by the ONEE's existing treatment plant (Canal de Rocade treatment plant, capacity: 3.1 m3 / s) which is currently being implemented with a capacity of 2.5 m3 / s as part of the Northern Water Transfer Project (Al Massira project).

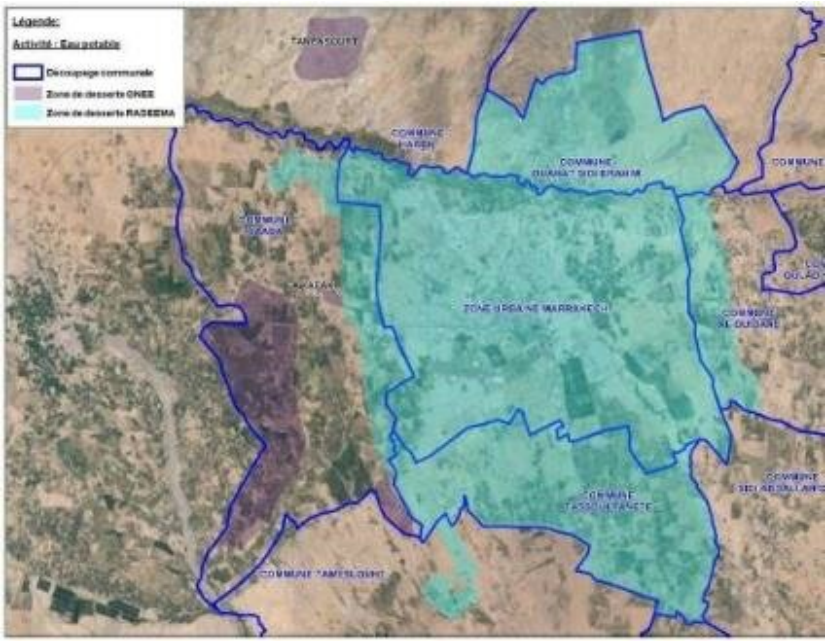

Figure X-1: Zone d'action de la RADEEMA (source : AUM, 2012)

The RADEEMA area of activity is part of a region whose economy is based on agriculture and livestock, tourism and crafts, industry and mining. Within the regional territory, this zone also positions itself as a space for very dynamic economic and social exchanges. The city is particularly dependent on tourism sector and industry characterized by high water intensities.

Tourism: The city of Marrakech is experiencing an important tourist development and the jobs related to the sector represent an important part of the jobs in the city. The city is now the leading tourist destination in the country, with more than 6 million overnight stays registered in 2013, accounting for 34% of the overnight stays registered at the national level. There are also 19 golf courses in Marrakech, 11 of which are functional, 3 under construction and 5 are in stand-by. On average, the consumption of water by golf goes up to 1 Mm^3 / year.

Industry: The agglomeration of Marrakech comprises three industrial zones. The city now houses around 350 industrial units that are served by RADEEMA. The industry has grown rapidly in the agri-food sector, which now accounts for 38% of establishments, in the chemical and para-chemical sector (30%), textiles (15%), metal and %) and the electrical / electronic sector (3%) (CRI Marrakech, 2013). As part of its regional spatial planning scheme (SRAT, 2014), the city of Marrakech and the neighboring municipalities plan to carry out several projects, such as the National Park for the industrial emergence of 10 hectares in the commune of Harbil.

2. Existing water supply and sewerage systems

Le système de production d'eau potable de Marrakech comprend les ouvrages suivants:

A water adduction system from the Canal de Rocade, with a capacity of 3.7 m3 / s;
Lalla Takerkoust dam water supply with a capacity of 1.4 m3 / s ;
A treatment plant with a nominal capacity of 3.1 m3 / s (98 Mm3 / year). The capacity of the station is largely oversized to deal with the supply of drinking water to the Grand Marrakech at the two Lalla Takerkoust and Hassan Ier - Sidi Driss complexes (recently 66 Mm3 / year);
An adductor system of treated water from the treatment plant to the reservoirs of Sidi Moussa and Route d'Ourika;
Production from 49 underground water abstractions, a drain and a Khettara. These groundwater is injected directly into the drinking water distribution system. The flow rate in 2014 reached barely 94 l / s (1.1 Mm3 / year).

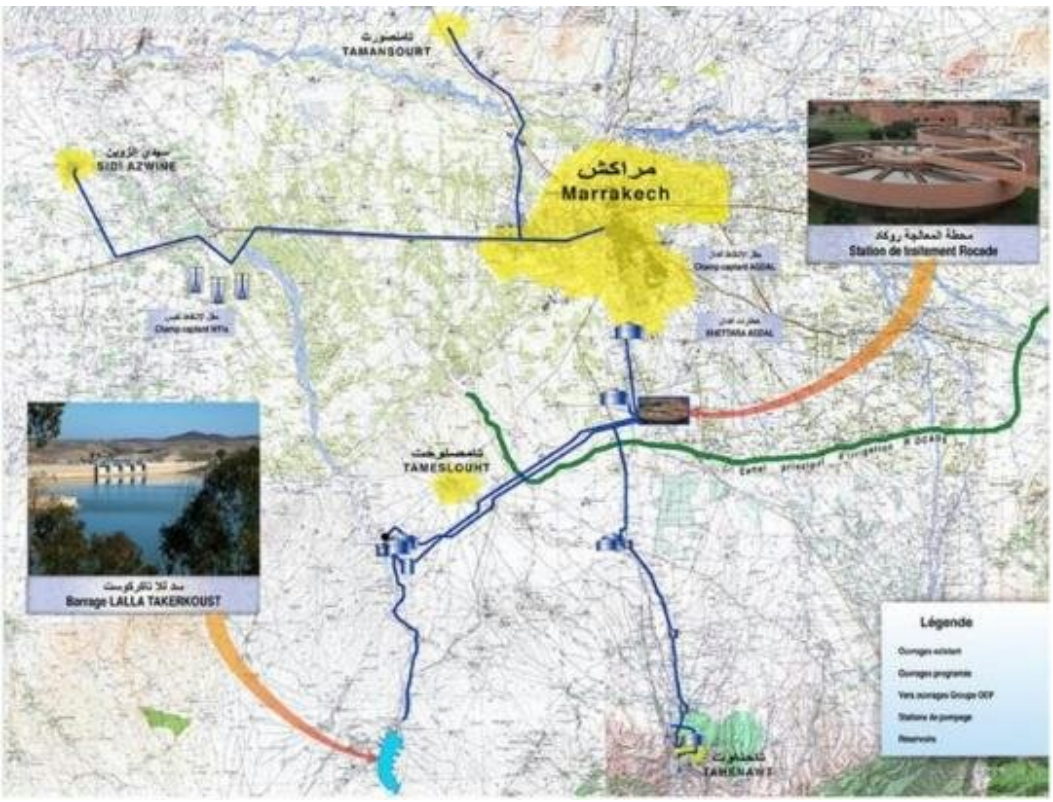

Figure X-2: Existing water supply facilities in the city of Marrakech from groundwater and surface water resources (source: ONEE)

This drinking water supply system will be strengthened from 2018 by a drinking and industrial water supply project based on the Al Massira dam water transfer project.

The RADEEMA drinking water pipeline includes the following works.

The distribution network of a linear system of approximately 2,600 km of pipes subdivided into three pressure stages;
The reservoir Route d'Ourika (85,000 m³) and the Sidi Moussa reservoir (50,500 m³) providing a daily autonomy of more than 15 hours;
Two North reservoirs (2 x 30,000 m³) under construction as part of the Northern Transfer and Drinking Water Project from the Al Massira dam.

The RADEEMA program to improve drinking water efficiency since 2007 has increased the physical return of the network from 63.6% in 2007 to nearly 75% in 2015.

Sewerage system : the area served by the RADEEMA liquid sanitation network includes the agglomeration of Marrakech. This zone of action covers an area of almost 238 km2 with a population of about 1 million inhabitants. The service rate is approximately 90% and the overall length of the network is 2,740 km. The system includes a wastewater treatment able to deliver a secondary level of treatment (a tertiary for part of the effluents)

3. Present and future water demands

Demographic projections of the areas served by RADEEMA

According to the 2014 census the growth rate of the urban population of Grand-Marrakech was 1.2% per year between 2004 and 2014, significant lower than the national urban growth rate of 2.1% per year over the same period; the growth rate between 1994 and 2004 for Marrakech was 2.1% per year. The reason of this lower urban growth rate of Marrakech is that communes such as Méchouar – Kasbah and the Medina have shown a negative growth rate since 1994, around -3% per year since 2004, while other communes hardly grow in population. Thus, the urban growth of the region migrates out of Grand Marrakech to surrounding communes, mostly outside the service area of RADEEMA, likely due to lack of space for expansion and a gradual decrease of the size of household in Marrakech. Instead, the annual growth rate in the rest of the Marrakech prefecture accelerated from 2.9% between 1994 – 2004 to 4.7% between 2004 and 2014. This yielded overall for the prefecture Marrakech a steady annual growth rate of 2.2% between 1994 and 2014, equal to the national average.

RADEEMA services also parts of 5 rural communities, overall about 25% of the population of these communities. These communities have shown the largest annual population growth, i.e. 4% between 1994 and 2004, and 5.8% between 2004 and 2014, clearly due to the migration from Grand Marrakech. For the total service area of RADEEMA this yields an annual growth of 2.2% between 1994 and 2004, and 1.4% between 2004 and 2014. The population serviced by RADEEMA in 2014 was 986,580 and about 1 million in 2015.

The recent population growth rate of the RADEEMA service area (1.4%) is 2/3rd of the national annual growth rate of 2.1% of the urban population between 2004 and 2014. Therefore, for the purpose of projecting future water demands for AEP for the RADEEMA service area, we have defined 3 urban population growth scenarios, i.e. i) a low growth scenario at 60% of the projected national annual growth rate for the urban population, slightly below the latest census data, ii) a median growth scenario at 80% of the national growth rate and slightly above the latest census data, and iii) a high growth scenario at 100% of the projected national annual growth rate, well above the latest census data for Marrakech.

Results are shown in tables below. The population projections used previously by ONEE are also included, at a constant annual population growth rate of 1.4%. This growth rate is accurate for the present situation, but as a constant growth rate it is above the national trend corresponding to an average growth rate of 1.3%/year between 2015 and 2050.

	Population ('000)			Pop.		Pop.
	1994	2004	Growth rate	2014	Growth rate	2015
Mechouar Kasba	25.1	22.1	-1.3%	16.9	-2.7%	16.4
Annakhil	38.4	54.1	3.5%	64.6	1.8%	65.7
Gueliz	148.3	173.1	1.6%	192.8	1.1%	194.9
Medina	192.3	167.2	-1.4%	120.6	-3.2%	116.8
Menara	148.4	281.7	6.6%	411.1	3.9%	426.9
Sidi Youssef Ben Ali	116.5	124.9	0.7%	122.9	-0.2%	122.7
Ville de Grand Marrakech	669.0	823.2	2.1%	928.9	1.2%	943.4
Rural communes covered by RADEEMA						
Alouidane	17.2	20.9	2.0%	28.2	3.0%	29.0
Ouahat Sidi Bramin	7.6	13.7	6.0%	25.3	6.3%	26.9
Saada	24.4	39.1	4.8%	67.1	5.6%	70.8
Tassoultante	18.2	30.1	5.2%	71.2	9.0%	77.6
Tamesloht	17.1	21.4	2.2%	29.0	3.1%	29.9
Totale rural communes - RADEEMA	84.6	125.2	4.0%	220.8	5.8%	234.2
Total RADEEMA (25% of Rurales communes)	690.2	854.5	2.2%	984.0	1.4%	1002.0
Marrakech prefectures	861.2	1070.8	2.2%	1330.5	2.2%	1359.7

Table X-1: Demographic growth in Greater Marrakesh (source : AUM)

Scénario \ Year	2015	2020	2025	2030	2035	2040	2045	2050
Low (60%)	1,002	1,063	1,118	1,167	1,210	1,248	1,281	1,310
Medium (80%)	1,002	1,084	1,159	1,227	1,288	1,342	1,390	1,432
High (100%)	1,002	1,105	1,202	1,291	1,371	1,443	1,508	1,565
ONEE medium (+1.4%/an)	1,002	1,074	1,151	1,234	1,323	1,418	1,521	1,630

Table X-2: Demographic growth scenarios for the area serviced by RADEEMA

Current water use and water deficit

As illustrated on the following figure, at the level of the city of Marrakech, drinking water consumption grew strongly until 2011, then stabilized in 2012 and then declined slightly in subsequent years.

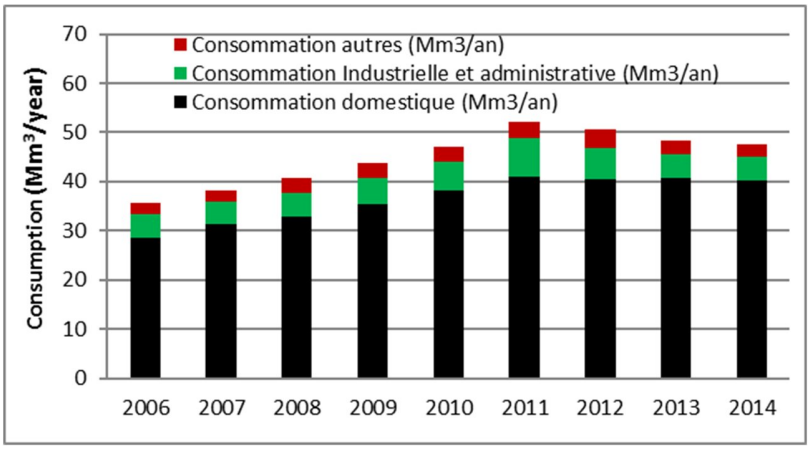

Figure X-3: Evolution of drinking water consumption in the RADEEMA area of service (source: RADEEMA)

Domestic consumption: About 85% of the drinking water consumed is used for domestic use. From 2006 to 2011, domestic water demand was growing, which is linked to urban population growth of about 1.3% per year, an increase in the connection rate from 92% in 2004 at present approximately 98%, to an increase in specific consumption from 89 l / inhab / d in 2004 to 112 l / capita / d (41 m3 / year / inhabitant) in 2014 and to the expansion of the area of action of RADEEMA in the context of the rapid urbanization of Marrakech. Nevertheless, domestic use stabilized after 2011 at 41 Mm3 / year, for a population of about one million inhabitants.

Industrial and administrative consumption: The city of Marrakech houses about 270 industrial units. These units consumed about 0.6 Mm3 / year in 2015, while drinking water consumption reached approximately 4.4 Mm3 / year, or 12 l / d / person. The public sector has a high consumption of water and the public use is often unreasonable mainly because of the misuse of water for the watering of gardens and parks.

Consumption in the tourism sector: In 2015, according to RADEEMA, tourism consumption of drinking water is about 2.7 Mm3 / year, which seems to be underestimated. Water per night can range from 200 to 800 l / d depending on the category of establishment. The growth rate of overnight stays during the period 1998 - 2009 is 5.4%. If this rate is maintained, and given the multiplication of tourism projects in the agglomeration of Marrakech, we can estimate that the demand for drinking water in the tourism sector rises to 6 Mm3 / year in 2030 and more than 16 Mm3 / year in 2050.

Total consumption of drinking water: The total net consumption of drinking water in 2015 was 49 Mm3 / year. Given that the distribution network of the city of Marrakech in 2015 was 75%, the gross domestic use was 65 Mm3 / year. This figure corresponds very well to the available data for the raw water volumes obtained from the Rocade Canal and the Lalla Takerkoust complex, estimating the volume of water supplied to the station of ONEE (for RADEEMA) to 66 Mm3 / year.

Consumption of groundwater and treated wastewater: In addition to this is consumption for swimming pools and watering green areas. According to a recent study, about 82% of establishments use well water for watering their green spaces, 15% use drinking water, while 3% are watered by rainwater. The gardens of hotels in Marrakech total about 500 hectares and require 1.7 Mm3 / year of water for watering (2015). In 2030, this demand is estimated at 3.2 Mm3 / year (SRAT, 2014).

To this must be added the demand for irrigation water for irrigation of the Agdal and Menara gardens, estimated at about 6 Mm3 / year. In this context, a program for micro-irrigation of green spaces was launched by the municipality in partnership with the AUM and the "Wilaya" of Marrakech in order to

reduce watering needs. Another option will be to create the necessary infrastructure to allow the reuse of treated wastewater for this purpose.

Finally, the demand for water from golf courses is very considerable. According to an ABHT study carried out in 2010 and based on an average requirement of almost 1 Mm^3 / year per golf course, the total current demand for golf courses is now close to 11 Mm^3 / year and will reach up to 2020 to close to 15 Mm3 / year and up to 2030 to close to 30 Mm3 / year. Water saving and the restoration of groundwater by treated wastewater is therefore a priority.

Physical water losses: Water is to a certain extent wasted through leakages in the distribution system, with no water saving technologies installed, too much unnecessary irrigation, dripping taps, etc. In RADEEMA's action zone losses amounted in 2010 reportedly 27% (Hati et al, 2012) or 17 Mm3 / year of the amount of water provided for municipal and industrial water demand (64 Mm3 / yr, not including the groundwater and green spaces, etc.). The overall consensus is that physical losses were 25% in 2015 (similar for Casablanca and Rabat); commercial losses may have been between 3% and 10%. In order to secure the city's drinking water supply, urgent actions are needed to increase the efficiency of the production and distribution networks. In its investment program 2015-2019, RADEEMA plans to improve the efficiency of the distribution system to 77% from 2020.

Water demand projection in RADEEMA's area of service

The analysis of the current and future situation of the demand for drinking water takes into account the demographic evolution as well as the dynamics of the sectors of tourism, industry and administration of the city of Marrakech. This analysis identified the characteristic ratios and assumptions for assessing water requirements and defining three demand scenarios. These projections and assumptions are based (although adjusted) on the water demand data set by the NEB in 2016 and can be summarized as follows:

It is assumed that water for irrigation and watering of gardens and golf courses is provided only by the treated wastewater.

The rate of connection to the drinking water system was 98% in 2015 in the RADEEMA zone of action. It is assumed that this rate remains stable over the period from 2015 to 2050.

A rate of 1.4% is selected for the population change in the RADEEMA area for the ONEE-average scenario, and the evolution of the population of the zone according to the three low, medium and high scenarios.

The domestic consumption in 2014 was 112 l / d / person. Three hypotheses of evolution are considered:

- low scenario: decrease in the average endowment which would reach 95 l / d / person from 2030; this can be difficult to achieve, among other things because the number of people per household decreases rapidly.
- average scenario: an allocation of 115 l / d / person from 2020;
- High Scenario: Increase in staffing to 120 l / d / person from 2025.
- Allocation for the non-connected population is reduced from 60 to 20 l / d / person after 2030

The industrial water demand recorded in 2014 is 2 l / d / person, ie 0.7 Mm3 / year. The water demand forecasts for the industry will be based on a gradually increased allocation to 5 l / d / person from 2030 for the three scenarios.

The administrative water demand in 2014 was 12 l / d / person, ie 4.4 Mm3 / year. Forecasts of administrative water requirements will be based on the same allocation for the three scenarios up to 2050.

The consumption of hotels and tourist residences in 2014 was specified by RADEEMA at 7,250 m3 / day, ie 2.65 Mm3 / year or 7.15 l / d / person. Three assumptions have been adopted to assess water requirements:

- low scenario: an increase in the volume allocation of 1.5% / year
- medium scenario: an increase in the volume allocation of 2% / year
- high scenario: an increase in the allocation in terms of volumes of 4% / year

The efficiency of the distribution and supply network of the city of Marrakech in 2015 was about 75%. Three assumptions have been adopted to evaluate future demand:

- low scenario: efficiency increase to 85 in 2030, then stabilized
- medium scenario: limited efficiency increase to 80% in 2020, then stabilized
- high scenario: stabilization of efficiency at 77%

The reuse potential of treated wastewater is calculated from the net quantity of water reaching consumers (gross volume less physical losses), of which 80% is estimated to reach the WWTP and 85% of this volume is then assumed to be processed for reuse.

Given the ratios and assumptions outlined above, the evolution of the water demand of the city of Marrakech is calculated as follows.

Municipal water demand	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Low scenario	66	65	66	63	63	65	67	69
Medium scenario	66	69	74	79	83	87	90	93
High scenario	66	73	83	91	97	103	110	116
Medium ONEE scenario	66	68	73	79	85	91	98	105
Potential for reuse								
Low scenario	33	34.5	35.2	35.7	35.6	36.8	37.9	38.9
Medium scenario	33	36.5	39.4	42.0	44.2	46.3	48.1	49.8
High scenario	33	37.4	42.7	46.5	49.8	53.1	56.3	59.5
Medium ONEE scenario	33	36.2	39.1	42.3	45.4	48.7	52.3	56.2

Table X-3: Water demand scenarios in RADEEMA area of service (Mm^3/year)

Under the lowest scenario water demands remain stable around the present 66 Mm3 / year. The impacts of a modest population growth are balanced by a significant reduction in demand for the management and the reduction of physical losses (leakage). The results for the "medium scenario" are similar to the projections of ONEE till 2035. According to the "medium scenarios", RADEEMA's demands would reach 90 Mm3 / year by 2040. The high scenario projects a 50% increase of water demands by 2035. The potential for reuse of treated wastewater would be about 40 Mm3 / year by 2030, and 50 to 55 Mm3 / year by 2050.

Low scenario	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Population RADEEMA ('000 hab)	1,002.0	*1,062.7*	*1,117.9*	*1,167.1*	*1,210.3*	*1,248.0*	*1,281.3*	*1,310.3*
Pop. growth		1.18%	1.02%	0.86%	0.73%	0.61%	0.53%	0.45%
Connection rate	98%	98%	98%	98%	98%	98%	98%	98%
Water Demand (lpcd)								
Connected population	112	*110*	*105*	*100*	*95*	*95*	*95*	*95*
Non connected population	60	40	30	20	20	20	20	20
Administrative	12	12	12	12	12	12	12	12
Tourism (+1.5% in volume)	7.2	*7.3*	*7.4*	*7.7*	*8.0*	*8.3*	*8.7*	*9.2*
Industries	2	3	4	5	5	5	5	5
Physical losses distribution	25%	*20%*	*20%*	*15%*	*15%*	*15%*	*15%*	*15%*
Physical losses conveyance	2%	2%	2%	2%	2%	2%	2%	2%
Demand at distribution (l/s)	2,043	2,012	2,053	1,956	1,952	2,019	2,080	2,136
Mm^3/year	64	63	65	62	62	64	66	67
Demand at production (l/s)	2,085	2,053	2,095	1,996	1,992	2,061	2,123	2,179
Mm^3/year	66	65	66	63	63	65	67	69
Potential for reuse (Mm^3/year)	32.9	34.5	35.2	35.7	35.6	36.8	37.9	38.9
Medium scenario	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**

Population RADEEMA ('000 hab)	1,002.0	*1,083.5*	*1,159.2*	*1,227.5*	*1,288.5*	*1,342.2*	*1,390.1*	*1,432.2*
Pop. growth		1.58%	1.36%	1.15%	0.97%	0.82%	0.70%	0.60%
Connection rate	98%	98%	98%	98%	98%	98%	98%	98%
Water Demand (lpcd)								
Connected population	112	*115*	*115*	*115*	*115*	*115*	*115*	*115*
Non connected population	60	40	30	20	20	20	20	20
Administrative	12	12	12	12	12	12	12	12
Tourism (+1.5% in volume)	7.2	*7.3*	*7.5*	*7.9*	*8.3*	*8.8*	*9.3*	*10.0*
Industries	2	3	4	5	5	5	5	5
Physical losses distribution	25%	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*
Physical losses conveyance	2%	2%	2%	2%	2%	2%	2%	2%
Demand at distribution (l/s)	2,043	2,129	2,295	2,450	2,579	2,696	2,804	2,903
Mm³/year	64	67	72	77	81	85	88	92
Demand at production (l/s)	2,085	2,172	2,342	2,500	2,632	2,751	2,861	2,962
Mm³/year	66	69	74	79	83	87	90	93
Potential for reuse (Mm³/year)	32.9	36.5	39.4	42.0	44.2	46.3	48.1	49.8
High scenario	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Population RADEEMA ('000 hab)	1,002.0	*1,104.7*	*1,201.7*	*1,290.8*	*1,371.4*	*1,443.1*	*1,507.7*	*1,565.0*
Pop. growth		1.97%	1.70%	1.44%	1.22%	1.02%	0.88%	0.75%
Connection rate	98%	98%	98%	98%	98%	98%	98%	98%
Water Demand (lpcd)								
Connected population	112	*115*	*120*	*120*	*120*	*120*	*120*	*120*
Non connected population	60	40	30	20	20	20	20	20
Administrative	12	12	12	12	12	12	12	12
Tourism (+1.5% in volume)	7.2	*7.9*	*8.8*	*10.0*	*11.4*	*13.2*	*15.4*	*18.1*
Industries	2	3	4	5	5	5	5	5
Physical losses distribution	25%	*23%*	*23%*	*23%*	*23%*	*23%*	*23%*	*23%*
Physical losses conveyance	2%	2%	2%	2%	2%	2%	2%	2%
Demand at distribution (l/s)	2,043	2,265	2,584	2,813	3,019	3,215	3,409	3,601
Mm³/year	64	71	81	89	95	101	107	114
Demand at production (l/s)	2,085	2,311	2,636	2,871	3,080	3,281	3,478	3,674
Mm³/year	66	73	83	91	97	103	110	116
Potential for reuse (Mm³/year)	32.9	37.4	42.7	46.5	49.8	53.1	56.3	59.5
Medium scenario ONEE	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Population RADEEMA ('000 hab)	1,002.0	*1,074.1*	*1,151.5*	*1,234.3*	*1,323.2*	*1,418.5*	*1,520.6*	*1,630.0*
Pop. growth	1.40%	1.40%	1.40%	1.40%	1.40%	1.40%	1.40%	1.40%
Connection rate	98%	98%	98%	98%	98%	98%	98%	98%
Water Demand (lpcd)								
Connected population	112	*115*	*115*	*115*	*115*	*115*	*115*	*115*
Non connected population	60	40	30	20	20	20	20	20
Administrative	12	12	12	12	12	12	12	12
Tourism (+1.5% in volume)	7.2	*7.4*	*7.6*	*7.8*	*8.0*	*8.3*	*8.5*	*8.8*
Industries	2	3	4	5	5	5	5	5
Physical losses distribution	25%	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*
Physical losses conveyance	2%	2%	2%	2%	2%	2%	2%	2%
Demand at distribution (l/s)	2,043	2,111	2,280	2,463	2,645	2,840	3,050	3,275
Mm³/year	64	67	72	78	83	90	96	103
Demand at production (l/s)	2,085	2,154	2,327	2,513	2,699	2,898	3,112	3,342
Mm³/year	66	68	73	79	85	91	98	105
Potential for reuse (Mm³/year)	32.9	36.2	39.1	42.3	45.4	48.7	52.3	56.2

Table X-4: Water demand scenarios in RADEEMA area of service – detailed calculation outputs

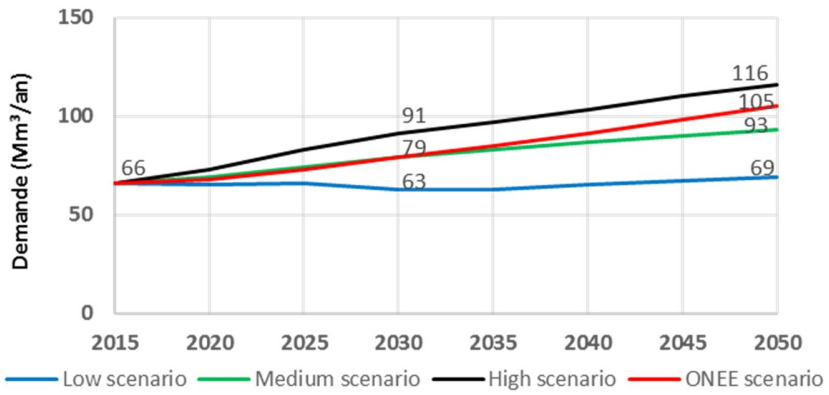

Figure X-4: Water demand scenarios in RADEEMA area of service

Water demand projection in RADEEMA's area of service

According to the PDO of Oum Er Rbia and Tensift, the area that would be fed from the Al Massira adduction, the Hassan 1st Sidi Driss complex and the Lalla Takerkoust complex consists of:

- Marrakech area including the districts of the city of Marrakech (served by RADEEMA), Tamensourt, Loudaya, M'Nabha and Sid Zouine as well as the rural population of the prefecture of Marrakech.
- the district of Haouz province comprising the municipalities of Aït Ourir, Amizmiz, Tahannaout, the centers of Tameslohte, Moulay Brahim, Lalla Takerkoust, Ghmate and Sidi Abdellah Ghiate as well as the rural population of this province.
- the area of Rehamna province comprising the municipalities of Ben Guerier and Sidi Bou Othmane, the center of Skhour Rhamna, as well as the rural population of that province.
- areas under the provinces of Kelaa Sraghna and Azilal.

ONEE has carried out forecasts of the demand for drinking and industrial water in this area on the basis of population projections, connection rates, domestic, administrative, tourism and industrial demands, similar to what is presented in the previous paragraphs for the RADEEMA area of action. The previous projections of ONEE for the RADEEMA area of service have been adjusted according to the above calculations. The water needs data for the provinces of El Kelaa and Azilal were taken from the PDO of the Oum Er Rbia. The results are shown in the following table. The total demand for the region is divided 50/50 between the RADEEMA area of action and the rest of the region. According to projections, in 2030 the demand for drinking water, industrial and tourist water in the prefecture of Marrakech and the neighboring provinces that draw from the same water resource would increase by 33 Mm3 / year to around 160 Mm3 / year, of which about 190 Mm3 / year by 2050):

Table X-5: Bilan d'eau de la région de Marrakech (en Mm³/an)

Zone/commune	Conveyance Al Massira					Canal de Rocade + Lalla Takerkoust					Groundwater contribution					Total				
	2015	2025	2030	2035	2050	2015	2025	2030	2035	2050	2015	2025	2030	2035	2050	2015	2025	2030	2035	2050
RADEEMA		**26.0**	**27.0**	**29.0**	**33.0**	**66.0**	**48.0**	**52.0**	**54.0**	**60.0**						**66.0**	**74.0**	**79.0**	**83.0**	**93.0**
Other urban centers																				
Tamensourt		4.3	6.6	8.3	9.1	2.45														
M'Nabha						0.06	0.06	0.06	0.06	0.06										
Loudaya						0.69	0.88	1	1.13	1.5	7.9									
Sid Zouine						0.4	0.53	0.59	0.66	0.85										
Grands Projets						0.4	1.1	1.63	2.45	2.45										
Marrakech rurale						7.71	8.5	8.8	9.04	9.04										
Sub-total urban centers		**4.3**	**6.6**	**8.3**	**9.1**	**11.7**	**11.1**	**12.1**	**13.3**	**13.9**	**7.9**					**19.6**	**15.4**	**18.7**	**21.7**	**23.0**
Haouz Province																				
Ait Ourir						1.63	1.89	2.17	2.42	2.40										
Amizmiz						0.63														
Tahannaout						0.53	0.72	0.82	0.91	0.91										
Ghmate						0.03	0.06	0.06	0.03	0.07										
Sidi Abdellah Ghiate						0.09	0.12	0.12	0.09	0.13	4.5									
Lalla Takerkoust						0.19	0.15	0.19	0.22	0.21										
Moulay Brahim						0.12	0.12	0.12	0.22	0.13										
Tameslohte						0.28	0.47	0.5	0.37	0.55										
Rural Haouz						11.08	11.55	11.84	12	13.08										
Sub-total Haouz province						**14.6**	**15.1**	**15.8**	**16.3**	**17.5**	**4.5**					**19.1**	**15.1**	**15.8**	**16.3**	**17.5**
Rehamna Province																				
Ben Guerir		3.8	4.3	4.6	4.7															
Sidi Bouhtmane		0.5	0.6	0.6	0.6															
Skhour Rhémna	3.7	0.2	0.2	0.3	0.3						3.0	1.7	1.7	1.7	1.7					
Rural Rhamna		4.4	4.3	4.2	4.7															
Grands projets		6.8	8.0	8.0	8.8															
Sub-total Rehamna Province	**3.7**	**15.6**	**17.4**	**17.8**	**19.1**						**3.0**	**1.7**	**1.7**	**1.7**	**1.7**	**6.7**	**17.3**	**19.1**	**19.5**	**20.8**
Demand El Kelaa et Azilal						**15**	**24**	**27**	**29**	**35**						**15.0**	**24.0**	**27.0**	**29.0**	**35.0**
Total water demand	**3.7**	**46**	**51**	**55**	**61**	**107**	**98**	**107**	**113**	**126**	**15**	**1.7**	**1.7**	**1.7**	**1.7**	**126**	**145**	**160**	**169**	**189**
Allocation for urban water potable water	**3.7**	**95**	**95**	**95**	**95**	**67**	**57**	**57**	**57**	**57**	**15**	**1.7**	**1.7**	**1.7**	**1.7**	**86.1**	**154**	**154**	**154**	**154**
Balance –potable water	**0.0**	**49**	**44**	**40**	**34**	**-40**	**-41**	**-50**	**-56**	**-69**	**0**	**0**	**0**	**0**	**0**	**-40**	**7.9**	**-6.0**	**-15.7**	**-35**

- 79 Mm3 / year for the supply of the RADEEMA zone (medium scenario)
- 19 Mm3 / year for the water supply of other urban centers, managed by the ONEE
- 10 Mm3 / year for water supply for major projects
- 25 Mm3 / year for water supply in rural areas
- 27 million cubic meters per year corresponding to the allocation for the water supply of the provinces of El Kelaa and Azilal from the Hassan 1er - Sidi Driss complex

The water allocations allocated to drinking water taken into account are those fixed within the framework of the Tensift and Oum Er Rbia PDAIREs:

- 57 Mm3 / a from the Canal de Rocade, of which 40 Mm3 / a from the Hassan 1er dam and 17 Mm3 / a from the Lalla Takerkoust complex; currently (2016) the allocation and 66 Mm3 / year
- 95 Mm3 / a from the Al Massira Dam
- 1.7 Mm3 / y from the Bahira water table

The water supply to be taken from the Al Massira water supply for the AEP in the RADEEMA area of action is currently limited to about 35% of the water requirements of this zone due to the non-programming of necessary for the interconnection of water tanks. Once the interconnections of the reservoirs are completed, the allocation to be taken from the Al Massira dam must be capped at 85 Mm3 / year due to the capacity of the existing water supply (7 Mm3 / year) and under construction (78 Mm3 /year).

ANNEX XI - Technical solutions for achieving future water security in Marrakesh

General remarks

In the sections below, options for mitigating the water shortage that are considered particularly relevant for the city of Marrakech are described in detail .For each of the options selected, data on projected water volumes or water savings were estimated in terms of average annual total volumes. The rough estimate of costs is based on the following assumptions:

For all options, the cost estimate is based on average annual water volumes and an average preliminary sizing of the infrastructure.
Only investment costs and additional transaction options are considered. The costs of the existing infrastructure used for the capture, transfer and treatment of water mobilized by an option are therefore not considered. For example, the investment costs of the existing Rocade Canal used for the transfer of water to Marrakech are not considered in options SW4, SW5, WT1 b and DS1.Only the additional operating, maintenance and transport costs, ie for extra volumes of water, are considered.
The environmental costs of the options are not considered. Environmental effects are part of the economic analysis of options and are assessed using the indicator " Environmental and Social Risk Management".
The effects of climate change and the corresponding volume reductions are not considered. The vulnerability of options to climate change is studied qualitatively in the economic analysis of options, using the indicator " Resilience to climate change".

The following diversification options to address water scarcity in the context of GIEU were considered particularly relevant for the case of Marrakech:

Desalination of seawater by reverse osmosis (DS1)
Reuse of treated wastewater for non-potable use (WW1, irrigation), and reuse of gray water in hotels (WW3)
Network rehabilitation, leak detection and accompanying measures (NR1)
Introduction of Best Practices for Demand Management (DM)
Construction of new dams (SW4) and increase of the storage capacity of existing dams to store surface water (SW5)
Rainwater harvesting, storage and reuse at city (RW3) and small-scale level (RW1)
Recharge of aquifers by infiltration (GW3)
Inter-basin water transfers or transbassin diversions (WT1a and WT1b)
Urban Landscaping (DM4)

1. **Desalination of seawater by reverse osmosis (DS1)**

Summary of the current situation: Desalination of seawater is now considered in Morocco as a feasible and feasible option against water scarcity. The National Water Plan (NCP) foresees the construction of desalination plants for seawater to produce around 515 million m 3 per year in 2030.

Description and impacts of the option for Marrakech: Desalination of seawater is not a direct water supply solution, because of the distance (about 150 km) and the difference in altitude (500 m altitude, 800 m of vertical drop) from the coast, which would cause prohibitive pumping costs. In contrast to this, the National Water Plan (PNE, 2015) provides for the construction of a water desalination plant to cover part of the water supply to the city of Casablanca, Office Chérifienne de Phosphate (OCP) is

currently undertaking the construction of two seawater desalination plants in Jorf Lasfar (18 km from the city of El Jadida) and Safi.

The cities of Safi and El Jadida were selected for the following reasons:

- the existence of water desalination plants in Jorf Lasfar and Safi;
- the existence of an agreement between ABHOER, ONEE, OCP and the Ministry in charge of Water which gives the possibility of supplying the city of El Jadida with the desalination plant of Jorf Lasfar,
- the importance of water losses between the Al Massira dam, the Daourat Dam and the Safi Dam;
- these two cities would release an allocation equivalent to that paid by the Al Massira - Marrakech adduction in progress, around 75 Mm 3 / year by 2050
- a very important advantage of this option is that desalination of seawater is not affected by climate change.

The OCP Convention, signed in 2012 with the Ministry in charge of Water, the Ministry of Agriculture, the ONEE and the Oum Er Rbia Basin Agency, has already considered the possibility of supplying the city of El Jadida from the desalination plant of the sea water of Jorf Lasfar. It is thus possible to feed the cities of Safi and El Jadida from the two desalination plants of the OCP. The supply of drinking water to the cities of Safi, El Jadida, Azemmour and Casablanca from desalination would free up the water allocation allocated to these cities, estimated at around 200 million m 3 per year at the level of and to use this volume of water for the Grand Marrakech, and the provinces of El Kelaa Sraghna, Rhamna and Azilal.Desalination to provide coastal cities with water and release water in the Al Massira reservoir for the city of Marrakech, for irrigation or to reduce the overexploitation of groundwater can be a very promising solution. This option should be further developed, including its cost, taking into account the experiences being launched (eg Chtouka, Agadir and Al Hoceima).

The Ministries of the Interior, Agriculture, Water, ONEE, OCP, ABH of Tensift, Oum Er Rbia, and Bouregreg, ORMVA of the Doukkala and Tensift are involved in the implementation of these seawater desalination projects. A convention should be signed by these bodies to define the institutional arrangements for this exchange and the conditions for the financing, operation and management of these projects.

It should be noted that the city of Casablanca could be well supplied from the desalination of the sea water which would release a relatively large amount of water at the Al Massira dam.This solution could be studied in the context of which the northern water transfer project (WT1a) would not be carried out or in the context of a comparison between desalination and water transfer. It would be interesting to feed the Doukkala perimeters both from the desalination of sea water and from the Al Massira dam, depending on the year's water supply.The water demand for this perimeter is close to one billion cubic meters. The experience of the C htouka perimeter under discussion could help to make this option clearer.

Projections of volumes

The volume of water to recover at the dam Al Massira by achieving water desalination projects to supply the cities of Safi and El Jadida would fall in 2030 to almost 60 million m 3 per year and will increase to 75 Mm 3 / year in 2050.The use of desalination of seawater will result in the recovery of both the volumes of water for drinking water in the cities of Safi and El Jadida and the loss of water

between the Al Massira dam and the dam Daourat and between the dam Al Massira and the dam of Safi. These losses are considerable and estimated at about 25%.

Volumes in Mm³/year	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Needs of the town of Safi Needs of the towns of El Jadida and related centers	14.7 25.4	15.5 28.0	16.2 30.2	17.2 32.5	18.0 35.0	19.0 37.0
Desalinated water volume	40.1	43.5	46.4	49.7	53.0	56.0
Recovered Water Losses (Safi)	6.0	6.2	6.5	6.8	7.2	7.6
Recovered water losses (El Jadida)	7.6	8.5	9.0	10.0	10.5	11.0
Volume recovered for the city of Marrakech at the Al Massira complex	53.7	58.2	61.9	66.5	70.7	74.6

Table XI-1: Estimation of the evolution of the volume of water released by desalination of sea water and the volume recovered for the city of Marrakech in Al Massira (source: consultant's estimate

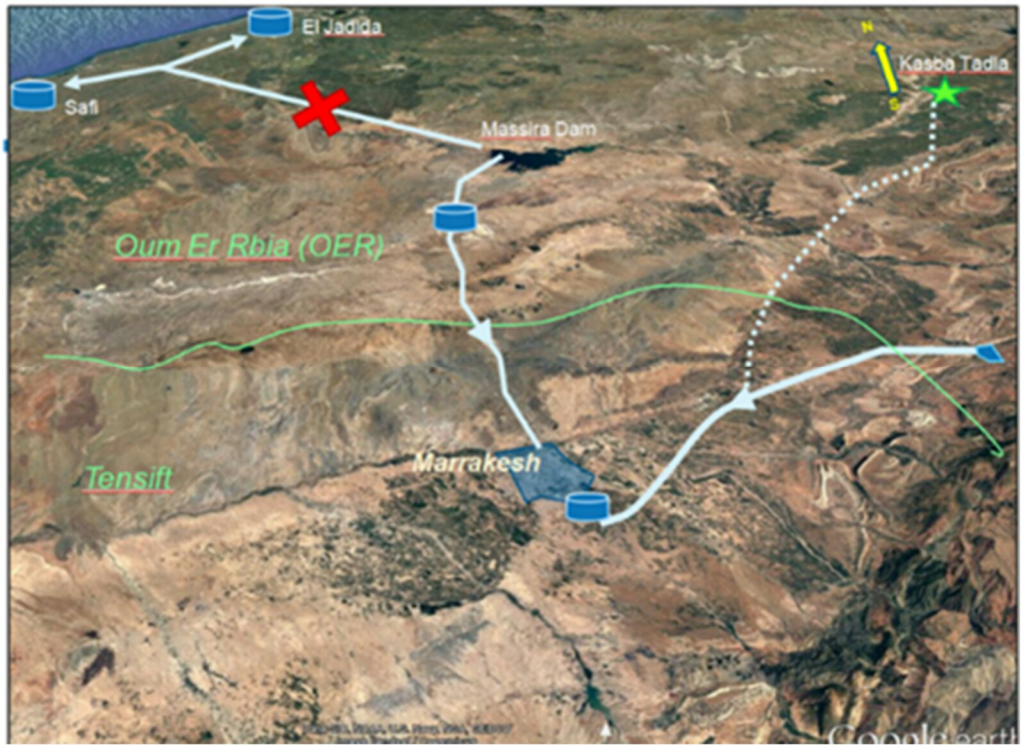

Figure XI-1: Alternative scheme with desalination of sea water and transfer of water from Kasba Tadla to Marrakech (DS1)

Cost Estimates: Estimated seawater desalination costs were based on the following:

Existence of the seawater desalination plant at Jorf Lasfar of the OCP, which is cheaper than a completely new plant because the land and some infrastructure are already available .An extension of the plant will be scheduled to meet drinking water requirements ;
The Safi seawater desalination plant is under construction. This plant, with a capacity of 25 Mm 3 / year, is just sufficient to cover the needs of the OCP. An extension of the desalination plant is therefore necessary to cover the drinking water needs of the city of Safi;

Connecting works between seawater desalination plants and drinking water systems in the town of Safi and the town of El Jadida;
Average annual water capacity and volumes.

Investment costs : The capital cost, including the cost of the land, water intake, pre-treatment and post-treatment of the equipment and the costs of the studies depends mainly on the capacity of the desalination plant (see Figure 4.1 in Chapter 4).The overall investment cost includes (Table 1.2):

The investment costs of the extension of the two desalination plants in the order of 56 Mm 3 / year, of which 37 Mm 3 / year at the level of Jorf Lasfar and 19 Mm 3 / year at the level of Safi.This cost would be MAD 1 230 million (8 000 [1] MAD / m 3 / day = 22 MAD / m 3 including a reduction of about 30% to take account of investments already made and land already available) of which MAD 870 million for equipment costs and MAD 360 million for Civil Engineering (GC).
Connection costs for desalination plants and drinking water systems would be close to MAD 250 million, including MAD 150 million for the city of El Jadida and MAD 100 million for the city of Safi.

These investment costs do not include the costs of existing installations and infrastructure of the platform of the OCP phosphorus industry in Jorf Lasfar and Safi .It is estimated that about 30% of the infrastructures with a sufficient capacity are already in place (water intake and water supply channel to the desalination plant, discharge channel and existing substations with sufficient capacity, existing access roads, etc.).

Cost of renewal: The renewal costs are calculated taking into account a lifetime of 40 years for civil engineering and 20 years for equipment.

Fixed operating costs : Fixed operating costs (Table 1.2) are calculated on the basis of 3% of the cost of works for equipment, 0.5% for civil engineering and connecting structures and 0.8% for of Kasba Tadla:

	Investment MAD millions	**Fixed operating costs% per year**	**Fixed Operating Costs MAD millions per year**
Civil engineering works	360	0.5%	1.8
Facilities	870	3.0%	26.1
Connections	250	0.5%	1.25
Adduction of Kasba Tadla	900	0.8%	7.2
Total	2 380	-	36.35

Variable operating costs, including processing costs, are estimated at 3 MAD / m 3 desalted on the following basis:

Number of kWh consumed per m 3 desalted: 3.0 kWh / m 3
Proportionate share of energy: 65%
Energy cost: 0.66 MAD / kWh

Variable costs: The major energy consumption of desalination plants is one of the main disadvantages of this alternative source of drinking water.This consumption is due, on the one hand, to high-pressure pumping through membrane filters (two thirds of the total) and on the other hand to the pumping of seawater and pretreated water, washing filters and membranes, etc.In recent years there has been a

decrease in specific consumption due to the progressive replacement of distillation by reverse osmosis, and to the concentrate energy recovery system for the membrane process. The energy recovered by the various systems varies from about 25 to 40%. Today, the consumption of electrical energy would be between 2.5 kWh and 3.0 kWh per m 3 of drinking water produced by reverse osmosis. This consumption also varies according to the temperature of the seawater, the distance from the capture of the raw water, the production of the plant in relation to its total capacity, the existence of one or two filtrations and the type of water intake. The reforms undertaken by the Kingdom of Morocco make it possible to envisage seawater desalination plants, coupled with renewable energies. The cost of kWh wind would currently be between 0.3 and 0.4 MDH per kWh.

Overview of volumes and costs

The table below summarizes the main characteristics and costs of desalination of seawater for the specific situation with the extension of the existing desalination plants of Safi and Jorf Lasfar and the equivalent mobilization of up to 75 Mm 3 / year at the Al Massira complex and the transfer of this volume of water from the Kasba Tadla dam to Marrakech.In addition to the desalination costs, the investment and operation costs for the transfer of an equivalent volume of Kasba Tadla to Marrakech must be included.On the other hand, there are no costs for the transfer of water from desalination plants to Marrakech .

The total cost is calculated at 7.5 MAD / m 3 (including 2.6 MAD / m 3 for transport costs from Kasba Tadla to Marrakech).Desalination cost (4.9 MAD / m 3) is significantly lower than cost generally found in the region (about 10 MAD / m 3 for a capacity of the order of 40 million m 3 / year).This is due to the 25% reduction in water losses between Al Massira and the coast and the savings of 30% of the already existing desalination infrastructure.

Duration of extension works	5 years from 01/01/2020
Date of commissioning	Starting at 209€
Desalinated water volume	40 Mm 3 / year (2025) and 56 Mm 3 / year (2050)
Volume of water released at Al Massira level	54 Mm 3 / year (2025) and 75 Mm 3 / year (2050)
Investment cost: Desalination Admission of the Kasba Tadla dam	MAD 1,480 million for 56 Mm 3 / year MAD 900 million for 75 Mm 3 / year
Fixed operating costs (desalination and transfer of the Kasba Tadla dam)	MAD 36.2 million (approximately 0.6 MDH / m 3)
Desalination Variable Costs	3.0 MAD / m 3
Variable costs of transfer from Kasba Tadla to Marrakech (to Canal de Rocade): - Pumping costs - Transport fee - Cost of water treatment	Total 1.3 MAD / m 3 as follows: 0.52 MAD / m 3 0.53 MAD / m 3 0.25 MAD / m 3
Cost per m 3 of clear water	7.5 MAD / m 3 (without 20% for unforeseen costs and contingencies)

Environmental and social impacts:

Desalination of sea water ensures a safe supply of drinking water. The positive externalities associated with desalination correspond to (i) decreased pressure on surface and groundwater, (ii) mitigation (see

abandonment) of investment (and negative externalities) for inter-basin transfers projects when cost of m 3 product becomes competitive and iii) the production of quality water, free of pollutants and viruses.The absence of limestone avoids the clogging of distribution networks and pumping installations, which reduces maintenance costs. These benefits are offset by the negative effects that are present during the life of this option (Table 7.1):

Measure : Desalination of seawater by reverse osmosis (RO)		
Phase	**Site Level**	**Downstream hydraulic**
Construction Phase	• Air pollution (dust and gases) {2}Ecosystems degradation{/2} • Safety of workers and local residents • expropriations • Loss of ecological values • Loss of asset values	• Deterioration of bathing water quality • Marine Pollution
Operation phase	• Loss of income (tourism, recreation) Noise • Ineffective management of chemical storage • Solid wastes (filters, futs, packing bags, etc.) • Brine discharge • Greenhouse gas potential (linked to high energy consumption)	• Changes in salinity of seawater • Decreased oxygen • Increase in heavy metal content • Loss of ecosystems • Loss of bathing water quality

Table XI-2: Environmental and social impacts of seawater desalination

2. **Reuse of treated wastewater for non-potable use (WW1)**

Summary of the current situation: The area served by the RADEEMA liquid sanitation network includes the agglomeration of Marrakech with the districts Menara, Gueliz, Medina, Méchouar-Kasbah, Sidi Youssef Ben Ali and Annkhil and extends partially in the rural communes in the vicinity.This zone of action extends over an area of 23,804 ha with a population of about 1 million inhabitants.The service rate is about 91% and the network line is about 2 500 km (see Figure 5.2).With the increase in the number of golf projects and especially the alarming deficit in the Canal de Rocade and the lowering of the Haouz aquifer, it was decided to build a Wastewater Treatment Plant (STEP) in the use of treated wastewater for watering golf courses and green spaces.

The STEP with a capacity of 1.3 million equivalent inhabitants (118,000 m 3 / d, ie <43 Mm 3 / year, rainy weather: 9,828 m 3 / h) treats almost all urban wastewater city of Marrakech and offers non-conventional water resources (purified waste water) with a capacity of 33 Mm^3 per year.

The tertiary treatment and distribution system with 5 pumping stations makes it possible to ensure the irrigation water requirements of the golf courses whose average requirements are estimated at about 1 Mm^3 per year per golf course.Of the 19 projects planned at the Marrakech level, 11 are currently operational, 3 are under construction and 5 are on stand-by. Of the 11 functional golf courses, 8 are served by the STEP with a volume of treated waste water of about 6 Mm^3 per year (2015).The water supply of each golf course, as well as the conditions of supply and financial contribution are governed by an agreement between RADEEMA and the promoters. Under the terms of the agreement, promoters are required to cover at least 80% of the golf course's requirements for treated water; the difference of 1.5 to 2 Mm 3 per year is pumped from the tablecloth because the m^3 pumped costs less (about 0.5 to 1.5 MAD / m 3 including the abstraction fee of 0.04 MAD / m 3) than

the cleaned m³ (2.5 MAD / m 3 , which is the selling price currently charged to the golf courses based on a currently and actually distributed volume of 6 Mm 3 / year).According to RADEEMA, 17 golf courses have signed an agreement and at least two of them continue to source exclusively from the aquifer and the Rocade canal and extract about 2.5 Mm 3 per year.

Apart from the use of wastewater for golf courses, the Palmeraie de Marrakech - part of UNESCO's heritage - is irrigated with waste water.In a first phase, 390 ha of palm plantations with about 200,000 palm trees are already irrigated with 0.75 million m 3 per year of treated wastewater.In the near future, the whole of the Palmeraie which extends over 810 h will be supplied by the STEP with 1.5 Mm 3 per year.The investment costs of this project are approximately MAD 35 million.

Treated wastewater that is not or can not be used for the irrigation of golf courses and the Palmeraie (approx. 26 Mm 3 per year in 2015) are evacuated to the Tensift.A considerable part of this volume should infiltrate into the water table.

Description and impacts of the option for Marrakech: According to information from RADEEMA and environmental studies [2] , the hydraulic capacity of primary, secondary and tertiary treatments will be saturated by 2020.RADEEMA therefore initiated planning for the extension of the STEP or the construction of a second STEP. For the moment the extension of the existing STEP is prioritized.

Considering water-saving measures (eg drip irrigation, automated watering of golf courses according to current requirements measured continuously, replacement of grass in green spaces with plants that are more economical in water consumption), irrigation needs per hectare should stabilize and decrease over the long term. By 2030, the demand for irrigation water for Marrakech is therefore estimated at about 35 million m 3 per year.The need for future irrigation will therefore be lower than the wastewater resources usable for irrigation or irrigation, estimated at 42 Mm 3 / year by 2030 and 50 to 55 Mm 3 / year by 2050 (see Table 5.3).

In order to cover irrigation and irrigation water requirements with treated wastewater, the treatment capacity of the wastewater treatment plant must be extended as and when the treated wastewater systems are developed. The increased processing capacity of currently 33 m 3 to 60 m 3 per year should involve investments of the order of MAD 1,000 millions.Since primary and secondary wastewater treatment is a legal requirement, the corresponding investment and operating costs should not be taken into account for the reuse of treated wastewater

Description of the feasibility and climatic vulnerability: Other positive effect on the groundwater by a reduction of pumping of the ground water and the infiltration of treated wastewater this option could have the following negative consequences:

> The purified waters are generally of high salt content. They are therefore likely to result in soil salinization effects, which could lead to soil leaching practices. The quantity of leaching water can represent nearly 30% of the water required for the watering of golf courses.
> The reuse of purified wastewater for golf courses and green spaces results in a significant reduction in volumes available for the informal irrigation sector.
> Irrigation with treated wastewater is likely to cause soil sterilization. It involves a risk of contamination of soils and groundwater with salts, nitrates, pesticides and heavy metals (eg chromium from tanneries).

However, this potential damage is very limited in terms of health benefits, in terms of public health and protection of water resources, generated by wastewater treatment. Wastewater is not affected by the impact on climate change.

Projections of the volumes: The realization of a recharge project from the purified wastewater of the city of Marrakech to improve the infiltration and recharge of the groundwater of Haouz with a volume of water of nearly 30 Mm 3 per year would include the following components:

Expansion of the STEP from 33 to 60 Mm 3 / a
STEP transport system to water use sites

The volume of purified water that would be reused was estimated on the basis of the drinking water requirements of the city of Marrakech of 79 Mm 3 in 2030 and 103 Mm 3 in 2050 (Table 5.3) and the water needs of the green spaces of the city of Marrakech and the golf courses.A water supply of 30 Mm 3 / year has been defined to satisfy these needs of these spaces and these lands.

The treatment and reuse of purified wastewater project in Marrakech is justified for:

ensuring compliance with discharge standards in the natural environment and improving the sanitary and environmental conditions of the city;
meet the water needs of golf courses and green spaces;
to meet the irrigation needs of the Nfis perimeter, irrigated by the Lalla Takerkoust complex or to reinforce the water resources of the Haouz aquifer.

The volume of treated wastewater from the second stage of the WWTP is given in the table below:

Mm^3/an	2020	2025	2030	2035	2040	2045	2050
Volume	-	-	10	15	20	25	30

Table XI-3: Estimation of the evolution of the volume of additional treated waste water (source: RADEEMA)

Cost Estimates: Capital costs are estimated as follows:

Expansion of the STEP from 33 to 60 Mm 3 / a: about MAD 1'000 million of which nearly 20% for tertiary treatment; the distribution of the cost of the STEP would be as follows [3] :

- MAD $ 800 million for the project on compliance with standards and improvement of sanitary conditions (cost of primary and secondary treatment);
- MAD 200 million for the wastewater reuse project (tertiary treatment)

Transport system from the STEP to the sites of use of the water: about MDH 300 million which add up to the investment of the STEP. Compared to the first phase of the STEP, transport system costs are likely to be lower because there will be no distribution system to supply the golf courses, but treated wastewater would be transported a distance of about 25 km to the Canal de Rocade.

This project could be carried out within the framework of the National program for the reuse of wastewater and purified water being launched by the Ministry in charge of Water.An average lifespan of 20 years seems realistic when considering infrastructure renewal costs .

Fixed operating costs are estimated at 2% of investment costs (international benchmarks).

Cost of maintenance, operation and treatment : AFD's summary note on the recent advances and major challenges of the water sector in Morocco, drawn up in April 2008, assessed the operating costs of the station wastewater treatment to almost 15% of the investment costs of tertiary treatment and

distribution works, ie MAD 75 million / year or 2.5 MAD / m 3 on the basis of the total treated volumes (approximately 30 Mm 3 / year by 2050).

Overview of volumes and costs: The table below summarizes the main characteristics of the reuse of treated wastewater for watering and recharge of groundwater.The total cost is calculated at 5.4 MAD / m 3 .The cost level is higher because the full benefits of planned investments for the period 1925 - 1929 would only mature during the 2040s.

Implementation phase	5 ans (2025 – 2029)
Date of commissioning	Starting 01/01/2030
Volume of water	10 Mm 3 / year in 2030 to 30 Mm 3 / year in 2050
Investment cost	MAD 200 million for tertiary treatment and MAD 300 million for the distribution of purified wastewater Total costs: MAD 500 million
Fixed operating costs	MAD 10 million / year (2% investment)
Operating Costs	2.5 MAD / m 3 : MAD 75 million per year by 2050
Cost per m3	5.4 MAD / m 3 (without 20% for unforeseen costs and contingencies)

Table XI-4: Estimated volumes and costs of m 3 for the reuse of purified wastewater for watering and recharge of groundwater

Environmental and social impacts: Recycled water is generally used for the following purposes:

Irrigation of golf courses, parks, sports grounds;

As industrial water for cooling systems, for the fire system, for dust abatement, for laundries, for car wash facilities;

For agriculture : irrigation, animal feed, etc.;

For administrative buildings for toilets;

For the replenishment of slicks; etc.

In addition to being a constant and independent source of rainfall, the most cited positive externalities for the reuse of treated wastewater are the avoided costs of environmental degradation. In Morocco, according to the World Bank (2016c), environmental degradation costs for wastewater discharged without treatment (62%) would average 818 million dirhams.Reuse of treated wastewater also reduces the pressure on water resources (surface and groundwater). The same report cited above suggests that for the Tensift basin, the reuse of wastewater to reduce the pressure on the aquifer, whose overexploitation is evaluated at 180 Mm^3 / year, will require six STEPs of the same capacity as the one currently installed in Marrakech in 2011 ... for a total investment cost (per plant) of MAD 1,232 million. Based on a lifetime of 25 years by STEP, a zero residual value at the end of the period, a capitalization rate of 6% and an inflation rate of 1.2%, the annuity discounted for the period 2014 would be MAD 551 million , 7.5% of an investment of almost MAD 7.4 billion (excluding operating costs) .These benefits are offset by the negative effects that are present during the life of this option :

Wastewater reuse for non potable purposes

Phase	**At site Level**	**Downstream hydraulic**	**Hydraulic upstream**
Construction phase	• Loss of arable soils • Air pollution (dust and gases)	• Pollution of surface and ground water	

(networks and STEP)	Ecosystems degradation • Safety of workers and local residents • Displacement of populations • Loss of ecological values • Loss of asset values		
Operation phase	• Increased frequency of water-borne diseases (workers, populations bordering on STEP) • Production of greenhouse gases • Sludge production	• Increased frequency of water-borne diseases (parks, golf courses, streams, springs, wells, agriculture, bathing waters)	• Increased frequency of water-borne diseases (parks, golf courses, agriculture, wells and springs) • Loss of income (tourism, fishing, agriculture)

3. Reuse of gray water in hotels (WW3)

Summary of the current situation: Drinking water consumption in hotels and accommodation in Marrakech is very considerable. By assuming, according to the figures below, a current capacity of about 80,000 beds, a specific moderate consumption of 300 liters per night and an average occupancy rate of 40%, the annual consumption is currently estimated at about 3.5 million m 3 per year. This figure is higher than the sales of RADEEMA to the tourist category customers specified for 2015 at 2.7 Mm 3 per year. RADEEMA's billing to the tourism sector thus appears to be too low.

Catégorie	Standards de consommation d'eau au Maroc(litre / nuitée)
Hôtel 5* Grand Luxe	600
Hôtel 5*	500
Hôtel 4*	400
Hôtel 3*	300
Ryad, équivalent 5*	500
Villa	300
Village de vacances, équivalent 4*	350
Appart-hôtel	250
Appartement	180

Table XI-5: Moroccan drinking water standards
(source: ONEP / ABHT, Mission I, Inventories of tourist establishments [...], 2010)

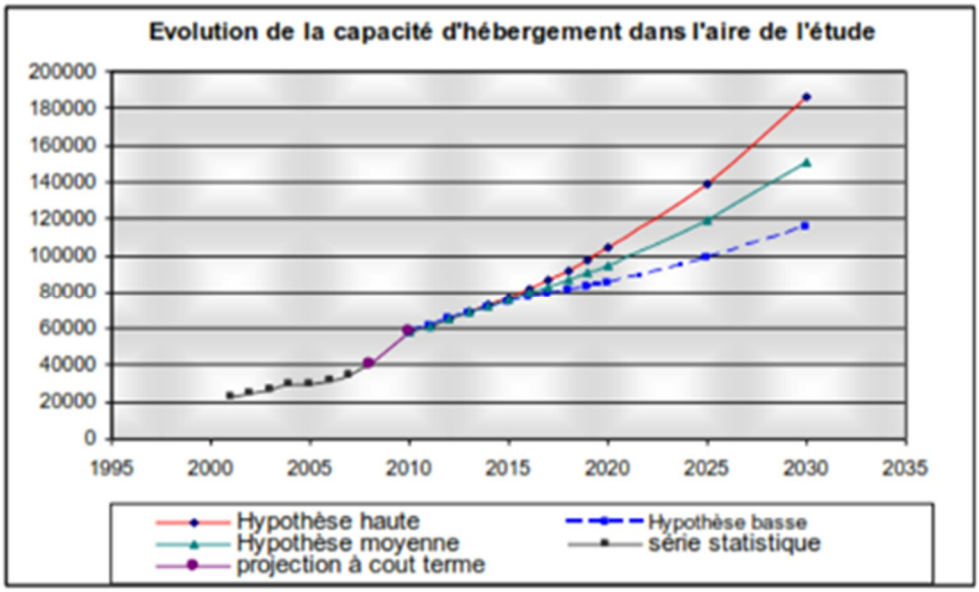

Figure XI-2: Evolution of hotel lodging capacity in Marrakesh in the long term (source: ONEE / ABHT, Mission I, Inventories of tourist establishments [...], 2010)

CATEGORIE	NOMBRE	NOMBRE DE CHAMBRES	NOMBRE DE LITS
LUXE	08	1.011	2.145
5 ETOILES	17	4.762	9.912
4 ETOILES	29	4.974	10.169
3 ETOILES	22	1.439	3.085
2 ETOILES	13	745	1.512
1 ETOILES	8	467	951
HÔTELS CLUB	12	2.898	6.242
R.H (Résidences Hôtelières)	26	933	2.306
AUBERGES	09	102	226
PENSIONS	14	249	567
GÎTES ET FERMES D'HÔTES	32	100	578
REFUGES	05	-	198
CAMPING	01	-	60
MAISONS D'HÔTES	650	3.910	8.588

Table 2.4: Typology of tourist establishments (source: ABHT / Waman Consulting, Mission II, State of play and perspective of rationalization of water use in the hotel sector of Marrakech [2010]

In Marrakech, hotels have various water sources. Drinking water is supplied mainly by RADEEMA. For other uses, facilities often have alternative resources to reduce water bills and have flexibility in water supply. The structure of water consumption can be summarized as follows (Figure 2.2):

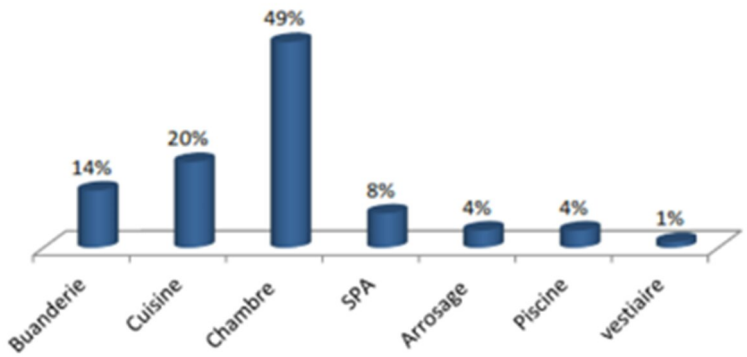

Figure XI-3: Distribution of drinking water consumption on the various services (source: ABHT / Waman Consulting, Mission II, State of play and perspective of rationalization of water use in the hotel sector of Marrakech [...] , 2010)

The National Plan for the Development of Tourism Activities designed in 2010 aims to impose Morocco as a tourist model combining sustained growth with responsible management of the environment and respect for the cultural authenticity of Morocco.

Description and impacts of the option for Marrakech: Considering that the drinking water consumption of the tourism sector is expected to increase further and could reach a demand of 5 to 10 million m 3 per year, the potential for savings is considerable.The realization of water savings in luxury establishments is a challenge, water recycling measures or the re-use of relatively unpolluted gray water from showers, laundries and swimming pools are a relevant option with potential for several million m3 per year.Indeed, in tourist establishments, more than 50% of drinking water consumption corresponds to gray water that is less polluted and relatively easy to process and reuse.

According to pilot studies in Jordan [4] the saving potential of gray water reuse is in the order of 15 to 20 m 3 per hotel room per year.An increase in capacity of 20,000 beds and 10,000 rooms corresponds to a potential saving of about 150,000 to 200,000 m 3 per year without compromising service quality or sanitation.

Since re-use of gray water requires double sanitary facilities, this option seems to be favorable for new tourist infrastructures where sanitary piping and adapted treatment systems can be planned and installed from the beginning.There are now a multitude of systems to treat the gray waters of hotels, such as the Pontos AquaCycle system (http://pro.hansgrohe-int.com/assets/global/pontos_ac2500_brochure.pdf) which has proved its effectiveness in a multitude of applications.

As shown by the experiences in Jordan, the implementation of gray water reuse systems requires an adaptation of the institutional and regulatory framework as well as the provision of rules and standards for the internal re-use of gray water (re-use for irrigation is already regulated). The draft water law currently under discussion in Parliament opens up the possibility of reusing gray water provided that it is not used for drinking, preparing, packaging or storing food products or foodstuffs.

Taking into account the water supply costs from the project, the reuse of gray water generates significant savings in terms of the cost of use for the ONEE, RADEEMA and the hotels.

Options for reuse of wastewater should be assessed more, for example through a pilot project in Marrakech, as requested in the workshop with the World Bank in July 2016. As part of such a pilot

project, a greywater program should be developed that will include a definition of the institutional framework, regulations to be put in place and incentives to promote greywater.

Volume projections: The hotel capacity is estimated in 2015 at 80 000 beds or approximately 40 000 rooms.The current consumption of the tourism sector is estimated by the consultant at about 3.5 Mm 3 per year, which corresponds to about 250 liters per room and day.

According to Table 5.4 (average scenario), the water requirements of hotel establishments are estimated at 4.4 Mm 3 / year in 2030 and 6.6 Mm 3 / year in 2050 (Table 2.5) .Taking account of the fact that nearly 50% of drinking water consumption corresponds to gray water which is relatively unpolluted and relatively easy to process and reuse , the gray water potential in all hotel establishments is estimated at 2.2 Mm 3 / year in 2030 and to 3.3 Mm 3 / year in 2050.A voluntary program to recover this gray water potential needs to be studied and implemented at the level of all the establishments in the city of Marrakech, given the scarcity of water in the Marrakech region, the cost of water may exceed 20 MAD / m 3 if the shortfall for irrigation is taken into account in the cost of drinking water from the water transfer project.

Volume dégagé	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Mm^3/an	1.8	2	2.2	2.5	2.7	3.0	3.3

Table XI-6: Estimation of the evolution of the gray water potential at the level of all hotel establishments

The water requirements of the hotel gardens, with an overall area of around 510 ha, are estimated at around 1.7 million m 3 per year.The gray water potential thus exceeds the watering needs of green areas at the hotel establishments.

Cost Estimates: The cost of the cubic meter of gray water was estimated in the study of Tarfaya and Al Hoceima [5] to about 22 MAD / m 3.This cost was estimated on the basis of the international benchmarks of re-use of gray water for households (35 l / pers / day of water saved at a cost of around 4000 EUR (source : Cambridge Water).This cost has been reduced by 50% to reflect the price level in Morocco. On the basis of these cost elements, the investment cost of the overall program would be close to MAD 400 million.

Renewal cost: To take into account the renewal costs of the collection and gray water treatment facilities, a lifetime of 20 years seems realistic.

Fixed operating costs: Based on international benchmarks, operating costs are estimated at 2% of investment costs. This cost includes all maintenance, maintenance and energy costs.

Volume and cost overview: Table 2.6 summarizes the main characteristics of gray water reuse in hotels and the cost per cubic meter of drinking water. The total cost is calculated at 26 MAD / m 3.

Duration of production	short term
Date of commissioning	Starting in 2018
Volume of water	1.7 Mm 3 / year from 2020 to 2050
Investment cost	MAD 400 million
Amortization period of the investment	years.
Cost of maintenance, including pumping costs and water treatment costs	MAD 8 million / year, or 4.7 MAD / m 3

Cost per m 3 of clear water	26.1 MAD / m 3 (without 20% for unforeseen costs and contingencies)

Table XI-7: Estimated cost of m 3 of water released by gray water reuse in hotels

Environmental and social impacts: Although gray water treatment costs are high, their reuse has an interesting positive externality in that it reduces the demand for drinking water for toilets and irrigation applications. gardens. This re-use leads to the reduction of the investments necessary for the treatment of waste water and the reduction of the associated pollution rates. It is accepted that more than 50% of the waste water generated by dwellings (and hotels) corresponds to gray water. These benefits are offset by the negative effects that are present during the life of this option:

Reuse of gray water in hotels

Phase	**Site Level**	**Downstream hydraulic**
Construction Phase	• Rejection of option for cost considerations	not applicable
Operation phase	• Increased frequency of waterborne diseases (if the treatment system fails) • Salinization of soils • Groundwater pollution	• Groundwater pollution

4. Network rehabilitation, leak detection and accompanying measures (NR1)

Summary of the current situation: The current status of the NEEE water supply and distribution system can be characterized as follows:

The overall efficiency of the ONEE for the supply and supply to the distributors of drinking and industrial water in the Marrakech region is around 90%. Most of the water losses correspond to the process needs of the treatment plant (continuous purges of the sludge cleaners, washing of the filters, etc.). It is assumed that these losses of water have returned to the Canal de Rocade.

Downstream of the treatment plant until delivery to RADEEMA, efficiency is estimated at 98% O NEE's infrastructure offers few prospects for water-saving potential.

ONEE initiates programs to improve the technical performance of drinking water distribution systems in the urban centers of the region. At present, the efficiency of the networks varies from 63% to more than 80%; the objective of ONEE is to achieve generally 80% returns in 2020.

According to RADEEMA, the current situation of the water distribution system of RADEEMA can be characterized as follows:

RADEEMA annually undertakes a program to improve the technical performance of the drinking water distribution network. At present, the efficiency of the network is around 75%. The objective of RADEEMA is to achieve a rate of return of 77% in 2019. The budget devoted to this objective is MAD 100 million.

The renewal rate of the drinking water pipeline (2,400 km in total) is 1.5% per year, corresponding to MAD 15 to 20 million per year.The rate of renewal of the sewage pipeline is about 1% per year.

The drinking water pipeline in the Medina is in a worse condition and water leakage can cause structural problems to the foundations of the houses. In addition, public fountains are not charged which implies financial losses in the Medina.

A leak detection program is underway.

The sectorisation of the network is underway and provides for two areas of pressure.

Description and Impacts of the Marrakech Option: According to the 2017 Master Plan, RADEEMA intends, among other things, to increase efficiency to at least 80% by 2025 and to make the supply of drinking water more reliable:

Maintain the renewal rate at at least 1.5% per year

Rehabilitation of pipelines in the Medina

Construction of two 60,000 m 3 reservoirs to better cover peak demands and to install reservoirs on both sides of the city (total 185,000 m 3 in the south and 60,000 m 3 in the north)

Establishment of a belt structure integrating the peripheral areas of Marrakech

Hydraulic modeling of the network

For our economic analysis, we will assume that the efficiency of distribution will improve at a rate of 5% over 10 years, from 80% in 2025 to 85% in 2035 and 90% in 2045, after what it will remain constant. During this period, RADEEMA would have renewed almost 50% of its distribution system. Improving performance with 5% expected to reduce water losses of about 5 m 3 / year due to gross demand in 2030 (80 million m 3 / year).Thus, in the analysis, water saving increases from 5 Mm 3 / year in 2025 to 10 Mm 3 / year in 2035 and to 15 Mm 3 / year in 2045.The improvement of efficiency generally does not present any opportunity costs (the leakage volumes recovered and reintegrated in the networks do not deprive users) and do not generate negative economic or environmental externalities. The cost of economic performance must be compared with that of the Al Massira water supply because one m 3 of water lost in the network would result in a water withdrawal from the Al Massira dam the cost of which would be close to 7 MAD / m 3, not including the cost of transferring water from the north to the Al Massira reservoir (7.4 MAD / m 3).

Description of the feasibility and the climatic vulnerability: It seems technically feasible to increase the efficiency of the distribution system at the level of the city of Marrakech to 85% in 2035 and to reduce physical losses to 15 %. Reducing drinking water losses at this level requires, inter alia :

The rate of renewal of the pipeline of drinking water currently of 1.5% is reinforced especially in the Medina;
The leak detection program is strengthened;
The sectorization of the network is carried out, including the establishment of District Metered Areas.

Mechanisms to finance this performance improvement should be explored and put in place. The rehabilitation of networks is not affected by climate change.

Projection of volumes: Given the scarcity of water in the Marrakech region and above all the importance of the cost of water (of the order of 15 MAD / m 3 from the water transfer project without take into account the shortfall), the objective of a return of 80% seems low.An 85% return at the level of the city of Marrakech and the urban centers of the region must be targeted by 2035 (and why not 90% by 2045?) to reduce physical losses significantly. With this efficiency improvement, water losses would be reduced by 10 Mm 3 / year in 2035 (Table 3.1).An increase in the efficiency of the 1% distribution results in a loss reduction of about 1 m 3 / s.

Reduction of losses (Mm 3 / year)	2020	2025	2030	2035	2040	2045	2050
Efficiency (%) - 75% in 2015	77.5%	80.0%	82.5%	85%	87.5%	90%	90%
Water saving (Mm 3 / year)	2.5	5.0	7.5	10	12.5	15	15

Table XI-8: Estimation of the evolution of the volume of water released by the rehabilitation of the distribution network

Estimated investment costs: According to RADEEMA, it is estimated that initially a budget of MAD 100 million is required, followed by an investment of MAD 15 million / year.The rate of renewal of the drinking water pipeline should be more than 1.5%.

Fixed operating costs: The maintenance and maintenance costs related to the network rehabilitation program are estimated on the basis of French professional standards at nearly 0.2 MAD / m 3 (AFD summary note).

Cost of operation: The rehabilitation of the network actually reduces operating costs.

Overview of volumes and costs:

The table below summarizes the main features and costs of the rehabilitation of the RADEEMA drinking water distribution network. The cost of saved water is calculated at 3.0 MAD / m 3 .

Date of commissioning	Starting at 2018
Volume of water	10 to 15 mm 3 / year (yield of 85% in 2035 and 90% in 2045)
Investment cost	Initial investment: MAD 100 million Annual investment: MAD 15 million / year
Cost of maintenance and leak detection	0.2 MAD / m 3
Cost of operation	No change from current situation
Cost per m 3 of clear water	3.0 MAD / m 3 (without 20% for unforeseen costs and contingencies)

Table XI-9: Estimated cost of m 3 of drinking water released by the rehabilitation of the distribution network

Environmental and Social Impacts: Improved distribution system performance requires, among other things, the replacement of damaged pipeline sections. These works are generally limited in time and concern a reduced linear. However, the impact on the neighboring population could be significant if :

several sections need to be rehabilitated

access and traffic are diverted

the noise nuisance (hammer for example) do respect the working hours

the dust generation inconvenient the local residents

The implementation of rational measures for site management makes it possible to get rid of all these impacts. Moreover, experience has shown that, by means of an effective communication plan , the riparian population adhere to the project and does not oppose the work.

5. **Construction of new dams to store surface water (SW4)**

Summary of the current situation: Plans for the development and integrated management of the water resources of the Oum Er Rbia and Tensift basins include projects to build dams that can strengthen water resources for the Marrakech region .These include the Ait Ziat, Bou Idel, Tiyoughza and the Sidi Driss dam. The realization of these dams would result in the improvement of the water resources of the Marrakech region:

The Bou Idel dam, with a capacity of 84 Mm 3 , will regularize nearly 83.3 Mm 3 per year (source : Tensift PDAIRE) to strengthen irrigation in the Marrakech region.This dam, located downstream of the city of Marrakech, is not intended for the supply of drinking water to the city of Marrakech ;
The Imizer dam would make it possible to regulate the waters of the Oued Rdat. This dam was not retained by the PDAIRE for reasons related to the salinity of the water.
The size of the Ait Ziat dam, retained under the Tensift PDAIRE, is estimated to be close to 45 Mm 3 , will allow an additional volume of water to be regularized in the order of 13 Mm 3 per year (source : Tensift).This PDAIRE has secured the volume of water of 13 Mm 3 / year to reinforce the irrigation downstream of the dam, currently practiced by diversion of the waters of Oued Za.
The site of the Ait Ziat dam would also make it possible to construct a dam with a size of 395 Mm 3 (Grand Barrage Ait Ziat).With this last era size, volume regularized would be increased from 13 to more than 100 m 3 per year.However, Dr. realization of a large dam with a capacity of 395 m 3 would result in a high environmental impact.

Description and impacts of the option: The construction of the Ait Ziat dam with an average size of around 95 Mm 3 would both significantly reduce environmental impacts, strengthen irrigation downstream of the dam and to allocate a new water endowment of around 30 Mm 3 / year (source: environmental impact study, 2009) to the drinking water supply of the Grand Marrakech.This new allocation would strengthen the diversification and security of the drinking water supply in Greater Marrakesh and the province of El Kelaa Sraghna and reduce the volume of water supplied by Al Massira to be used for the water supply of the city of Marrakech.This reduction in the volume of water from the Al Massira adduction will result in a reduction in the operating cost, in particular the pumping costs.The water from the Ait Ziat dam will be dropped into Oued Zat to be gravityly diverted into the Canal de Rocade by a diversion structure to be built under the Ait Ziat dam.

The Ait Ziat dam can thus be a solution to strengthen the waters of the Canal de Rocade, to properly upgrade the existing treatment plant with a capacity of nearly 100 Mm 3 / a for a water allocation of 57 Mm 3 / a and reduce the operating costs, in particular the energy costs of the Al Massira conveyance. The regular volume of the Ait Ziat Dam is close to 90 million m 3 / year (source: Environmental Impact Assessment , 2009).This regularized volume could be allocated as follows:

30 Mm 3 per year for drinking water (33% of the total water volume regulated)
60 Mm 3 for irrigation of the perimeters downstream of the dam

Volume projections: Given the importance of the cost of water for the Al Massira adduction, in particular the pumping costs and the existence of equipment to transport, treat and distribute the water mobilized by the Ait Ziat dam, water volume of 30 Mm 3 per year would be used for the supply of drinking water to Marrakech since the commissioning of the Ait Ziat dam.

Volume (Mm^3/an)	2020	2025	2030	2035	2040	2045	2050
Allocation for potable water	-	-	30	30	30	30	30

Table XI-10: Evolution of the volume of drinking water available for Marrakech from the Ait Ziat dam

Cost Estimates

Investment cost : The cost of the Ait Ziat dam, with a total capacity of 95 Mm 3 , would be close to MAD 900 million (source: environmental impact study).Taking into account the volume allocated to drinking water and the level of its guarantee, the share of the cost of the dam to be allocated to drinking water would be of the order of 50%, ie a cost of about MAD 450 million, or 15 MAD / m 3 .

Cost of renewal: The allowable life for dams is 50 years. The investment must be renewed every 50 years. Another approach to renewal is possible. It consists of taking into account not the renewal work but an annual maintenance provision equal to the cost of the investment divided by its lifespan. In this case, the maintenance provision is estimated at MAD 18 million, including MAD 9 million for the drinking water sector.

The costs of investing and renewing the existing infrastructure that will be required by this option, such as the Canal de Rocade and the water treatment plant, are not included in the costs of this option.

Fixed Operating Costs: Annual fixed maintenance and operating costs are calculated based on the capital costs of works using an allowance rate of 0.5% for dams.

Taking this maintenance rate into account, the annual fixed maintenance and operating costs of the Ait Ziat Dam to be allocated to drinking water would be in the order of MAD 2.25 million.

Pumping costs: The Ait Ziat dam dominates the Canal de Rocade.Pumping costs are therefore zero.

Cost of transport: For the present situation, the Agricultural Development Board estimates the share of the cost of transporting water to be paid by the drinking water sector at the Canal de Rocade at around 0.264 MAD / m 3 .On the basis of this cost, the cost of transporting the water supply mobilized by the Ait Ziat dam is estimated at around MAD 8 million per year.

Treatment cost : The cost of treatment is estimated on the basis of a cost of 0.25 MAD / m 3 which corresponds to the use of reagents and electricity for the operation of the station (source: supply of drinking water to the city of Marrakech, the neighboring centers and douars from the Al Massira dam ").This cost does not include personnel and overhead costs because the treatment plant is in operation and these costs are not expected to increase as the volume of treated water increases. The cost of treatment of the water supply mobilized by the Ait Ziat dam is estimated to be close to MAD 7.5 million per year.

Cost of impacts: The Ait Ziat dam has a strong environmental and social impact (displacement of populations, disappearance of traditional irrigation activities, loss of landscaping amenities, etc.).

The environmental impact study of the Ait Ziat dam, carried out by the DRPE in 2001, identified the impacts of the Ait Ziat dam at:

740 ha of agricultural properties will be flooded by dam reservoir

30,000 feet will be lost including 90% of olive trees

320 households will lose their homes

The equivalent of 360 permanent jobs will be lost

Several socio-economic facilities (2 schools, 3 mosques, 4 cemeteries, 5 shops, 2 mills, 7 oil mills and 4 collective wells) will be flooded

The average loss of income is MAD 1 000 / household / month: 64% of households will lose less than 25% of their income, and 15% of households will lose more than 50%.

The submersion of a stretch of road, about 3 km

The flooding of an electrical transformer substation and 3 km of power line

This study estimated the total cost of these impacts at close to MAD 176 million, of which 50% should be billed to ASP, equivalent to about MAD 0.3 / m 3 .In this study, we took these costs into account in the economic analysis by the criterion " Management of social and environmental risks".It should be noted that the DRPE is currently undertaking an update of the impact study of the Ait Ziat dam.

Actions	**millions MAD**
Compensation of people for lost property	160
Replacement of AEP works	10
Restoring infrastructure	6
Total cost	176

Table XI-11: Estimated Cost of Environmental Impacts of the Ait Ziat Dam

Description of the feasibility and the climatic vulnerability: Concerning the technical feasibility of the Ait Ziat dam, the studies carried out at the preliminary design stage showed that the construction of the dam is technically feasible.The variant retained is of type dike with impermeable core of clay of 60 m of height on foundation.

Water resources at this dam are vulnerable to the impact of climate change. Climate change forecasts for the Ait Ziat basin are in the direction of a 20% reduction in water intake compared to those considered in the PDAIRE. This climate vulnerability applies to the entire water resource for the supply of drinking water to the city of Marrakech, namely the Hassan 1 st complex, the Lalla Takerkoust complex, the Al Massira dam and the Haouz .

The impact of this reduction in water inputs would result in a reduction in the regularized volume, estimated at almost 10%. The reduction in water inputs will not be fully reflected in the regularized volume due to the annual and interannual regularization of the dam's water inputs, water deficits, spill reduction, management rules adopted etc.This reduction in volume regularized by 10% should be offset by improvements in agricultural productivity and the use of integrated management of all dams Hassan 1 - Sidi Driss, Takerkoust and reservoir Al Massira.Despite this climatic vulnerability, the Ait Ziat dam, which will be managed in an integrated manner with the Hassan 1 st complex and the Al Massira dam, could play a fundamental role in the Marrakech diet.

Advantage of the Ait Ziat dam: The main advantages of the construction of the Ait Ziat dam could be summarized as follows:

Assuming that the drinking water supply of the city of Marrakech will be satisfied in any case, the contribution of the dam Ait Ziat to drinking water supply of the city of Marrakech at 30 m 3 / year to will translate into a reduction in the contribution of the Al Massira dam to this diet.A reduction in pumping costs of a volume of 30 million m 3 per a from the Al Massira dam will be achieved;

The contribution of the dam Ait Ziat to drinking water supply of the city of Marrakech at 30 m 3 / year will result in an increase in irrigation water availability of about 30 m 3 / year.A valuation of a water volume of thirty million m 3 per year in irrigation perimeters central Haouz or Doukkala will be conducted;

A valorisation of the existing treatment plant;

A reduction in the cost of adapting the RADEEMA distribution network.

Volume and cost overview: The table below summarizes the main characteristics of the dam and the cost of the cubic meter of drinking water from this dam.

Capacity of the dam	95 Mm^3
Duration of production	10 years
Date of commissioning	2030
Volume of water allocated to drinking water	30 Mm^3/an
Investment cost	MAD 450 million (AEP part)
Cost of maintenance	MAD 2.25 million / year (AEP part)
Transport fee	7.9 million MAD / year (0.264 MAD / m 3 , without pumping fees for the gravity system)
Cost of water treatment	MAD 7.5 million / year (AEP part)
Cost of environmental impacts	MAD 88 million (50%, these costs are taken into account in the economic analysis under the criterion "Management of social and environmental risks", not in the financial analysis)
Cost per m 3 of clear water	2.3 MAD / m 3 (without 20% for unforeseen costs and contingencies)

Table XI-12: Estimated cost of m 3 of water regulated for drinking water from the dam Ait Ziat

Environmental and social impacts: The social and economic benefits attributed to the construction of dams include:

Food security and protection against drought in vulnerable areas;

Hydroelectric power generation;

Protection against floods;

Development of recreation and leisure areas

These benefits are offset by the negative effects that are present during the life of this structure:

Construction of new dams to store surface water & increase storage capacity of existing dams		
Phase	**Site Level**	**Downstream hydraulic**
Construction Phase	• Loss of arable soils Ecosystems degradation • Air pollution (dust and gases) • Safety of workers and local residents	• Pollution of surface and ground water
Operation phase	• Submersion of large surfaces • Displacement of populations • Loss of ecological values • Loss of asset values • eutrophication • GHG emissions (decomposition of flooded vegetation cover)	• Limitation of nutrient and sediment inputs • Loss or alteration of ecological flow • Loss of income (tourism, fishing, agriculture) • Risk of flooding (large drops, dam failure)

6. **Increased storage capacity of existing dams (SW5)**

Summary of the current situation: The raising of dams to recover the capacity of the reservoirs lost by siltation is a common practice in Morocco.Three dams have been raised. These are:

Lalla Takerkoust on the Oued Nfis
El Kansera on the Oued Beht
Sidi Driss on the Wadi Lakhdar which was the subject of a first overhang

The PDAs currently provide for the raising of the following four dams:

Mohammed V on the Oued Moulouya
Ibn Battouta on the Oued Mharhar
Aoulouz on the Oued Souss
Sidi Driss on the Wadi Lakhdar

The other dams, including dam Hassan Moulay Youssef 1 and can not be subject to elevation.

Description and impacts of the option for Marrakech: Among the dams that contribute to the supply of drinking water to the Grand Marrakech, Tensift's PDAIRE has retained the possibility of raising the Sidi Driss boom.The extension of the Sidi Driss embankment (from 643.50 m to 680.00 m) will allow to move from a storage volume of 1.2 Mm 3 to a volume of approximately 73.2 Mm 3 .

Projection of the volumes: The raising of the Sidi Driss dam would make it possible to partially recover the waste water by silting the capacities of the Hassan dams 1 st and Sidi Driss.The volume likely to be recovered by this increase was estimated in the framework of the PDO of Oum Er Rbia and Tensift at nearly 50 Mm 3 / year .This recovered volume will strengthen the water resources of the Canal de Rocade. A water allocation in the order of 27 m 3 per year was allocated to drinking water (source PDAIRE Oum Er Rbia).

Given the importance of the water cost of the Al Massira adduction, in particular the pumping costs and the existence of equipment to transport, treat and distribute the water mobilized by the Sidi Driss dam, the volume of water of 50 Mm 3 per year of which 27 Mm 3 per year for drinking water would be used in full since the commissioning of the Sidi Driss dam.

Cost Estimates

Investment cost : The total investment cost is estimated at MAD 605 million (source: Environmental Impact Assessment).Taking into account the volume allocated to drinking water and the level of its guarantee, the share of the cost of the dam to be allocated to drinking water would be of the order of 60%, ie a cost of about MAD 360 million, or 13.3 MAD / m 3 .

Cost of renewal: The allowable life for dams is 50 years.The investment must be renewed every 50 years. The costs of investing and renewing the existing infrastructure that will be required by this option, such as the Canal de Rocade and the water treatment plant associated with this channel, are not included in the costs of this option.

Fixed Operating Costs: The annual fixed maintenance and operating costs are calculated based on the capital costs of the works by applying the 0.5% allowance for dams.Taking account of this maintenance rate, the fixed annual maintenance and operating costs of the Sidi Driss Dam raising is of the order of MAD 3 million per year, of which approximately MAD 1.8 million per year for the endowment drinking water for Marrakech.

Cost of transport : The Sidi Driss dam dominates the Canal de Rocade.Pumping costs are therefore zero. For the present situation, the Agricultural Development Authority estimates the share of the cost of transporting water to be paid by the drinking water sector at the Canal de Rocade at around 0.264 MAD / m 3 .The cost of transporting the drinking water supply mobilized by the Sidi Driss dam is thus MAD 7.1 million per year.

Treatment cost : The cost of treatment is estimated on the basis of a cost of 0.25 MAD / m 3 which corresponds to the use of reagents and electricity for the operation of the station (source: supply of drinking water to the city of Marrakech, the neighboring centers and douars from the Al Massira dam ").This cost does not include personnel and overhead costs because the treatment plant is in operation and these costs are not expected to increase as the volume of treated water increases. The cost of treatment of the water supply mobilized by the Sidi Driss dam is estimated at nearly MAD 6.75 million per year.

The table below summarizes the main characteristics of the Sidi Driss dam overhang.

Capacity of the dam	73 Mm^3
Implementation period	5 years (2020 – 2024)
Date of commissioning	2025
Volume of water allocated to drinking water	Total volume 50 Mm 3 / year including 27 Mm 3 / year for AEP
Investment cost	MAD 360 million (AEP part)
Cost of maintenance	MAD 1.8 million per year (AEP part)
Transport fee	MAD 7.13 million per year (0.264 MAD / m 3 , no pumping costs, gravity system)
Cost of water treatment	MAD 6.75 million / year (additional costs)
Cost of environmental impacts	MAD 100 million (60%, which is taken into account in the economic analysis under the criterion "Management of social and environmental risks", not in the financial analysis)
Cost per m 3 of clear water	1.7 MAD / m 3 (without 20% for unforeseen costs and contingencies)

Table 4.5: Estimated Cost of Regulated Drinking Water from the Sidi Driss Raised Dam

Description of the environmental impacts: The Sid Driss dam will drain the entire Oued Lakhdar watershed between the Hassan 1 st dams and the current Sidi Driss.This basin covers 75,000 inhabitants over 1,260 km² living largely within the circle of Demnate in the province of Azilal.

The increase in the current holdback is expected to overwhelm land at a slightly higher level. This increase should not have a significant impact on the human environment, nor on the natural environment (source : PDNA of the Oum Er Rbia basin).

Description of the feasibility and climatic vulnerability: The water resources at this dam are vulnerable to the impact of climate change. Predicted climate change for Lakhdar basin, controlled by Hassan Ole Dam 1 - Sidi Driss go in the direction of a reduction of 20% of inflows compared to those included in the PDAIRE.

The impact of this reduction in water inputs would result in a reduction in the regularized volume, estimated at almost 10%. This reduction in volume regularized by 10% would be offset by improvements in agricultural productivity and the use of an integrated management of all the dams Hassan 1 - Sidi Driss, Takerkoust and the Al Massira dam.Despite this climate vulnerability, the Sidi Driss dam, which will be managed in an integrated manner with the Hassan 1 st complex , the Ait Ziat

dam and the Al Massira dam, could play a fundamental role in the supply of drinking water to the city of Marrakech .

Advantages of the Sidi Driss dam: The main advantages of the Sidi Driss dam can be summarized as follows:

The contribution of the Sidi Driss dam to the water supply of the Canal de Rocade will maximize the volume mobilized in the Lakhdar basin.This contribution was estimated under the Tensift and Oum Er Rbia PDSs at nearly 50 million m 3 per year.This additional volume of 50 m 3 / year would improve the security of the drinking water supply of the city of Marrakech and mitigate the water deficit, currently observed at the perimeter of Haouz;
The contribution of the Sidi Driss dam to the drinking water supply of the towns of Kelaa Sraghna and Azilal;
Reduced turbidity in the water of the Canal de Rocade, which will result in reduced operating costs for the canal and the treatment plant;
Better use of energy production of the hydropower plant Ammouguez associated with the dam Hassan 1 and located downstream of the dam Sidi Driss (the increase in energy production is not taken into account the costs of option).

7. Rainwater harvesting , storage and reuse at city level (RW3)

Summary of the current situation: Rainwater harvesting is an ancestral practice in the region, carried out for example by harvesting water discharged during periods of flood or drained by relief during the rainy season by canal systems, dikes and basins (Rabta and Tabia systems).

According to the table below, stormwater potential is considered important and recovery practices should be diversified, improved and innovated by considering good practices borrowed from regions with similar backgrounds.

Unité morphologique	Superficie (km²)	Pluviomètre moyenne (mm)	Potentiel Pluviométrique (Mm³/an)
Plaine	7.358	225	1.655
Piémont	4.380	400	1.752
Montagne	6.969	650	4.530
Total			**7.937**

Table 5.1: Rainfall potential in the Haouz-Mejjate Basin (source: IWRM Convention development in Haouz-Mejjate Basin, Global Basin Diagnosis)

The current sanitation network in the city of Marrakech includes 8 open retention basins with volumes ranging from 2,000 to 20,000 m 3 .Two large retention ponds have already been built or planned in the south of the city : It is a 12 000 m 3 basin already operational and linked to the flood ditch west of Mohammed VI Avenue and a 9,000 m 3 basin east of the same avenue that is scheduled to be constructed.The retention basins are spread to the south of the city to create a buffer zone with the diversion ditches to protect the city from flooding caused by exceptional rainfall periods. The water

retained in these basins is not recovered and the amount of this water that infiltrates in the subsoil and low.

Urban sanitation planning is based on the Master Plan, which defines, among other things, investment projects. According to information from RADEEMA, the Master Plan prescribes for the construction of large residential, tourist or industrial complexes of sewer pipes and retention and infiltration ponds.

Description and impacts of the option for Marrakech: Since the potential for rainwater harvesting is considered important, the solutions proposed below can contribute to the preservation of water resources, in particular to the restoration of the water table (see Figures 5.2 to 5.5).

The rainwater harvesting program proposed for this study is part of a comprehensive water use project in the city including rainwater, gray water, groundwater and conversion to localized irrigation and landscaping of green spaces. This global program for watering green spaces is summarized in Table 5.2:

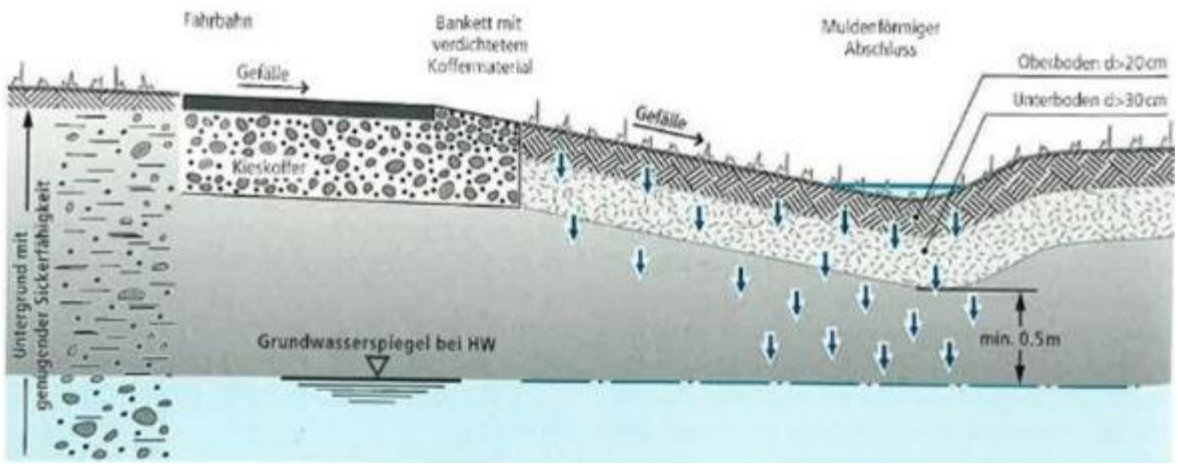

Figure XI-4*: Example for infiltration of rainwater from roads (source: Professional Association for Water in Switzerland, VSA)*

Figure XI-5: Aspect of the modern urban landscape of Marrakech with turf and irrigated roses (source: EBP, 2016)

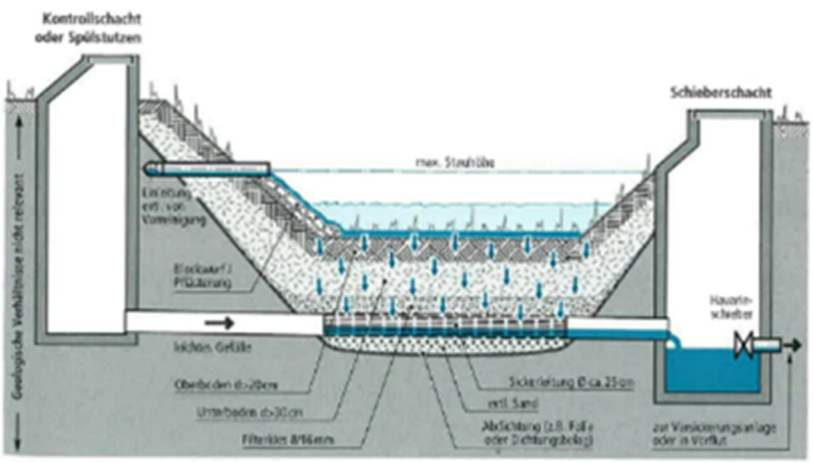

Figure XI-6: Example for open retention ponds (source: Professional Association for Water in Switzerland, VSA)

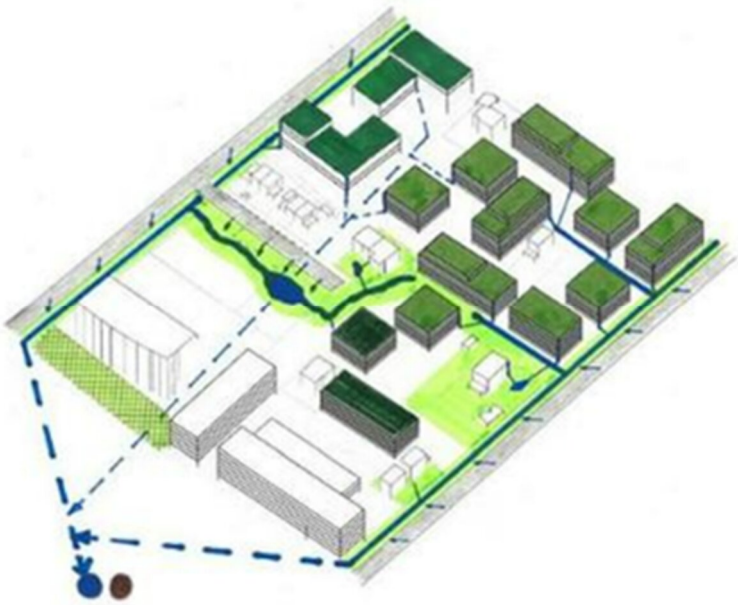

Figure XI-7: Example for subdivision with sewer pipes, roofs and retention ponds, infiltration of road storm water (source: Grand Projet Vernier-Meyrin-Aéroport, Geneva State - Department of Urban Planning, EBP 2012)

Type of green space	**Needs in Mm 3 / year**	**Proposed program**	**Water requirements to be met with the proposed rainwater program (Mm 3 / year)**
Royal Domains	6	reconversion.	-
Managed by the municipality	4	landscaping, rainwater, conversion to localized irrigation, groundwater	0.2
Inside the city	2	gray water and rainwater	-

As regards the collection of rainwater at city level, the proposed program includes the following measures:

15 covered masonry retention ponds (35 m * 15 m * 3 m);
Rehabilitation of existing reservoirs;
500 rainwater harvesting projects at the level of the administrative institutions. Installation of 25 m 3 tanks at the level of administrations, hospitals and hotels;
1,000 individual Metafias projects, to be carried out by the populations
Establishing a regulatory and incentive framework;
Program to promote different techniques of catchment and use of rainwater and their extension to different potential users

Projection of volumes: According to the table below, the water resources to be mobilized through the recovery of rainwater would be of the order of 200 000 m 3 / year.The volume of water likely to be released by the proposed program has been estimated taking into account the following assumptions:

three fillings each year of Metafias and reservoirs
a yearly use of all the water of the Metafias and reservoirs

Mm^3/year	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Volume dégagé	0.05	0.10	0.10	0.15	0.15	0.20	0.20

Table 5.3: Estimation of the evolution of the volume of water released by the collecting of rainwater at the city level for the irrigation of green spaces (source: estimate of the consultant)

Rainwater harvesting is already taking place in several places, for example in real estate complexes.This option is therefore feasible in the short term.

Cost Estimates

Investment costs:

The cost of retention basins is estimated at about MAD 9 million (MAD 600 000 per basin).

The cost of rainwater recovery projects is estimated at about MAD 40 million (MAD 80,000 per project).

The cost of Private Metafias is estimated at about MAD 30 million

A provision of MAD 10 million is reserved for the rehabilitation of existing reservoirs.

The total investment cost is therefore close to MAD 90 million. To take into account the renewal costs of the rainwater harvesting facilities, a 50-year life span for retention basins and 20 years for rainwater recovery projects seems realistic.

Fixed operating and maintenance costs: Based on international benchmarks, operating costs are estimated at 2% of investment costs, including operating costs.

Description of the feasibility and climatic vulnerability:

The proposed measures are technically feasible and approved. Indeed, there are already in Marrakech several installations and basins for the collection of rainwater.A pilot project could be carried out to test the effectiveness of the program, refine costs and establish financing, operating and management

conditions. At the end of this pilot project, a rainwater harvesting program will be developed. This program will include :

The institutional framework;
The regulations to be put in place (texts implementing the new water law);
Incentives to promote rainwater harvesting.

It should be noted that stormwater that enters sewers and is treated at STEP is not necessarily lost. Rainwater that is not discharged from the pipeline during heavy rainfall exceeding the capacity of the pipeline is treated and available for watering golf courses and green spaces.On the other hand, the retention of rainwater at the source can reduce pumping costs, peak flows and the amount of mixed wastewater discharged into the environment. In addition, rainwater retention can reduce the risk of flooding of the pipeline.

Rainwater is affected by the impact of climate change. A study by FAO, the World Bank, the Directorate of National Meteorology (DMN) and INRA indicates that by 2050, rainfall declines could reach nearly 20% in the Marrakech region compared to the rainfall series of the period 1961-1990.

Volume and cost overview The table below summarizes the main features of rainwater collection and reuse at city level and the specific cost of the cubic meter mobilized.

Duration of production	short term
Date of commissioning	2018
Volume of water	0.2 Mm 3 / year
Investment cost	MAD 90 million
Cost of maintenance and operation	MAD 1.8 million per year
Pumping, water transfer and treatment costs	0
Cost per m 3 of clear water	44.4 MAD / m 3 (without 20% for unforeseen costs and contingencies)

Table XI-13: Estimated cost of water from stormwater collection at city level

8. Small-scale rainwater harvesting at the rural level (RW1)

Summary of the current situation: Rainwater harvesting is an ancestral practice in the region, carried out for example by tanks (Metfias).

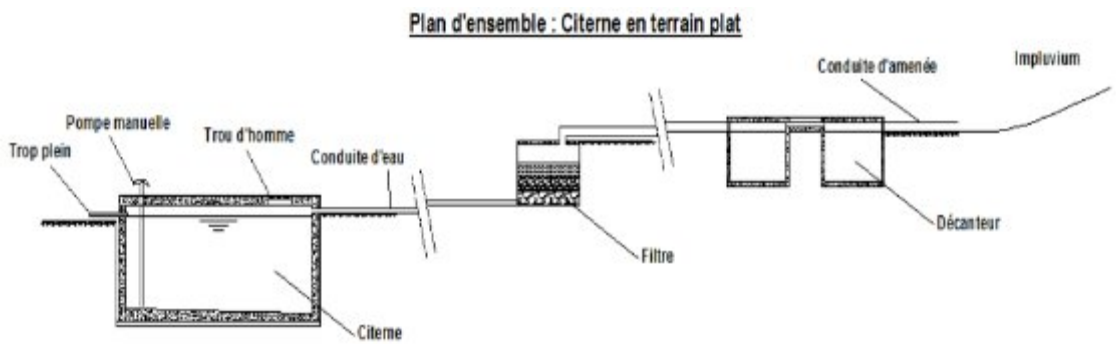

Figure XI-8: Functional diagram of a traditional tank (source: Slaid Rouzlane, Workshop on the capture and use of stormwater in Morocco, 2011)

Recovery and reuse of stormwater, which is a component of the SNE and the NPP, is an alternative technique for mobilizing small-scale water resources.Traditionally, it is particularly suited to remote areas and areas where groundwater resources are non-existent and is a means of:

ensure the supply of drinking water and the watering of livestock by the metfias systems ;
irrigation by spreading of floods by water-based sampling;
water and soil conservation through land-use management techniques;
the creation of storage basins for irrigation.

The area served by the RADEEMA sewerage network is predominantly equipped with a unitary piping system. In some areas, such as the Sidi Ghanem industrial zone as well as the M'hamid and South zones, there are pseudo-unitary systems where part of the rainwater from the roads and the impermeable spaces are separately evacuated. In principle, all wastewater from the city of Marrakech is therefore channeled and intercepted by collectors who take them to STEP. As for rainwater, including roof water, they are mostly collected by the same pipeline unit and partially discharged into the natural environment during periods of flood.

Description and impacts of the option for Marrakech: The Tensift Basin Agency has carried out a rainwater harvesting study to promote the use of stormwater in urban and rural areas to reduce the cost of investing in rainwater drainage and to ensure the water needs of rural populations.This program, developed within the framework of the PDAIRE, aims at the realization of ten metfias per year during the next ten years.The cost of this program is estimated to be close to MAD 20 million (Tensift PDS source).

Taking into account that the Marrakech area has an alarming water deficit, rainwater constitutes an important water resource. The solutions proposed below can therefore contribute to the preservation of water resources, in particular by the recovery of rainwater for the irrigation of green areas and golf courses, and the restoration of the water table.

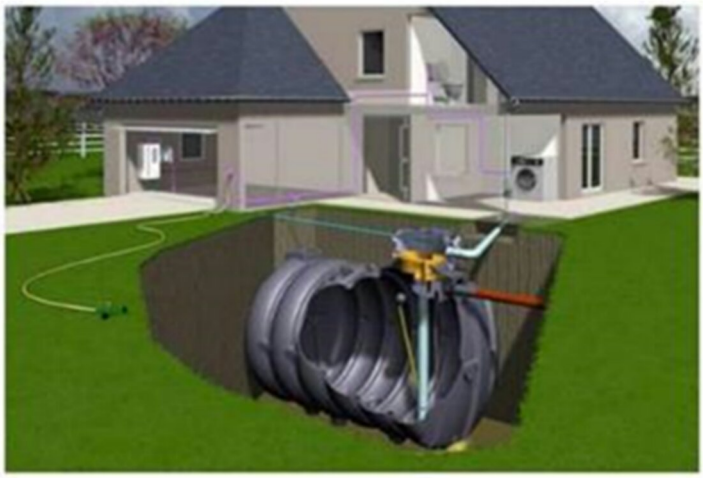

Figure XI-9: Example of a reservoir for rainwater retention and recovery (source: Grand Projet Vernier-Meyrin-Aéroport, Geneva State - Department of Urban Planning, EBP 2012)

Figure XI-10: Eco-village Vauban in Freiburg, Germany with solar panels and 80% infiltration of rainwater (source: Grand Projet Vernier-Meyrin-Aéroport, Geneva State - Department of Urban Planning, EBP 2012)

Figure XI-11: Stormwater retention and recovery system at the level of a single-family dwelling (source: Grand Projet Vernier-Meyrin-Aéroport, Geneva State - Department of Urban Planning, EBP 2012)

The option of rainwater recovery in the city of Marrakech should be studied within the framework of a global vision taking into account the problem of the scarcity of water in the region, the importance of the costs of drinking water from the city of Marrakech from the Al Massira dam and the need to reduce the investment costs of sanitation (mixed and / or segregated pipelines) and sewage treatment.

The Tensift Water Basin Agency has developed a study on rainwater harvesting in the Tensift Basin. The rural stormwater recovery program proposed in this study aims to provide, in part, the supply of drinking water to rural populations and the watering of livestock and the restoration of groundwater. It includes the realization:

of a hundred collective metfias with a total capacity of 60,000 m 3 ;

of about 20 hilly lakes, with a total capacity of 4 million m 3 (an average capacity of 200 000 m 3 / lake);
fifty projects for the rehabilitation of collective metfias;
of a program of 1,000 individual metfias, to be carried out by the populations;
establishment of a regulatory and incentive framework;
a program to promote different techniques of catchment and use of rainwater and their extension to the different potential users.

The cost of this program was estimated to be close to MAD 100 million of which MAD 18 million for collective metfias, MAD 76 million for hill lakes and close to MAD 5 million for the rehabilitation of collective metfias. The tables below7 show for each province the consistency of the proposed stormwater collection program.

CR / Mu	Métfias					Iferd		Lacs collinaires		
	Création de nouveaux systèmes			Réhabilitation		Réhabilitation		Création de nouveaux ouvrages		
	Nombre	Capacité/métfia en m³	Coût/métfia en M dh	Nombre	Coût/métfia en M dh	Nombre	Coût/ ouvrage en M dh	Nombre	capacité en m³	Coût/ouvrage en M dh
Sidi M'hamed ou Marzouq	1	600	0,6	-	-	-	-	1	26780	0,936
								1	395333	1,909
Sidi laaroussi	1	600	0,6	1	0,2	-	-	1	44320	1,044
								1	160666	2,213
								1	160700	2,484
Sidi Jazouli	1	600	0,6	-	-	-	-	1	85240	2,52
Korimate	-	-	-	-	-	-	-	1	70700	2,862
Adaghas	1	600	0,6	3	0,2	-	-	-	-	-
Aglif	1	600	0,6	4	0,2	-	-	-	-	-
Ida ou Guelloul	1	600	0,6	3	0,2	-	-	-	-	-
Imgrade	1	600	0,6	2	0,2	-	-	-	-	-
Takoucht	1	600	0,6	1	0,2	-	-	-	-	-
Timizguida Ouftas	1	600	0,6	2	0,2	-	-	-	-	-
Assais	1	600	0,6	4	0,2	-	-	-	-	-
Ait Aissi Hahane	1	600	0,6	3	0,2	-	-	-	-	-
Bouzemmour	1	600	0,6	1	0,2	-	-	-	-	-
Ida ou kazzou	1	600	0,6	2	0,2	-	-	-	-	-
Imi n'tlit	1	600	0,6	1	0,2	-	-	-	-	-
Sidi Ahmed Essayeh	1	600	0,6	-	-	-	-	-	-	-
Sidi el Jazouli	1	600	0,6	1	0,2	-	-	-	-	-

Table XI-14: Overview of the proposed rainwater harvesting program for the Province of Safi (source: Tensift Water Basin Agency)

CR / Mu	Métfias					Iferd		Lacs collinaires		
	création de nouveaux systèmes			Réhabilitation		Réhabilitation		*création de nouveaux ouvrages*		
	Nombre	Capacité/métfia en m³	Coût/métfia en M dh	Nombre	Coût/métfia en M dh	Nombre	Coût/ ouvrage en M dh	Nombre	capacité en m³	Coût/ouvrage en M dh
El Ghiate	1	600	0,6	1	0,2	-	-	1	289500	5,84
								1	382000	10,32
Ighoud	-	-	-	-	-	-	-	1	943000	6,35
Sidi Chiker	1	600	0,6	-	-	-	-	1	1210400	7
								1	763333	5,15
								1	2104000	11,45
Ataimim	-	-	-	-	-	-	-	1	1730333	10,9
Lamrasla	1	600	0,6	2	0,2	-	-	-	-	-
Laamamra	1	600	0,6	2	0,2	-	-	-	-	-
Nagga	1	600	0,6	2	0,2	-	-	-	-	-
Jdour	1	600	0,6	-	-	-	-	-	-	-

Table XI-15:Overview of the proposed rainwater harvesting program for the provinces of Youssoufia and Safi (source: Tensift Hydraulic Basin Agency)

CR / Mu	Métfias					Iferd		Lacs collinaires		
	création de nouveaux systèmes			Réhabilitation		Réhabilitation		*création de nouveaux ouvrages*		
	Nombre	Capacité/métfia en m³	Coût/métfia en M dh	Nombre	Coût/métfia en M dh	Nombre	Coût/ ouvrage en M dh	Nombre	capacité en m³	Coût/ouvrage en M dh
Douirane	1	600	0,6	3	0,2	-	-	-	-	-
Ichamraren	1	600	0,6	2	0,2	-	-	1	45780	1,152
Kouzemt	1	600	0,6	4	0,2	-	-	-	-	-
Oued Lbour	1	600	0,6	2	0,2	-	-	-	-	-
Timlilt	1	600	0,6	2	0,2	-	-	1	41040	1,278
Ahdil	1	600	0,6	3	0,2	-	-	-	-	-
Zaouia Annahlia	1	600	0,6	5	0,2	-	-	-	-	-
Sidi Bouzid	-	-	-	-	-	-	-	1	57160	1,476
Sidi Mokhtar	-	-	-	-	-	-	-	1	79480	1,134

Table XI-16: Overview of the proposed rainwater harvesting program for the Province of Chichaoua (source: Tensift Hydraulic Basin Agency)

Description of the feasibility and climatic vulnerability:

Rainwater is affected by the impact of climate change. The FAO / World Bank / Department of National Meteorology / INRA study indicates that by 2050, rainfall declines could reach nearly 20% in the Marrakech region compared to the 1961-1990 rainfall series.

Proposed program : The program proposed for this study includes rainwater harvesting in the rural areas of the provinces of Azilal, Rhamna, Kelaa Sraghna and Haouz by the construction of a hundred metafias to ensure part of the livestock watering.It includes the realization :

of a hundred collective metafias with a total capacity of 60,000 m 3 ;
of about 20 hilly lakes, with a total capacity of 4 million m 3 (an average capacity of 200 000 m 3 / lake);
fifty projects for the rehabilitation of collective metafias;
of a program of 1,000 individual metafias, to be carried out by the populations;
establishment of a regulatory and incentive framework;
a program to promote different techniques of catchment and use of rainwater and their extension to the different potential users.

The implementation of this stormwater recovery program would reduce the demand for drinking water from the Hassan I - Sidi Driss complex and the Al Massira dam.

Projection of volumes: The volume of water likely to be released by the proposed program has been estimated taking into account the following assumptions:

a total annual filling of the metals and hilly lakes;
an annual use of all the water of the metals;
An annual use of nearly 70% of the volume of water stored in hilly lakes (problems of evaporation and infiltration).

Taking these assumptions into account, the implementation of this stormwater recovery program would result in approximately 3 million m 3 per year.Table 5.8 below gives an estimate of the evolution of the volume of water likely to be released by the proposed program.

Mm^3/year	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Volume m3	0.5	1	2	3	3	3	3

Table 5.8: Estimation of the evolution of the volume of infiltrated water for the recharge of the water table in the Marrakesh area

Cost Estimates

Investment cost : The cost of the program, estimated on the basis of the costs of the program realized by the Tensift Basin Agency, would be close to MAD 130 million of which:

MAD 60 million for collective metafias;
MAD 5 million for the rehabilitation of collective metafias;
MAD 3 million for private metafias;
MAD 60 million for hilly lakes;
MAD 2 million for the promotion program for 5 years.

Renewal cost : To take into account the renewal costs of the rainwater harvesting facilities, a lifetime of approximately 40 years seems realistic.

Fixed Maintenance, Maintenance and Processing Costs : Due to the nature of the structures, annual operating and maintenance costs represent close to 0.5% of capital costs.

Energy cost: Given the low depth of water in the metfias, the cost of energy is negligible.

Overview of Volumes and Costs: Table 5.9 below summarizes the main features of small-scale stormwater collection as well as the cost per cubic meter of drinking water.

Duration of production	short term
Date of commissioning	Starting at 209€
Volume of water	Maximum 3 Mm 3 / year (from 2035)
Investment cost	MAD 130 million
Cost of maintenance	MAD 0.65 million per year
Pumping, Transfer and Treatment Fees	0
Cost per m 3 of clear water	4.4 MAD / m 3 (without 20% for unforeseen costs and contingencies)

Table XI-17: Overview of Water Costs from Small Scale Rainwater Harvesting at the Rural Level

Environmental and Social Impacts: Running on pavements, gardens, roofs, etc., stormwater is loaded with suspended solids, nutrients, heavy metals, toxic organic products, pathogenic microorganisms, hydrocarbons, etc. Stormwater has a high polluting load and is a major cause of environmental degradation in urban streams and adjacent coastal waters. Depending on the end use of the water, some stormwater may require further treatment such as microfiltration or reverse osmosis and disinfection using chlorination or UV radiation. In typical urban developments, the space required for storage is generally unavailable and consequently costly.

However, the collection and use of stormwater relieves pressure on the drainage infrastructure during periods of storms and avoids saturating wastewater treatment facilities in the case of non-segregated systems.

The most important positive externality for rainwater harvesting is the avoided or reduced size water infrastructure for water mobilization. Indeed, the volumes mobilized through the collection of rainwater can be subtracted from other projects that can be programmed to mobilize surface water. They see their investments diminish as well as their negative socio-environmental externalities.

These benefits are offset by the negative effects that are present during the life of this option:

Small-scale rainwater collection & collection, storage and reuse at city level		
Phase	**Site Level**	**Downstream hydraulic**
Construction Phase	• Loss of soil quality Ecosystems degradation • Air pollution (dust and gases) • Pollution of surface and ground water • expropriations • Displacement of populations • Loss of ecological values • Loss of asset values	• Pollution of surface and ground water
Operation phase	• Water Diseases • Proliferation of disease vectors during periods when the system is not in charge	• Pollution of surface and ground water • floods

9. Groundwater recharge by infiltration (GW3)

Summary of the current situation: According to the PDNAs, the currently exploited groundwater resources are estimated at 4.3 billion m 3 at the national level , while groundwater resources that can be used in a sustainable way do not exceed 3.4 billion of m 3 .Overexploitation of groundwater is therefore estimated at an average of nearly 1 billion m 3 per year, and much more in the dry years .The capacity of the three main well fields around the city of Marrakech (Agdal : 9 wells, Ourika: 6 wells, Issil: 5 wells) decreased by more than 1,200 l / s in the 1970s and currently less than 200 l / s illustrates the consequences of overexploitation of aquifers in the Marrakech region.

Given the impact of climate change and the growing demand for water, the authorities have developed a program to safeguard groundwater. This program, developed within the framework of the National Water Strategy, aims to ensure the sustainable management of groundwater. This program involves the implementation of the irrigation water saving program, the use of surface and sea water resources, the artificial recharge of groundwater, and a strengthening of the control and penalties in the event of overexploitation.

It is within this framework that the Government launched the initiative to establish and sign groundwater contracts with the following main objectives:

Analyze the current state of groundwater resource utilization with assessment of socio-economic impacts and future challenges, including protection of groundwater and preservation of existing water investments;

Define a plan of action based on the best scenario for the improvement of the groundwater situation, while specifying its cost, its duration and the responsibilities of each stakeholder in the implementation of the program;
Develop and implement monitoring and sanctioning mechanisms to achieve the objectives and ensure sustainable and integrated management of underground water resources.

According to the ABHT, the Haouz- Mejjate water table covers about 50% of the surface area of the Tensift hydraulic basin.The level of the groundwater and therefore the yield of groundwater Haouz-Mejjate has decreased considerably in recent years, due to uncontrolled and excessive groundwater withdrawals, well beyond the natural recharge of the groundwater.Groundwater overexploitation is mainly due to the following reasons:

The city of Marrakech still covers about 10% of its water needs with groundwater
100% of the drinking water needs of the small urban centers, the rural population and the tourist complexes in rural areas of the Haouz region are covered by the groundwater
50% of the irrigation water needs are satisfied with the water table

With a view to ensuring sustainable exploitation of the groundwater of Haouz - Mejjate, which records according to the GIZ report [6] of 2016 currently a deficit balance of nearly 176 Mm 3 / year, Tensift's PDAIRE recommended the implementation of the following provisions:

Implementation of an irrigation water-saving program to substantially reduce groundwater withdrawals;
The use of surface water resources and the transfer of water from the Oum Er Rbia basin as a substitution for ground water withdrawals. It is in this context that the supply of drinking water to the Grand Marrakech would no longer be assured from the Haouz-Mejjate water table.
Artificial recharge of underground aquifers

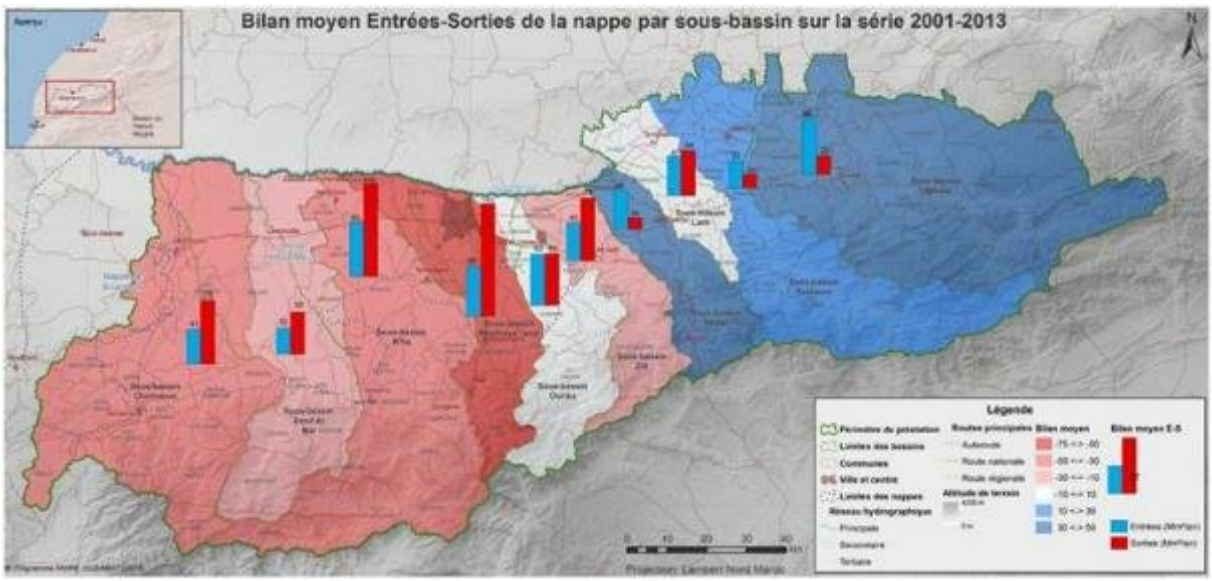

Figure XI-12: Balance of the Haouz-Mejjate aquifer (source: ABHT / AGIRE, Elaboration of the Haouz-Mejjate Basin IWRM Convention, Diagnosis of the global basin)

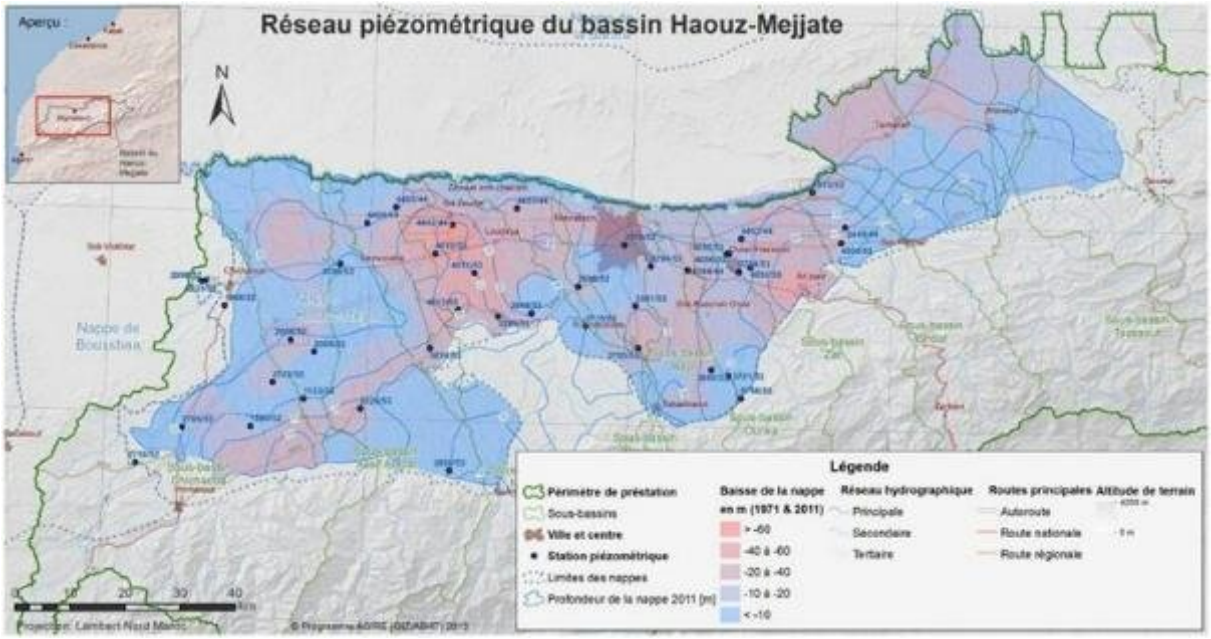

Figure XI-13: Haouz-Mejjate water table drop (source: ABHT / Elaboration of the Haouz-Mejjate Basin IWRM Convention, Global Basin Diagnosis)

Tensift's PDAIRE refers to the recharge experiments carried out between 1985 and 1986 in the bed of the Oued Nf is and the achievements undertaken in the Jbilet area.These experiments have highlighted the role that artificial recharge of groundwater can play in the increase of water resources. The purpose of these recharge projects is to promote underground aquifer infiltration through appropriate management of the wadis beds or flood waters.The potential for artificial recharge in the Tensift Basin area was identified at Wadi Nfis downstream of the Lalla Takerkoust dam and along the tributaries of Wadi Tensift, Zat, Ghmat and Rherhaya:

At the Oued Zat, studies have shown that achieving 14 thresholds would bring the volume infiltrated from 20 to 30 m 3 per year for an annual gain of 10 m 3.Currently, eight thresholds are achieved.

The programming of 5 recharge thresholds on the Oued Ghmat for a budget of MAD 20 million including a few piezometers and a hydrological station for the monitoring of recharging operations.

The launch of a study for the realization of 5 recharge thresholds on the Oued Rhérhaya including a flood-damning dam also promoting the recharge of the groundwater.

An artificial recharge master plan is being developed by the ABH of Tensift. Given the high operating costs of the Marrakech drinking water supply project and the strategic role that the Haouz water table can play in the supply of drinking water to the Grand Marrakech during the drought years , stabilization and reconstruction of the Haouz- Mejjate aquifer is a priority for ABH and ONEE. This aquifer is considered strategic for the supply of drinking water and watering of rural areas.In addition, this water table should also play a role in managing shortages at the basin level and at the level of the city of Marrakech.

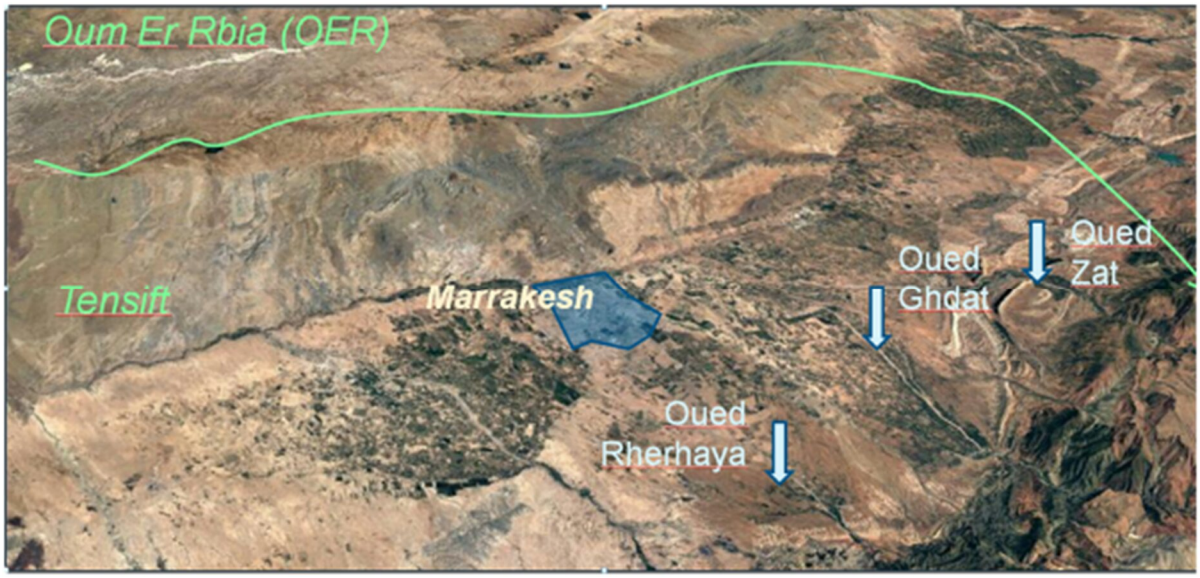

Figure XI-14: Groundwater recharge reserves (GW3)

Description and impacts of the Marrakech option: The Haouz-Mejjate groundwater recharge action plan, initiated by Tensift ABH, needs to be revised to allow for a contribution of this water table to the water supply of the city of Marrakech.It must include :

A supply of wastewater and purified from the city of Marrakech to recharge the tablecloth of the Haouz at the level of Oued Nfis. Wastewater and purified wastewater structures must be studied and carried out.This project to recharge the Haouz water table from sewage could bring to the water table nearly thirty million m 3 per year.The cost of m 3 of wastewater would be much lower than the cost of other water supply solutions from the Oum Er Rbia basin.This project to recharge the groundwater from wastewater and purified water must be carried out within the framework of the National Plan for the Reuse of Wastewater and Purified Water and according to the provisions of the new water law.

Retention thresholds in wadis and Tensift to promote infiltration. The design of the thresholds must take account of past experience, in particular concerning problems of clogging. The construction of a threshold hundred would improve the volume infiltrated fifty m 3 per year.

Reinforcement of groundwater recharge along the Hria and Bahja wadis, M'hamid Issyl in relation to flood management. To combine the development of the banks, reprofiling of intersections with the construction of ponds and retention and infiltration surfaces. In order to minimize clogging of retention and infiltration infrastructures, heavy flooding loads during flood periods should be washed away by flooding in the wadis. Ponds and retention and infiltration areas should preferably be fed only after the first flood. Since the land around Marrakech is relatively flat, large areas are necessary for the infiltration of water. Alternatively, basins and water retention channels for wadis and rainwater as presented below could be designed.

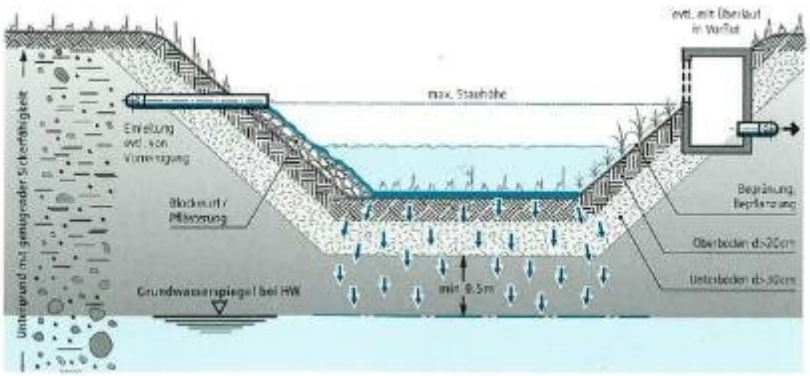

Figure XI-15: Examples for infrastructure for groundwater recharge by infiltration

Description of environmental impacts: The main impacts of the infiltration thresholds can be summarized as follows:

Spreading and rolling of floods which improves protection against flooding
Modification of the water regime of wadis

Description of the feasibility and climatic vulnerability: The achievement of the infiltration thresholds is technically feasible.Several infiltration thresholds are made along the 'Oueds du Sous and Oued Zat. These low height structures are constructed of concrete. They are well anchored in the banks of the Wadi and have downstream works of dissipation. The thresholds proposed for this study will be carried out along the wadis Nfis, Ghmat, Zat, Rdat, Rheraya, Ourika, whose water inputs would be close to 500 Mm 3 / year.These wadis constitute a privileged place for recharging the Haouz aquifer.

The surface water resources of the various wadis are vulnerable to the impact of climate change. Climate change forecasts for these basins are in the direction of a 20% reduction in water intakes compared to those taken into account in the PDAR. The impact of this reduction in water inputs would result in a reduction in the volume of water infiltrated into the groundwater, estimated to be less than 20%. Surface water storage in groundwater is an approved method that minimizes water loss through evapotranspiration.

Projection of volumes: The Haouz groundwater recharge project proposed for this study consists of the construction of a hundred or so thresholds along the tributaries of Oued Tensift (Nfis, Ghat, Zat, Rdat, Rheraya, Ourika, etc.) to improve the infiltration of 50 Mm 3 / year (0.5 Mm 3 / year per threshold), from 2023 for groundwater recharge around Marrakech (source: PDAIRE Tensift) .

Cost Estimates

Investment cost: The cost of constructing these thresholds is estimated on the basis of the costs of the thresholds constructed along the Wadi Zat by the Tensift Hydraulic Basin Agency and the experiments carried out in the Souss basin.The cost of this program would be close to MAD 300 million (MAD 3 million per threshold).

Cost of renewal: The objective of these thresholds is generally to reduce the velocity of flow and thus to favor the infiltration of water. These concrete structures, of a low height, are well anchored in the banks of the Wadis. The lifetime of these structures is estimated to be nearly 40 years. The investment must therefore be renewed every 40 years.

Operating Costs: Operating costs include costs related to (i) repairing flood damage, and (ii) performing a clean-up operation. These costs are estimated at 1% of the investment costs.

Cost of treatment: None, because by infiltration the water is purified.Water is not primarily used for drinking water, but rather for irrigation.

Volume and cost overview: Table 6.1 summarizes the main features of the dam and the cost per cubic meter of drinking water from this dam.

Number of infiltration weirs	100
Duration of production	50 years
Date of commissioning	Starting on t 01/0/1/2023
Volume of groundwater obtained	up to 50 Mm 3 / year
Investment cost	MAD 300 million
Cost of maintenance	MAD 3 million / year
Cost of water treatment	0
Cost per m 3	0.6 MAD / m 3 (without 20% for unforeseen costs and contingencies)

Table XI-18: Estimation of the cost of m 3 of groundwater obtained by infiltration of surface water

Environmental and Social Impacts: Recharge of groundwater includes two types of technologies: (i) methods used to increase the volume of water stored in aquifers; and (ii) water or wastewater treatment methods (the unsaturated zone is used as a natural filter to remove or reduce suspended solids, biodegradable organic materials, nutrients, metals and of pathogenic microorganisms).

Potential benefits include reducing groundwater pumping costs and avoiding replacing or deepening production wells and preventing saltwater intrusion. The exploitation of the aquifer is optimized and the benefits induced (agriculture, drinking water, industry, etc.) are perpetuated.

These benefits are counterbalanced by the negative effects that are present during the life of this option: The technology analyzed in this chapter concerns infiltration by the development of thresholds on the wadis beds.

Groundwater recharge by infiltration		
Phase	**Site Level**	**Downstream hydraulic**

Construction Phase	Ecosystems degradation • Air pollution (dust and gases) • Safety of workers and local residents	• Pollution of surface and ground water
Operation phase	• Bank flooding	
	• Degradation of surface and ground water quality • Recurrence of water-borne diseases • Changes in the flow pattern of the wadi	

10. Inter-basin water transfers or trans-basin diversions (WT1)

Summary of the current situation: With the construction of the Hassan 1 st complex - Sidi Driss and the Canal de Rocade, the area of Marrakech has benefited since 1984 from a water transfer from the Oued Ou Er Rbia basin.The Canal de Rocade carries raw water on a 118 km line and has a transit capacity of 20 m 3 / s.In the middle year the canal should carry a volume of around 300 Mm 3 / year including 40 Mm 3 / year to supply the town of Marrakech with drinking water and 260 Mm 3 for irrigation in the central Haouz area.

Another major transfer project is scheduled under the National Water Plan. This project to transfer water from the Oued Laou, Loukkos and Sebou basins via the Al Massira dam aims to strengthen the water resources of the Bouregreg, Oum Er Rbia and Tensift basins .The idea for this water transfer project came from the following main findings:

> the pooling of available or projected storage capacities in the Laou, Loukkos, Sebou and Oum Er Rbia basins, notably in Al Massira, which has a large storage capacity not always met, can mobilize resources additional water currently lost at sea;
>
> the basins of Oum Er Rbia and Tensift have structural water deficits which will be aggravated by the decrease in the water supplies observed in these basins and the increase in the demand for drinking water, industrial and tourism, especially in Marrakech.

This project provides water transfer 845 m 3 / year basins of Oued Lau, Loukkos and Sebou to the basins of the Bouregreg, Oum Er Rbia Tensift and allow the extension of the irrigation on an area of 70 000 ha, reinforcement of irrigation on an area of 125 000 ha and satisfaction and securing of the drinking water needs of the city of Marrakech.

The water transfer project is a nearly 400 km journey in a straight line, which crosses situations of relief and different geology imposing tunnels. Four tunnels are planned, ranging in length from 7 to 63 km, or 164 km in total. This transfer project includes the following hydraulic works: (i) transfer from the north to the Al Massira dam; and (ii) the supply of drinking water from the Al Massira dam to Marrakech.

The sampling point for the supply of drinking water to the city of Marrakech is located at the bottom of the Al Massira dam. The date of implementation of the first phase of the project of Al Massira to Marrakech, currently being carried out by ONEE, is scheduled for 2018.

Feeding Marrakech with drinking water from a the sampling point downstream of the existing Kasba Tadla dam located on the Oued Oum Er Rbia upstream of the Al Massira dam via a channel system and

a pressurization station which flows back into the Canal de Rocade represents an alternative to the transfer via the Al Massira dam to Marrakech.

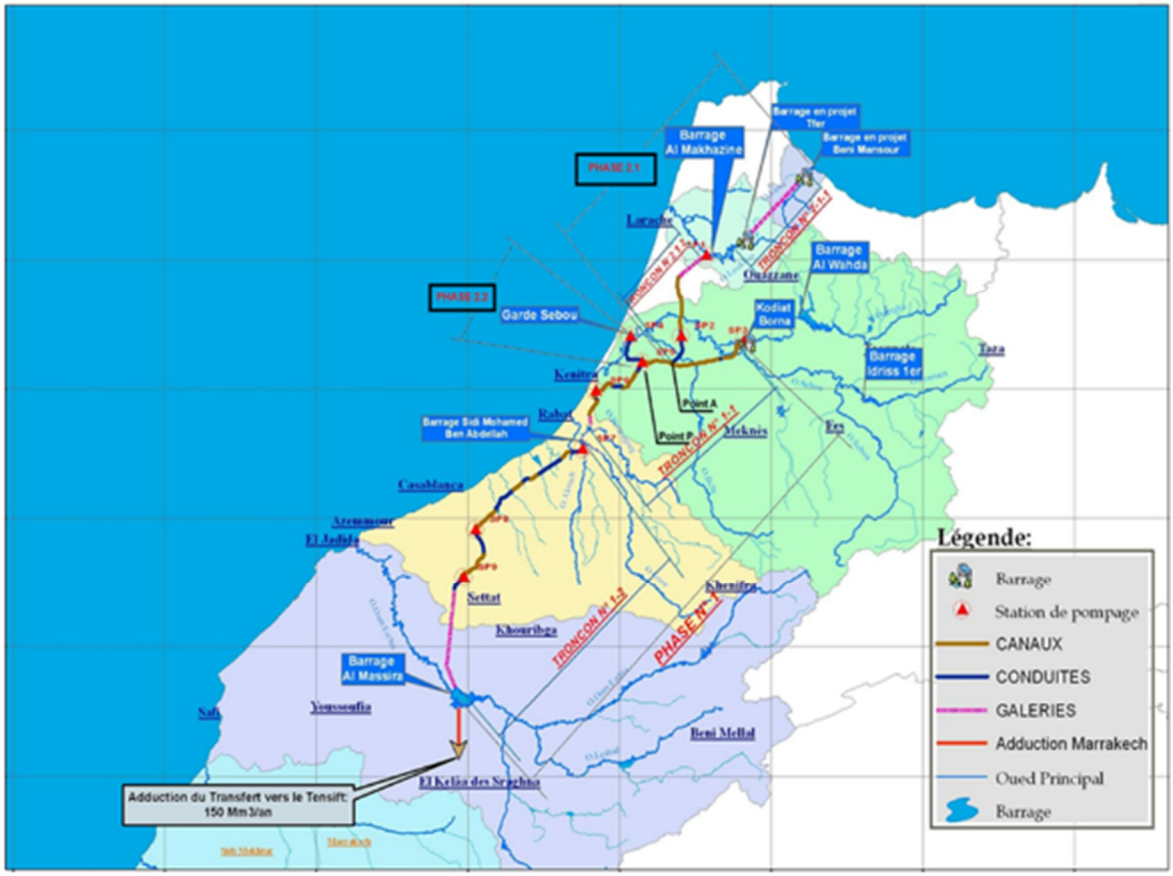

Figure XI-16: Inter-Basin Water Transfer Project to Al Massira and Marrakech (source: ONEE)

Transfer from the North to Al Massira dam

Volume projections: The table below shows the distribution of water supplied by the Northern Transfer Project to the Al Massira Dam, including 95 Mm 3 / year for the supply of drinking water to Marrakech.

Hydraulic basin	Potential development area	Origin of the resource	Allocation (2030)	Resource in Mm^3/year (2030)		
				To address aquifer deficit	To supply Large irrigation	Including extension
Oum Er Rbia	Doukkala - Large Hydraulic Reinforcement (GH)	transfer	74		74	
	Doukkala-Extension	transfert	188			188
	Rhamna-Bahira	transfert	50	50		
	Rhamna- Bouchanne	transfer	70			70
Total Oum Er Rbia			382	50	74	258
Tensift el Haouz	Renforcement GH Haouz Central	transfer	50		50	
Total Irrigation Oum Er Rbia and Tensift			432	50	124	258
Marrakech drinking water			95			

Table XI-19: Allocation of Project Water Transfer from the North to the Oum Er Rbia and Tensift Basins

Cost Estimates

Investment cost : The cost of the Northern Transfer Project's hydraulic infrastructure (excluding investments related to hydro-irrigation and drinking water) was estimated at MAD 31 billion:

Phases de realization	Investment cost, billion MAD
Phase I	16.2
Phase II	14.7
Investment cost	30.9

Table XI-20: Investment Costs of the Northern Transfers Project with Cost Allocation by Phase (source: Feasibility Study of the Hydro-Farming Project for the Northern and Southern Water Transfer Project)

Cost of Maintenance, Maintenance and Renewal : Table 7.3 shows renewal and maintenance costs.T hese costs are:

Cost of maintenance and maintenance: MAD 185 million / year
Annual depreciation allowance: MAD 628 million / year

			Barrages / Dessableur	Conduites	Pièces Spéciales	Equipement Pompage	GC Pompage	Réservoir	GC Galerie	GC Canaux	Régulation	TOTAL
Investissement	1er Phase	MDH	544	3 420	69	903	595	94	4 276	3 009	190	13 099 MDH
	2eme Phase	MDH	2 134	4 060	82	1 074	145		5 058	519	19	13 089 MDH
	Total	**MDH**	**2 678**	**7 480**	**151**	**1 976**	**740**	**94**	**9 333**	**3 528**	**209**	**26 187 MDH**
Amortissement annuel	*Durée*	*années*	*50*	*40*	*40*	*20*	*40*	*40*	*50*	*50*	*30*	
	Annuel	MDH	54	187	4	99	18	2	187	71	7	**628 MDH**
Entretien / Maintenance	*Taux*	*%*	*0,5%*	*0,5%*	*1,0%*	*3,0%*	*0,5%*	*0,5%*	*0,5%*	*0,5%*	*2,5%*	
	Annuel	MDH	13,39	37,40	1,51	59,28	3,70	0,47	46,67	17,64	5,23	**185 MDH**

Table XI-21: Costs of maintenance and renewal of the water transfer project (source: Feasibility study of the hydro-agricultural development related to the project of transfer of water from North to South)

Energy cost : Table 7.4 shows the variation in the cost of water as a function of the pumping energy associated with each level of lifting, of the investments attributable to each section and this is related

to the transferable volumes.From this table, the pumping costs, as well as the total specific cost of the water delivered to the Al Massira dam are derived (Table 7.5).

		Horizon 2022								
		Caractéristiques des tronçons				Co¾t théorique par tronçon				Côut réel du m³ transféré
Désignation		Tronçon	Q	*HMT*	**V pompé**	Investissement annuel sur 30 ans	Amortissement	Entretien maintenance	Energie	
		KM	m3/s	*(m)*	**Mm3/an**	MDH/an	MDH/an	MDH/an	DH/m3	**DH/m4**
GRA	BM (Laou) - Makhazine	54	20	*?*	**250**	93,53	67,30	19,85	0,00	**0,723**
SP1	Makhazine-Sebou	49	30	*10,5*	**273**	84,87	61,07	18,01	0,04	**1,363**
SP2	Sebou-Pt L	32	30	*26,6*	**273**	55,42	39,88	11,76	0,05	**1,809**
SP3	KB-Pt P	73	45	*10,7*	**272**	126,43	90,98	26,83	0,03	**0,929**
SP4	Garde - Pt P	26	45	*35,0*	**191**	45,03	32,40	9,56	0,07	**0,523**
SP5	Pt P - SP5	48	45	*74,0*	**736**	83,13	59,82	17,64	0,18	**3,655**
SP6	Entrée SMBA	20	45	*68,1*	**736**	34,64	24,93	7,35	0,17	**5,363**
SP7	Sortie SMBA	89	30	*163,5*	**628**	154,14	110,92	32,72	0,39	**6,227**
SP8	Berrechid	41	30	*87,4*	**455**	71,01	51,10	15,07	0,20	**6,728**
SP9	Entrée Galerie	72	30	*53,3*	**455**	124,70	89,73	26,47	0,12	**7,383**

Table XI-22:Costs of 3 m per segment (source: Planning Feasibility Study hydroagricultural attached to North Water Transfer Project in the South)

Volume and Cost Overview The table below summarizes the main features of the Northern Transfer Project and the cost per cubic meter of water transferred to the existing Al Massira Dam.

Volume of water transferred	845 Mm 3 / a of which 527 Mm 3 / year for the Al Massira dam including 95 Mm 3 / a for AEP
Duration Phase I: Duration Phase II:	5 years ; period 2025 - 2030 (optimistic hypothesis) 5 years ; period 2030 - 2035 (optimistic hypothesis)
Investment Cost Phase I: Investment Cost Phase II:	MAD 16.2 billion of which 1.82 billion for AEP MAD 14.7 billion of which 1.65 billion for AEP
Cost of maintenance including transport cost	MAD 185 million / year of which 21 million / year for AEP
Pumping costs	1.25 MAD / m 3
Cost of water treatment	0 for the transfer of water to the Al Massira dam
Cost of water delivered to Al Massira Dam	7.4 MAD / m 3

Table XI-23: Estimated cost of m 3 transferred from the north to the Al Massira dam

Drinking water supply from the Al Massira dam to Marrakech (WT1a)

Phase I: The first phase of the project for the supply of drinking water and industrial water to the Marrakech region from the Al Massira dam includes the components related to the production, storage and water supply (see Figure 7.2):

Construction of a raw water intake from the Al Massira dam (7 m 3 / s)
Laying of a raw water supply pipe (diameter 2'000 mm, linear about 3 km)
Construction of a settling station (3.5 m 3 / s)
Laying of a drainage pipe (diameter of 1,600 to 2,000 mm, linear of about 45 km)
Construction of 2 tanks (R1, RMC1)
Construction of 2 pumping stations (SR1: HMT 182m and SR2: HMT 182m)
Construction of a treatment plant (capacity = 2.5 m 3 / s)

Installation of a pipe for the supply of treated water (diameter of 1,300 to 1,800 mm, linear of approximately 65 km) from the treatment plant to Marrakech

Construction of 3 tanks (R2, RMC2 and North reservoir)

Construction of a pumping station SR3 (HMT of the order of 100m)

This project is currently being carried out by ONEE at an investment cost of about MDH 30 billion .It is financed with the African Development Bank (ADB) and the Office Chérifien de Phosphate (OCP). The date of commissioning of this project is scheduled for 2018. This solution, which is currently being implemented, is not taken into account in the financial and economic analysis because it concerns existing infrastructures. On the other hand, the costs of Phases II and III of the supply of drinking water from Al Massira to Marrakech are taken into account.

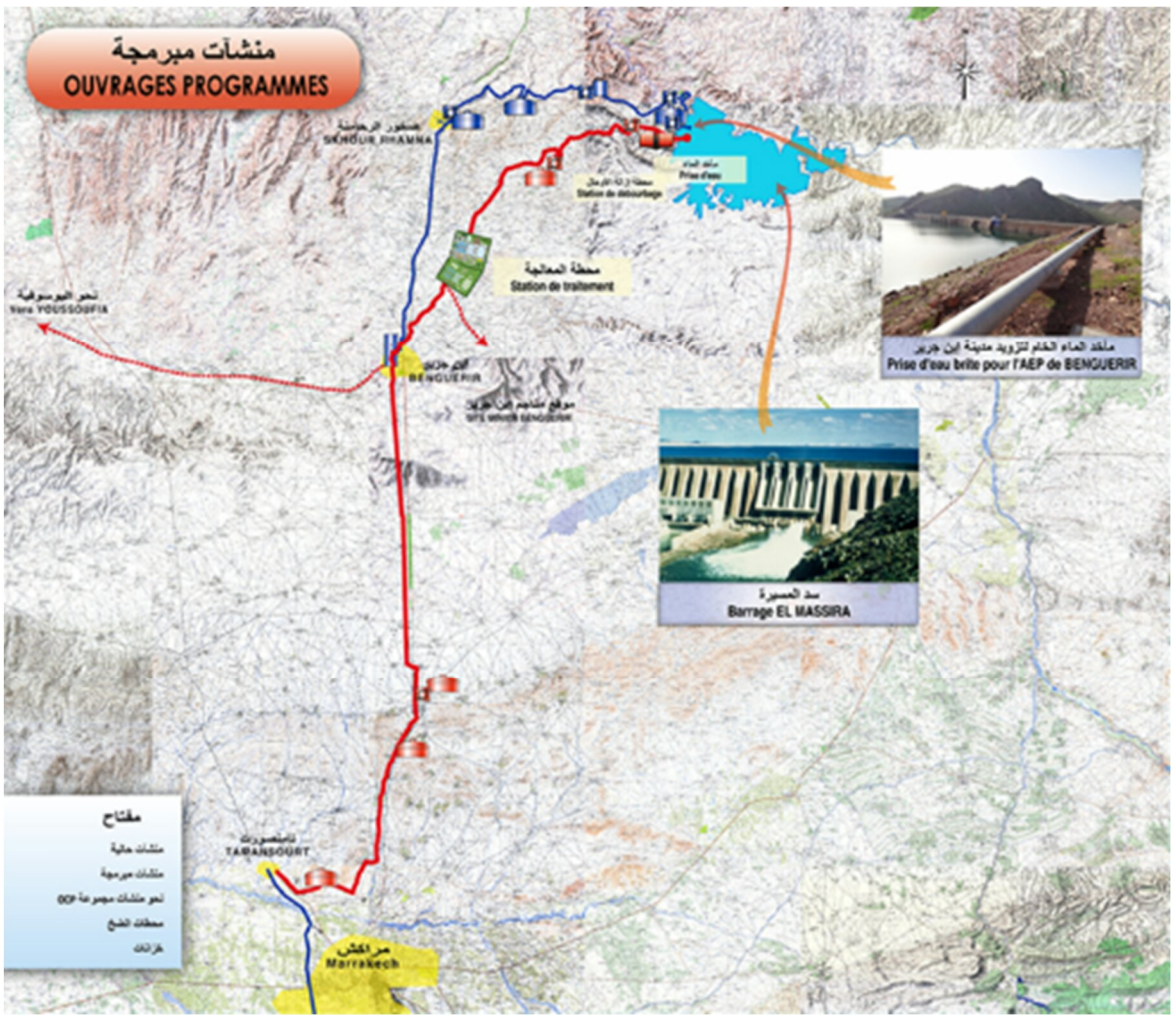

Figure XI-17: Scheduled drinking water works in the city of Marrakech from the "North-South Transfer" via the Al Massira dam (source: ONEE)

Projection of volumes: The project for the supply of drinking water (Phase I) under construction is designed to produce a drinking water volume of 78 million m 3 per year.This volume is intended for the supply of drinking water to the city of Marrakech and some urban centers.The first phase of the Marrakech adduction does not completely dominate the RADEEMA area.

Cost estimates: The total cost of m 3 of drinking water delivered to the city of Marrakech would be close to MAD 14.4, including the transfer costs from the north to the Al Massira dam (Table 7.6).

Source: Transfer Studies, ONEE	**Cost of m 3 of drinking water (MAD / m 3)**
Transfer Project (Phase I and II) ver Al Massira	7.4
Adduction Al Massira (Phase I) in Marrakech	7.0
Total Cost	14.4

Table XI-24: Overall cost estimates including the transfer of raw water from the north to the Al Massira dam and the first phase of the drinking water supply from the Al Massira dam to Marrakech

Phase II: Phase I of the Project will be completed in Phase II by the construction of the interconnection structures between the RADEEMA reservoirs. The water balances carried out in the context of this study showed that:

> The Hassan 1 st - Sidi Driss complex is expected to contribute more than 125 million m 3 per year to the supply of drinking water.The raising of this water endowment would result in major disruptions to the irrigation of the central Haouz and Nfis perimeters.
> During periods of drought similar to that observed during the period 2000-2007, a water break Stock dam I. Hassa could be saved.
> The loss of Lalla Takerkoust dam capacity by silting could result in a significant reduction in the volume mobilized at the Nfis branch, controlled by the Lalla Takerkoust complex;

The city of Marrakech should therefore rely solely on the water resources of the Al Massira complex during periods of drought. It must therefore have the necessary equipment to be fed entirely from this dam.It is in this context that the construction of the interconnection works between the reservoirs of the RADEEMA is necessary.

Cost estimate

Investment cost : The total cost of the interconnection works is estimated at nearly MAD 250 million, all of which is attributable to the supply of 29 Mm 3 of drinking water per year to Marrakech.The lifetime allowed for pipes is 50 years (55% of the investment) and 20 years for the pumping station (45%).

Fixed Operating Costs: Annual fixed maintenance and operating costs are calculated on the basis of the investment costs of the works by applying the maintenance rate allowed for civil works of 0.5% (86% of investment) and 3% for equipment (14% investment).Taking these rates into account, the annual fixed maintenance and operating costs are estimated at MAD 2,125 million / year.

Cost of operation: Pumping costs are calculated on the basis of the KWh price of 0.66 MAD / kWh, a pump efficiency of 0.75, a pumped volume of about 29 Mm 3 / year and d an HMT of the order of 50 m. The specific pumping costs therefore correspond to 0.12 MAD / m 3 .

Phase III: The Hassan 1 st - Sidi Driss complex could not guarantee both the supply of drinking water to the city of Marrakech and the minimum water supply of the Haouz perimeter, adopted within the framework of the PDOs of the Oum Er Rbia and Tensift, especially during periods of drought, similar to those observed during the period 2000-2007.The third phase of the adduction project from the Al Massira dam can therefore be carried out as one of the options available .This third phase consists of doubling the works of the first phase, including a new treatment station, with the exception of the water intake.

The third phase of the project is expected to be completed in 2025, to be operational in 2030, and includes the following components for production, storage and water supply:

Laying of a raw water supply line (diameter 2 000 mm, linear about 3 km)
Construction of a settling station (3.5 m 3 / s)
Laying of a drainage pipe (diameter of 1,600 to 2,000 mm, linear of approximately 45 km)
Construction of 2 tanks (R1, RMC1)
Construction of 2 pumping stations (SR1: HMT 182 m and SR2: HMT 182 m)
Construction of a treatment plant (capacity = 2.5 m 3 / s)
Installation of a water supply pipeline (diameter of 1,300 to 1,800 mm, linear of approximately 65 km) from the treatment plant to Marrakech
Construction of 3 tanks (R2, RMC2 and North reservoir)
Construction of a pumping station SR3 (HMT of the order of 100 m)

Projection of volumes

The assumptions taken into account in the calculation of the pumped volume are as follows:

demand for drinking water according to the average hypothesis;
contribution to the drinking water supply of the complex Hassan I. Sidi Driss is 40 m 3 / year, of which nearly 15 million m 3 / year for the province of Azilal;
the contribution of the Al Massira adduction will be 158 Mm 3 / year including 79 Mm 3 / year for Phase II (Phase I and interconnection works)
the contribution of the Lalla Takerkoust complex will be zero from 2030;
the contribution of the Haouz aquifer will be zero;
the supply of minimum irrigation water adopted at PDAIRE will be provided from the Hassan 1 st dam - Sidi Driss and Lalla Takerkoust;
the Sidi Driss dam will be totally silted up, the raising of the dam will not be carried out;
an average silting rate of 1 Mm 3 / year at the Hassan 1 st dam and Lalla Takerkoust dam ;
the project for the transfer of water from the north to the Al Massira dam will be put into service only after 2035.

Phases	**2022**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Phase I	50	50	50	50	50	50	50
Phase II	29	29	29	29	29	29	29
Phase III	-	-	40	50	60	79	79
Total	79	79	119	129	139	158	158

Table XI-25: Projection of drinking water volumes transferred from the Al Massira dam to Marrakech, Phase I, II and III (rounded figures)

Phase III Cost Estimates: The costs of the third phase of water supply from the Al Massira dam to Marrakech, including the costs of the reservoir interconnection structures in Marrakech are estimated below.

Investment cost: According to the study of the supply of drinking water to the city of Marrakech, adjacent centers and douars from dam Al Massira, the investment cost would be close to MAD 2,500 million of which nearly 55% for pipelines, 29% for equipment and 16% for civil engineering.

Cost of renewal: To take into account the cost of renewing the installations, a lifetime of 20 years is adopted for equipment and 50 years for civil engineering and pipelines.

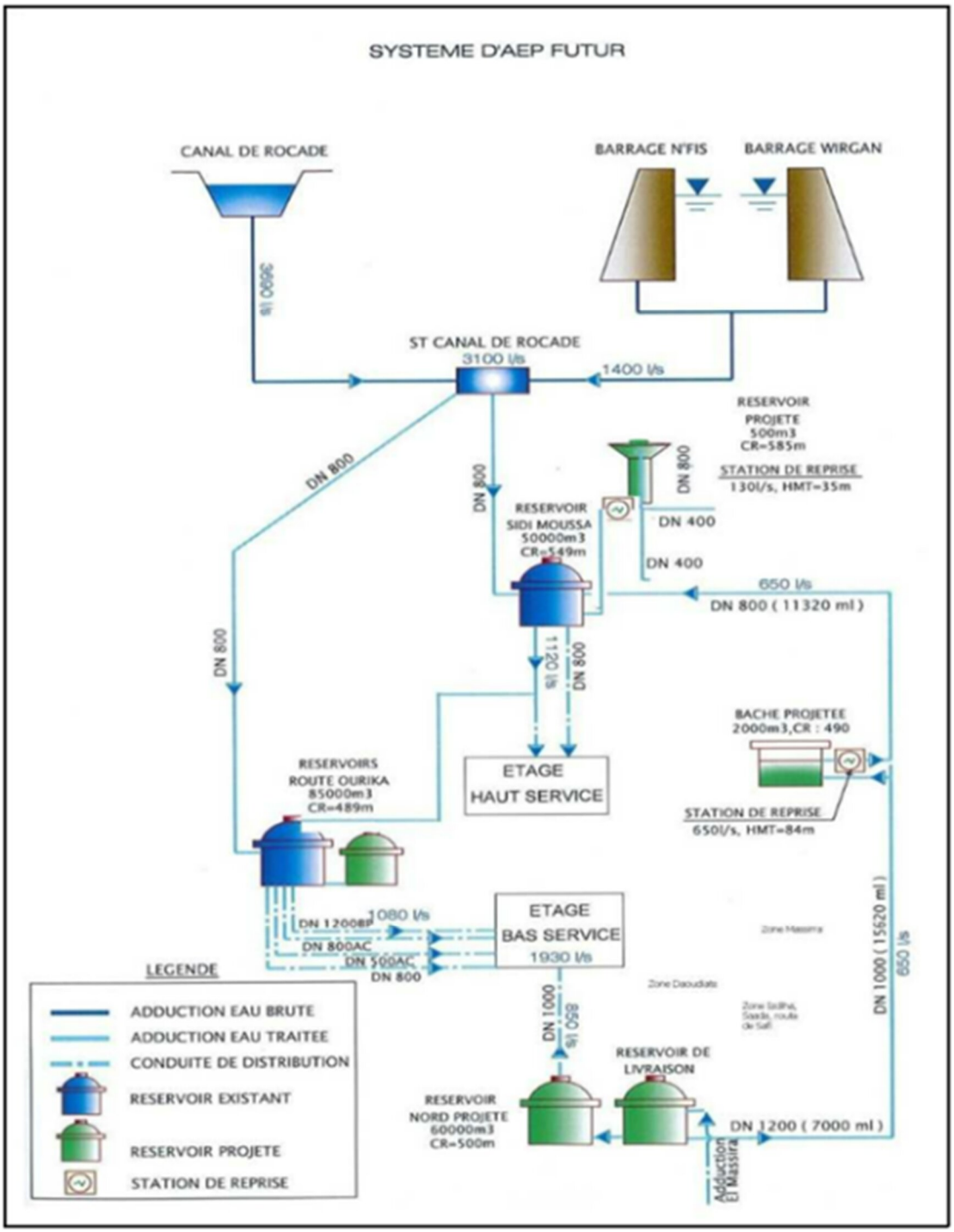

Figure XI-18: Future plan for the supply of drinking water to Marrakech (source: RADEEMA, 2014)

<u>Fixed operating costs</u> : Fixed annual maintenance and operating costs are calculated on the basis of the investment costs of the structures by applying the maintenance rate allowed for the various

structures of this third phase, ie 0.5% of investment costs for civil engineering and pipelines (71% of total investment) and 3% of investment costs for equipment (29% of total investment).On the basis of these maintenance rates, capital expenditure is estimated at MAD 30.6 million / year for the additional water supply of the Al Massira dam Marra Marra.

Cost of energy: The pumping costs of the drinking water supply from Al Massira to Marrakech are calculated on the basis of the price of 0.66 MAD / kWh, a pump output of 0.75, a volume pumped of the order 79 Mm 3 / year and an HMT of the order of 500 m.The specific pumping costs therefore correspond to 1.2 MAD / m 3 .

Treatment cost: According to the study of "Drinking water supply of the city of Marrakech, adjacent centers and douars from dam Al Massira" (ONEE), the cost of treatment is estimated at 0.25 MAD / m 3 .This cost includes staff costs, overheads and reagents.

Overview of Volumes and Costs: The table below summarizes the main features of the Northern Water Transfer project and Phases I, II and III of the Al Massira Drinking Water Supply Project Marrakesh.

Implementation period: Transfer from the North (Phase I) Admission to Marrakech (Phase I) Adduction to Marrakech (Phase II) Adduction to Marrakech (Phase III)	 5 years ; period 2025 - 2030 4 years ; period 2015 - 2018 2 years ; period 2020 - 2021 4 years ; period 2026 - 2029
Volume of water allocated to drinking water: Admission to Marrakech (Phase I) Adduction to Marrakech (Phase II) Adduction to Marrakech (Phase III)	 50 Mm 3 / year (without interconnection, existing) 29 Mm 3 / year (Phase II) of 2022 79 Mm 3 / year for Phase III of 2030
Investment cost: Transfer from the North (Phase I) Adduction to Marrakech (Phase II) Adduction to Marrakech Phase III	 Phase I costs are currently invested and therefore should not be taken into account MAD 250 million (interconnection) MAD 2.5 billion
Cost of maintenance: Adduction to Marrakech (Phase II) Adduction to Marrakech Phase III	 MAD 2.125 million / year MAD 30,625 million / year
Pumping costs: Adduction to Marrakech (Phase II) Adduction to Marrakech Phase III	 0.12 MAD / m 3 for 29 Mm 3 / year 1.2 MAD / m 3 for 79 Mm 3 / year (after 2045)
Cost of water treatment: Adduction to Marrakech (Phase II) Adduction to Marrakech Phase III	 0.25 MAD / m 3 for 29 Mm 3 / year 0.25 MAD / m 3 for 79 Mm 3 / year (after 2045)
Cost per m 3 of clear water	3.9 MAD / m 3 (without 20% for unforeseen costs and contingencies)

Table XI-26:: Estimated cost of m 3 of water transferred via the Al Massira dam to Marrakech

Description of the feasibility and climatic vulnerability: Technical feasibility is assured.The impact of climate change on water resources has been studied in the context of the study of water transfer patterns from the Loukkos, Laou and Sebou basins to South-East IV; choice of the development project, carried out by the Ministry in charge of Water.

This study showed that the impact of climate change would translate into a reduction of about 10% in transfers of water. Improved management of all the storage facilities in the 5 basins could mitigate this reduction.

Description of environmental impacts: The Environmental Impact Assessment for the Northern Transfer Project, carried out under Mission IV, identified the main environmental impacts .It focused on the impact of pipes, galleries and canals on the environment during construction and operation.

Since the selected routes have moved away from the inhabited areas, the impact on the surrounding populations is rather weak and diluted.The study also made it possible to make an inventory of the sensitive areas which may require some special precautions.

In conclusion, the proposed transfer does not raise any major problems from an environmental point of view. According to the impact study, the drinking water project from the Al Massira dam is not expected to cause major problems from an environmental point of view.

Project Benefits: The benefits of the project can be summarized as follows:

Strengthening diversification and securing the drinking water needs of the city of Marrakech
A joint project for drinking water (ONEE) and industrial (OCP)

7.4 Transfer project from the Kasba Tadla dam (WT1b)

This transfer project includes the following hydraulic works:

Water supply to Marrakech from the dam Kasba Tadla
Transfer from the north to the Al Massira dam (same works as the project of the transfer of water from the north to Marrakech via the Al Massira dam) : Instead of transferring water from the north via the Al Massira dam to Marrakech, water will be taken at the Kasba Tadla dam, which is upstream of the Al Massira dam, which will result in a reduction in the supply of the Al Massira dam from the Kasba Tadla dam.This reduction in the Al Massira dam must be offset by the transfer from the north.

This transfer consists of the following works (Figure 7.4):

of a water pipe from the Kasba Tadla dam to supply the existing (GM) channel from the Bin El Ouidane dam. This channel will in turn supply the channel T2 (existing) ;
a pressurization station that discharges water from the T2 canal (near El Kelaa Sraghna) via a pipe that crosses Tessaout Aval towards the Canal du Rocade.

Figure XI-19: Inter-basin water transfer project from the Kasba Tadla dam to Marrakech (source: PDAIRE Tensift)

The water balance at the Kasba Tadla Dam located in the Upper Er Rbia Basin releases an excess of water that is currently being transferred to the Al Massira dam. Some of this surplus could be transferred to the Tensift basin. This allocation from the waters transferred to the Al Massira dam would be offset by the waters of the Northern Transfer Project or the desalination of the sea water. Table 7.9 below shows the water balance at the Kasba Tadla dam.For the supply of drinking water to the city of Marrakech, the transfer from the Kasba Tadla dam to the Al Massira dam would reduce water losses by transport between Kasba Tadla and Al Massira, to enhance the treatment works already carried out at the Canal de Rocade.

The PDU of the Oum Er Rbia basin plans to build a canal from the Ahmed Al Hansali dam to strengthen the water resources of the Bin El Ouidane dam in order to mitigate the water deficit observed at the perimeter Béni Moussa and the Tessaout Aval. A channel from the Kasba Tadla dam to supply the GM channel coming out of Afourer will be built. According to the PDO Oum Er Rbia, the cost of this channel, with a flow rate of 10 m 3 / s (> 300 Mm 3 / year) and a length of about 25 km is estimated to be close to MAD 800 million.

		Wet period (1941-1980)	**Dry period (1981-2008)**
Water resources	Groundwater	50	50
	Surface wtaer	1,124	800
Water demand	Potable water	99	99
	Irrigation	433	300

Evaporation	50	50
Water balance(Mm^3)	592	400

Table XI-27: Water balance of the Haut Oum Er Rbia basin at Kasba Tadla (source: PDAIRE)

Description of the Feasibility and Climate Vulnerability: The feasibility study of the hydro-agricultural development , attached to the project of transfer of water from the North to the South, carried out by the Ministry in charge of Agriculture, supply of water from the Bouchane, Bahira and Central Haouz perimeters from the Kasba Tadla dam.This diagram is composed of :

of a canal from the Kasba Tadla dam to supply the GM channel which leaves Afourer;
a channel that will leave in parallel of the channel T2 and will be fed by the Canal GM which leaves Afourar. The flow rate of this channel is 25 m 3 / s.
the Haouz will be powered by a pressurization station which drives through a pipe that crosses Tessaout Aval towards the Canal du Rocade.

Water resources at the Kasba Tadla Dam are vulnerable to the impact of climate change. Climate change forecasts for the Oum Er Rbia basin are in the direction of a 20% reduction in water intakes compared to those taken into account in the PDAR. Despite this climatic vulnerability, the Kasba Tadla - Afourer - T2 - Canal de Rocade channel could secure the supply of drinking water to the city of Marrakech, as it can be fueled both by the large dams of Ahmed Al Hansali and Bin El Ouidane.

The reduction of water resources due to the impact of climate change would be offset by the implementation of the project for the transfer of water from the north to the Al Massira dam or the seawater desalination projects for the towns of Safi and El Jadida and possibly Casablanca.

The realization of this project whose cost is estimated to be more than MAD 7 billion is related to that of the Northern Transfer Project. The reinforcement of the water resources of the Canal de Rocade to improve the safety of the drinking water supply in the greater Marrakesh and the provinces of El Kelaa Sraghna and Azilal would make it possible to upgrade the treatment facilities at the Canal de Rocade. Rocade and reduce the energy bill compared to the adduction from the Al Massira dam.

The allocation to be taken from the Kasba Tadla dam is part of the water supply reserved for the city of Marrakech. Part of this allocation would be taken from the Kasba Tadla dam and the remaining part from the Al Massira dam.

Description of the environmental impacts: The transfer of water would have the same environmental impacts as the transfer from the north to the city of Marrakech via the Al Massira dam.The project of water supply from the Kasba Tadla dam does not raise any major problems from the environmental point of view.

Projection of volumes: The volume of water to be supplied by the transfer project from the Kasba Tadla dam is 60 million m 3 / year from 2025.

Cost estimate

	Cost (million MAD)	Additional volume (Mm^3/year)
Trunk line Kasba Tadla – Afourer Pumping station (HMT : 35 m) Trunk line connecting T2 - Canal de Rocade Pumping station (HMT : 180 m)	250 50 500 100	60
Total	**900**	**60**

Table XI-28: Investment cost for the transfer project from the Kasba Tadla dam

Renewal cost : The investment must be renewed every 50 years for pipelines and civil engineering works at pumping stations (88% total investment) and every 20 years for equipment at pumping stations (12% of total investment).

Fixed Operating Costs : Annual fixed maintenance and operating costs are calculated based on the capital costs of the works by applying the maintenance rate for the various works, ie 3% for equipment (12% total investment) and 0.5% for conduits and civil engineering (12% total investment), on average 0.8%.Taking into account the distribution of costs and the percentages of fixed operating costs, annual fixed maintenance and operating costs are estimated at MAD 7.2 million / year.

Cost of operation : Pumping costs are calculated on the basis of the price of 0.66 MAD / kWh, a pump efficiency of 0.75, a pumped volume of about 60 Mm 3 / year and a HMT of the order of 215 m.Taking these assumptions into account, the specific cost is estimated to be close to 0.52 MAD / m 3

Cost of transport : The cost of transporting water to the new transport system (Canal de Rocade and Canal T2) is estimated on the basis of the estimated transport cost at the Rocade Canal of 0.264 MAD / m 3 (source: estimate of the Ministry of Agriculture).On the basis of this specific cost, the total cost of transporting water to the new transport system is estimated at MAD 31.8 million / year (MAD 15.9 million / year for each channel).

Treatment cost: The cost of treatment is estimated on the basis of a cost of MAD 0.25 / m 3 .This cost does not take into account the cost of staff and overhead costs of the existing treatment plant with sufficient capacity to process an additional volume of 60 Mm 3 per year.The water treatment cost of 60 Mm 3 / year mobilized by the transfer from the Kasba Tadla dam is estimated at MAD 15 million per year.

Summary of volumes and costs: Table 7.11 summarizes the main transfer project characteristics from the Kasba Tadla dam to Marrakesh and the cost of the cubic meter of drinking water.

Implementation phase	5 years ; period from 2020 to 2024
Volume of water that can be collected	60 Mm 3 / year
Investment cost	MAD 900 million
Fixed maintenance cost	MAD 7.9 million / year
Pumping costs	0.52 MAD / m 3
Transport fee	MAD 31.8 million / year (MAD 0.53 / m 3)
Cost of water treatment	MAD 15 million per year (MAD 0.25 / m 3)
Cost per m 3 of clear water	2.7 MAD / m 3 (without 20% for unforeseen costs and contingencies)

Table XI-29:: Estimated cost of water transferred via the Kasba Tadla dam to Marrakech

Project Advantage

The implementation of this transfer project from the Kasba Tadla dam would enable:

strengthen the diversification and security of the drinking water supply in the greater Marrakech since the proposed canal can be fed from three dams: Bin El Ouidane - Ahmed Al Hansali - Kasba Tadla;
valorize the treatment works already carried out at the Canal de Rocade;
reduce energy costs by almost half;
reduce the water deficit observed at the perimeter of the central Haouz;
reduce the cost of adaptation of the RADEMA distribution network;
to avoid the 3rd phase of the transfer of the north via Al Massira towards Marrakech.

Environmental and social impacts: The balance between needs and available water resources is established through the transfer of water from the surplus basins to the deficit basins.These transfers are made by infrastructures (pipelines, treatment plant, pumping stations, basins, etc.) which are spread over a large linear line (sometimes hundreds of kilometers) and require the acquisition of land, the crossing of water, sites of biological and ecological interest, forests, pastures etc. The footprint of these projects includes (i) the pipeline right-of-way that is not limited to the trench, but also includes a runway that runs along the line for maintenance and (ii) civil works, are not limited to pumping and treatment stations but include all crossing structures and river crossings as well as visitor visits .

Generally, several routes are studied to compare their technical, financial and socio-environmental feasibility. This latter parameter can strongly influence the choice of the variant to be retained and orient it towards the one with the weakest environmental externalities.

Inter-basin transfers are generally considered as a solution to adapt to the effects of climate change on deficit basins. Their design must take account of the impact of climate change on the surplus basins in order to avoid inducing water deficits.These benefits are offset by the negative effects that are present during the life of this option:

Option: Inter-basin water transfers or trans-basin diversions			
Phase	**Site level**	**Hydraulic downstream**	**Hydraulic upstream**
Construction	• Loss of arable soils Ecosystems degradation • Air pollution (dust and gases) • Safety of workers and local residents • Displacement of populations • expropriations	• Pollution of surface and ground water	
Operation	• Loss of ecological values • Loss of asset values		• Loss or alteration of ecological flow • Loss of income (tourism, fishing, agriculture)

11. Urban Landscaping

Summary of current situation: Based on an environmental diagnosis [7]) , the green spaces of the city of Marrakech cover about 300 ha, corresponding to 0.26 ha per 1,000 inhabitants, representing a value much lower than the norm which is 2 ha per 1,000 inhabitants .By counting the olive groves of Agdal and Menara, this rate goes back to 0.8 ha per 1,000 inhabitants. In addition, the distribution of green spaces on the urban territory is uneven. New neighborhoods and subdivisions often lack parks and gardens.

Figure XI-20: Aspect of the modern urban landscape of Marrakech with a considerable number of fountains (source: EBP, 2016)

According to the following table, green spaces are spread over several categories of parks, gardens, olive groves and alignment plantations along major avenues and boulevards.The green spaces contain several types of settlements, such as trees, shrubby massifs, flower beds, grass, hedges, etc. composed of palm trees, roses, olives, bigaradiers, succulents, cacti, etc.

Catégorie	Superficie (ha)	%
Parcs Publics	117	13,8
Jardins Publics	84	10,0
Petits Jardins de Quartier et Squares	9	1,0
Espaces verts d'Accompagnements	42	5,0
Jardin Agdal	344	40,8
Jardin Menara	91	10,8
Jardin Ghabet Echabab	143	17,0
Espaces verts privés	15	1,7
Total	**845**	**100**

Table XI-30: Categories of green spaces in the city of Marrakech (source: Diagnosis and analysis of the state of the environment of Marrakech)

Spraying green spaces results in excessive consumption of groundwater, primarily due to traditional, uneconomic irrigation methods, inappropriate and voracious plantations of water (eg turf), and inadequate management of municipal services.In addition, green spaces represent a risk of contamination of the aquifer by phytosanitary and fertilizing products.

Figure XI-21: Aspect of the modern urban landscape in Marrakech with an alignment plantation of a boulevard with grass and roses (source: EBP, 2016)

Type de culture	Besoins de pointe saisonnière	Besoins moyens	Coefficient de pointe
Gazon pour un terrain de golf de Golf	70 m³/j/ha soit 0.81 l/s/ha	45 m³/j/ha = 4.5 mm/ha/j	1.60
Jardins et espaces verts	2 mm/j = 20 m³/j/ha = 0.23 l/s/ha	13.70 m³/ha/j = 1.37 mm/ha/j	1.46

Table XI-31: Water supply requirements by type of crop (source: ABHT, Mission I, Inventories of tourist establishments [...], 2010)

	Superficie (ha)	Besoins Mm³/an
Espaces verts gérés par la commune urbaine et les arrondissements	**399**	**4.0**
Domaines Royaux	**580**	**6.00**
Jardins de l'Agdal	500	
Jardins de la Ménara	80	
Espaces verts à l'intérieur de la ville	**541**	**2**
Jardins d'hôtels	511	**1.7**
Jardins d'INRA	30	**0.3**
Total	**1 520**	**12**

Table XI-32: Estimation of water demand for green areas in the city of Marrakech without taking account of golf courses and palm groves (source: Diagnosis and analysis of the state of the environment in Marrakech)

According to the above tables, irrigation water needs for the green areas of the city of Marrakech are very significant and estimated at 12 million m 3 per year without irrigation of the palm grove.The Palmeraie extends over an area of nearly 1,000 ha.The demand for water for the preservation and extension of palm groves is estimated at 1.5 to 2.9 million m 3 per year.

Description and impacts of the Marrakech option: Given the high watering requirements for green spaces, the solutions proposed below can contribute to the preservation of water resources, in particular to the restoration of the water table:

Promotion of cacti and succulents; replacement of irrigated plants with high watering needs (eg grass);
Implementation of a micro-irrigation program for green areas and golf courses

Figure XI-22: Planting of cacti and succulents in a roundabout in Marrakech (source: EBP, 2016)

Figure XI-23: Cactus planting and grass replacement by gravel on a golf course in Marrakech (source: EBP, 2016)

Figure XI-24: Example of drip irrigation in downtown Marrakech (source: EBP, 2016)

Description of Feasibility and Climate Vulnerability: A pilot project could be conducted to test the effectiveness of the program, refine costs, and arrest financing, operating and project management conditions.Urban landscaping should not be significantly affected by climate change.

Projected volumes: The urban landscape for green spaces managed by the urban commune and districts.The water needs of this area, with an area of 400 ha, are estimated at nearly 4 million m 3 per year.With the goal of reducing water requirements by 50%, an urban landscaping project could be adopted. This project would consist of :

50% of the area would be managed with irrigated plants;
40% of the area would be developed with self-locking block
10% of the area would be managed with dry plants;

The volume likely to be cleared would be 2 Mm 3 per year.

Mm^3/year	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Volume produced	0.2	0.5	1.3	2	2	2	2

Table XI-33: Estimated Urban Landscaping Water Volume (Source: Consultant's Estimate)

Cost Estimates

Investment costs: The cost of this development is estimated at nearly MAD 250 million:

MAD 10 million for the area planted with dry plants;
MAD 240 million for self-locking block area (150 MAD / m 2).

Fixed operating costs: Urban landscape development would not result in an increase in the current fixed operating costs of urban green spaces.

Cost of Operation: Urban landscape development would not result in an increase in the current operating costs of urban green spaces.

Volume and cost overview: The table below summarizes the main features of urban landscaping and the cost per cubic meter of saved drinking water.

Date of commissioning	short term
Volume of water	2 Mm 3 / year
Investment cost	MAD 250 million (renewal in 40 years)
Cost per m 3	14.0 MAD / m 3 (without 20% for unforeseen costs and contingencies)

Table XI-34: Estimated cost of m 3 of water generated by the urban landscape (Source: estimates of the consultant)

12. Demand Management (GD)

Management of internal household demand

Summary of Current Status: Despite significant technical, institutional, tariff, public awareness efforts, quantities of water measured and invoiced by the distributor are wasted by the consumer.The source of consumer water wastage may be either abnormal use by users who are uninformed about the cost of production, which usually results in abusive practices or losses in poorly maintained or poorly designed indoor facilities. Three studies were carried out in Morocco (1990, 1996 and 2000) with support from WHO, AFD and the Mediterranean Water Institute, according to which 15-20% water is lost or wasted inside the fireplaces (after the water meter).

Description and impacts of the option for Marrakech: Given the scarcity of water and the high cost of water in the Marrakech region, the management of internal water demand for households needs to be strengthened.In order to avoid or at least reduce losses, the following technical and institutional measures must be put in place.An internal water demand management program for households must

be implemented with the objective of reducing losses by more than 50%. This program, which must be based on an action plan, will include :

Strengthening the organization of awareness campaigns for drinking water users with the aim of developing more general awareness of the scarcity of water, the importance of the cost of developing water, water and the need to save water.Awareness raising plays a very important role in limiting waste. Indeed, and according to a study by survey carried out by the ONEE, the subscribers who appreciated the advertising spots consume less than the others. In addition, the impact of youth awareness has a significant impact on household consumption. Children and young people are the main targets for schools, holiday camps, women's homes, youth centers, fairs and fairs by means of presentations, exhibitions, the organization of competitions and the distribution of documents adapted according to the different age groups .

Pricing adapted to deter detergents (billing based on actual consumption, but with a rate per consumption band)

Strengthening of technical measures: the implementation of water-saving policies outside the behavioral aspects calls for technical means. Three types of technical measures are proposed:

- Development of a pilot project for the installation of economizer equipment (aerators, pushbutton valves, timed valves, economical shower stalls and shower stops, toilet flushing systems, economical washing machines and dishwashers, etc.)
- Development of a pilot project on preventive and curative maintenance. Preventive maintenance ensures greater durability of installations, improves user comfort and reduces the frequency of water damage. This maintenance consists of having a maintenance visit of the housing materials carried out once a year by a qualified technician.
- Reinforcement of the individual counting program, which is a very effective means of combating waste, by empowering the occupants of each dwelling;
- Monitoring of consumption by subscribers is a means of detecting accidental overconsumption and anomalies relating to the operation of the meter (malfunctioning or blocking, for example).

Management of external demand for households

Summary of the current situation: Despite the technical efforts made, the overall performance of the drinking water system in the city of Marrakech is currently only around 75%.Water quantities, on the order of 25% of the quantity of water distributed, are therefore lost in the distribution network.In order to reduce these water losses, technical and incentive measures are taken. ONEE and RADEEMA undertake programs to improve the technical performances of the distribution networks:

ONEE is engaging programs to improve efficiency to achieve 80% by 2020;

RADEEMA annually undertakes a program to improve the technical performance of the drinking water distribution network. At present, the efficiency of the network is around 75%. The objective of RADEEMA is to achieve a rate of return of 77% in 2019. The budget for this objective is MAD 100 million;

The renewal rate of the drinking water pipeline (2,400 km in total) is 1.5% per year, corresponding to MAD 15 to 20 million per year;

A leak detection program is underway;

The sectorisation of the network is under way and provides for 2 areas of pressure;

RADEEMA undertakes actions to improve and optimize its information system.

In addition, the Tensift Water Basin Agency has introduced incentives for water withdrawal fees to encourage water saving and reduce waste.

Description and impacts of the option for Marrakech: The measures undertaken aim to bring the overall return to the level of the RADEEMA zone to 78% in 2030.Given the problems of water, linked to water scarcity and the high cost of water, the 78% target must be increased to over 85%, which could translate into a recovery of a water volume of 15 Mm 3 per year (see NR1)

9.3 Management of tourism / commercial / industrial demand

Summary of the current situation: The demand for tourist and industrial water for the city of Marrakech in 2030 would fall to almost 8 million m 3 of which almost 4.6 million m 3 for the tourism sector and 3.4 m 3 for the industrial sector.

Liquid industrial emissions are major constraints to the proper functioning of the wastewater treatment plant.

The implementation of a water demand management program would result in a reduction in water demand and a reduction in liquid discharges.

In order to reduce water demand in the industrial sector and to combat pollution generated by this sector, the government has developed economic and financial tools (National Environment Fund (FODEP) and the Sustainable Development Mechanism) to ensure respect for the environment, upgrade industries and reduce gaseous, solid and liquid emissions.

Several industrial pollution control projects have been developed with the support of FODEP in the Marrakech region.

Description and impacts of the option for Marrakech: Given the scarcity of water, the high cost of water in the Marrakech region and the wastewater and wastewater reuse program of the city of Marrakech Marrakech, a water demand management program in the tourism, industrial and commercial sectors is needed.This program, which must be based on a specific action plan, will include :

Industrial sector :

Organization of awareness-raising campaigns among industry leaders with the aim of developing a general awareness of the scarcity of water, the importance of the cost of water development in the Marrakech area and the need to save and clean up water;
Enactment of regulations relating to discharge standards;
Application of levy and discharge charges;
Implementation of a program to clean up pollution with a sustained rhythm and support for the Sustainable Development and National Environment Fund;
Strengthening of the water police.

Tourism sector:

Organization of campaigns to raise awareness among tourism project managers with the aim of developing a general awareness of the scarcity of water, the importance of the cost of water

development in the Marrakech area , the need to save water and the obligation to meet standards;
Implementation of technical measures: three types of technical measures are identified:

- Development of a pilot project for the installation of economizer equipment (aerators, pushbutton valves, timed valves, economical shower stalls and shower stops, toilet flushing systems, economical washing machines and dishwashers, etc.)
- Monitoring of consumption at hotel level is a means of detecting accidental overconsumption and anomalies relating to the correct operation of the meter;
- Development of a pilot project for the use of greywater including the development of regulations on the use of gray water.

---

[1] It is noted that the investment cost of the seawater desalination plant with a capacity of 400,000 m 3 / day to be built in southern Morocco to provide water supply drinking water in the city of Agadir and the Chtouka perimeter is specified as MAD 2.53 billion, ie 6,325 MDH / m 3 / d (excluding costs for the drinking water backup station).The agreement relating to the construction of this station was signed in July 2017 at the Ministry of Finance.

[2] Diagnosis and analysis of the state of the environment in the agglomerated area of Marrakech, Provisional Reports of Missions II and III, Market no.12/2012, Resing, February 2014 .

[3] According to RADEEMA, the total investment cost of the first stage of the existing STEP with a capacity of 33 Mm 3 / year was MAD 1,232 million, ie MAD 746 million for the cost of primary and secondary treatment, and 486 MAD for the cost of tertiary treatment and distribution network (about 80 km).The project was subsidized by the state with 150 MAD and golf promoters contributed 265 MAD (instead of 486 million as originally planned).

[4] Silke Rothenberger and. al, 2011: In-house Gray Water Reuse for Large-Volume Consumers in Jordan,

[5] Tarfaya and Al Hoceima, 2015: Study of the economic analysis: reduction of the gap between urban water supply and demand in Morocco

[6] The report of the GIZ of 2016 presents the most up-to-date diagnosis and balance sheet of the Haouz aquifer, for the period from 2001 to 2013.

[7] Diagnosis and analysis of the state of the environment in the agglomeration area of Marrakech, Provisional report of Mission II, Market no.12/2012, Resing, February 2014

ANNEX XII - Financial and multi-criteria analysis of technical options

Les options de diversification pour remédier à la pénurie de l'eau à Marrakech sont évaluées à l'aide d'une analyse financière et économique. A l'aide de l'analyse financière le prix de revient de l'eau en Dirhams par mètre cube (MAD/m^3) est calculé pour toutes les options. Ce coût spécifique entre comme critère « Coût-efficacité » dans l'analyse économique, qui prend en compte d'autres critères comme la durabilité, le volume d'eau dégagé et les risques des différentes options.

1. Financial analysis

Methodology: The financial analysis is based on a rough estimate of the investment and operating costs as well as the volumes of water released up to 2050 for the various options. Estimates of costs and projections of water volumes were made on the basis of studies carried out by administrations and bodies responsible for water management, based on information from similar projects in the region or comparative figures. Estimates are based on average annual volumes and average infrastructure capacity. The degree of accuracy of costs and volumes is therefore limited and cost estimates, in detail in the dedicated Annex, do not include contingencies. For this reason, we have chosen to add 20% to the cost estimates to cover unforeseen costs and contingencies in this chapter to ensure that our cost estimates are realistic.

The financial analysis was conducted using a Net Present Value (NPV) analysis. The NPV and cost price were determined for the different options based on long-term projections (up to 2050) of average costs and volumes. A discount rate of 5% was chosen, which corresponds to an average economic growth rate of 2.5% per year. For drinking water and irrigation water options, only costs attributable to drinking water were taken into account.

Only capital and operating costs directly related to the options have been taken into account. The costs of the existing infrastructure used for the capture, transfer and treatment of water mobilized by an option are therefore not considered. For example, the investment costs of the existing Canal de Rocade that will be used for the transfer of water to Marrakech are not taken into account in various options.

Results of the financial analysis: The results of the financial analysis are summarized in *Table XII-1*:

Options	Code	Cost (MAD/m^3)	+20% (conting.) (MAD/m^3)	Volumes (Mm^3/yr)
Construction of new dams to store surface water	SW4	2.3	2.8	30
Increased storage capacity of existing dams	SW5	1.7	2.0	27
Groundwater recharge by infiltration	GW3	0.6	0.7	50
Interbasin water transfers: Phases II and III of water supply from the Al Massira dam to Marrakech (excluding the transfer costs from the north estimated at MAD 7.4 / m3)	WT1 a	3.9	4.7	108
Interbasin water transfers: Water supply via the Kasba Tadla dam to Marrakech (excluding the transfer costs from the north estimated at MAD 7.4 / m3)	WT1 b	2.7	3.2	60
Small-scale / rural rainwater harvesting	RW1	4.4	5.3	3
Rainwater harvesting, storage and reuse in the city	RW3	44.4	53.3	0.2
Reuse of treated wastewater for non-potable use	WW1	5.4	6.5	30
Reuse of gray water in hotels	WW3	26.1	31.3	1.7
Desalination of sea water by reverse osmosis and transfer of an equivalent volume of the Kasba Tadla dam to Marrakech	DS1	7.5	9.0	75

Network rehabilitation, leak detection and accompanying measures	NR1	3.0	3.6	15
Urban landscaping	DM4	14.0	16.7	2

Table XII-1: Summary of specific costs and water volumes for the different options (2050) (blue color: conventional solutions, green: non-conventional solutions, brown: demand management)

Discussion of the cost-effectiveness of the options: In order to evaluate the different options envisaged, a comparison of the specific costs was carried out. According to above table:

- From the financial point of view, the recharge of the groundwater using the infiltration thresholds in the wadis upstream of Marrakech (GW3) represents the most advantageous option with very advantageous unit costs. Estimating costs and projecting water volumes are considered reliable because they are based on the PDAIRE and pilot projects already carried out. On the other hand, and since water tables are largely overexploited by multiple actors, access to infiltrated water or use as irrigation water is a considerable challenge.

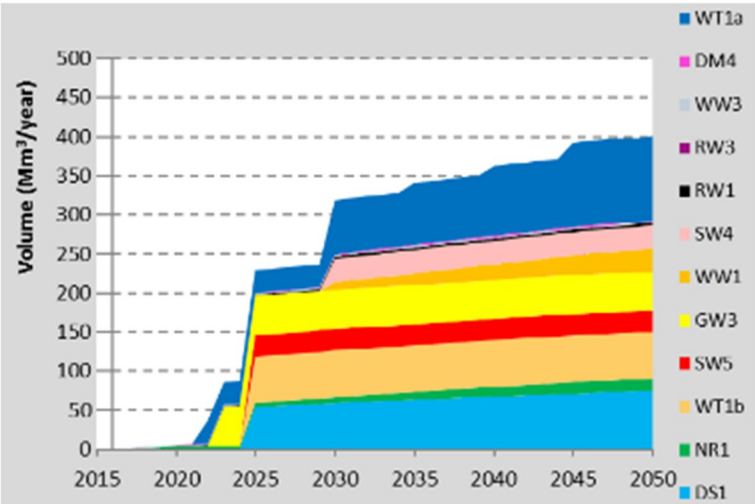

Figure XII-1: Volumes produced on an annual basis by the various options for Marrakesh water supply

- The options relating to the construction of the Ait Ziat dam (SW4) and the raising of the Sidi Driss dam (SW5) appear to be interesting in terms of cost and the volumes of drinking water released. These options should therefore be examined more closely.
- Options for transferring water or transferring water from the north to the Al Massira / Kasba Tadla complex and from there to Marrakech seem relatively advantageous. The transfer of the north via the Al-Massira dam (WT1a) seems more expensive than the transfer via the Kasba Tadla dam (WT1b), since it can enhance existing transport and treatment infrastructures (Canal de Rocade). Including the specific costs of about 7.4 MAD / m3 for the transfer from north to Al Massira, transfer options WT1a and WT1b with 12.1 MAD / m3 and 10.6 MAD / m3 respectively are relatively expensive. Desalination of seawater, including the transfer of an equivalent volume of 75 Mm3 / year from Kasba Tadla to Marrakech (DS1), would cost only MAD 9.0 m / m3.
- Options for rainwater and gray water recovery are among the most expensive options. In these cases, high costs are due to relatively high costs (RW3) and / or relatively low volumes of water released (RW3, WW3). Small-scale rainwater harvesting (RW1) can result in attractive costs if it is carried out at the rural level using hilly lakes.
- The reuse of purified wastewater (WW1) is likely to bring significant volumes of water at moderate costs, as the costs of primary and secondary treatment should not be considered; these treatments are mandatory by law, with or without the reuse of wastewater.
- With relatively low costs, reducing the losses of the drinking water distribution system (NR1) is certainly one of the interesting options. The contribution of this option is rather restricted given

the efforts already made and envisaged by RADEEMA and the ONEE in the management of the networks and considering the challenge to increase the efficiency far beyond 80%

2. Multi-criteria analysis

For this study, a full cost-benefit analysis is not considered appropriate for this type of study, mainly because it would be costly and complex to monetize all costs (including environmental and social costs) and economic and since the many data required for this are not or only partially available. Instead of such an analysis, the different options were evaluated using a multi-criteria analysis using a set of weighted evaluation criteria that are shown in the table below.

Aspects	Performance indicator	Evaluation
A Sustainability of water resources	Impact on groundwater resources	1: No benefit / advantage 2: Minor benefits / advantages anticipated 3: Moderate benefits / advantages anticipated 4: Significant benefits / advantages anticipated 5: Major benefits / advantages anticipated
	Dependance on des freshwater resources (by inhabitant)	1: No impact 2: Minor decrease anticipated 3: Moderate decrease anticipated 4: Significant decrease anticipated 5: Major decrease anticipated
	Protection against flooding	1: No benefit / advantage 2: Minor benefits / advantages anticipated 3: Moderate benefits / advantages anticipated 4: Significant benefits / advantages anticipated 5: Major benefits / advantages anticipated
	Nutrients and pathogens In water resources	1: No benefit / advantage 2: Minor benefits / advantages anticipated 3: Moderate benefits / advantages anticipated 4: Significant benefits / advantages anticipated 5: Major benefits / advantages anticipated
	Resilience to climate change	1: Non-renewable resources 2: Source available on a non continuous basis (rainwater) 3: Climate dependent sources on the short term (surface water) 4: Climate dependent source on the long term (storage) 5: On a yearly basis, climate independent source (seawater, wastewater)
B Demand	Water demand satisfaction	1: Negligible volume available (< 2% of total water demand) 2: Volume available between 2% and 10% of total water demand 2: Volume available between 10% and 20% of total water demand 2: Volume available between 20% and 00% of total water demand 5: Large volume available (> 40% of total water demand)
C Water quality	Water quality	1: *Non applicable (Non valid)* 2: Non-controlled uses 3: Non-potable water whose use directly relieves pressure on drinking water 4: Use for drinking water after storage / treatment 5: Direct uses for drinking water
D Financial aspects	Cost-effectiveness	1: Less cost-efficient options (>$10/m3) 2: Cost of the options between $2/m3 and $10/m3 3: Cost of the options between $1/m3 and $2/m3 4: Cost of the options between $0.2/m3 and $1/m3 5: Most cost-efficient options (<$0.2/m3)
E Risk management	Management of social and environmental risks	1: Major risks, requiring a full risk management plan 2: Significant risks, requiring mitigation measures 3: Moderate risks, requiring a partial assessment 4: Minor risks, requiring vigilance 5: No known risk
	Management of legal and institutional risks	1: Existing regulatory provisions discourage or explicitly prohibit this measure 2: No legal and institutional framework in place or under preparation 3: A legal and institutional framework is in place but there are ambiguities to be clarified 4: A legal and institutional framework is in place, but there are ambiguities to be clarified: these ambiguities have been identified and preparatory activities to remove them are ongoing 5: A clear legal and institutional framework is in place and explicitly encourages this option
	Management of technical risks	1: Associés à des défis techniques considérables pour leur implantation 2: Technology under development 3: The technology only exist as a pilot and requires further testing 4: The technology to implement the measure is well mastered but can be complicated to install 5: The technology to implement the measure is well mastered and easy to install

Table XII-2: List of criteria and scoring principles for the multi-criteria analysis

	Sustainability / Resilience	Demand satisfaction	Water quality	Cost effectiveness	Risk management	Total Score	*Ranking compared to financial analysis*
	30%	20%	10%	20%	20%	100%	
Aquifer recharge	3.4	4.0	5.0	5.0	3.4	**4.0**	=
Desalination	3.1	5.0	4.0	4.0	3.7	**3.9**	
Non-potable reuse	3.9	4.0	3.0	4.0	3.7	**3.8**	
Increase of reservoirsôcapacity	2.7	4.0	4.0	5.0	3.0	**3.6**	
Leak reduction	3.0	2.0	5.0	4.0	5.0	**3.6**	=
Inter-basin transfer via Al Massira	3.0	5.0	4.0	4.0	2.3	**3.5**	=
Inter-basin transfer via Kasba Tadla	3.0	5.0	4.0	4.0	2.3	**3.5**	
Construction of new dams	3.0	4.0	4.0	4.0	2.7	**3.4**	
Rural rainwater harvesting	2.2	2.0	3.0	4.0	3.4	**2.8**	
Urban landscaping	2.5	1.0	3.0	3.0	4.7	**2.8**	=
Greywater reuse	3.3	2.0	3.0	2.0	2.7	**2.6**	=
Urban rainwater harvesting	1.8	1.0	3.0	2.0	3.4	**2.1**	=

Conventional solution
Non-conventional solution
Demand management

Table XII-3: Summary of options multi-criteria analysis

Evaluation of options:

Assessing and prioritizing options using financial and economic analysis presents a considerable challenge. Indeed, the overall score often does not vary much between the different options. The three options that perform best in economic analysis are:

- Groundwater recharge by infiltration (GW3, score 4.0)
- Desalination of sea water by reverse osmosis (DS1, score 3.9)
- Reuse of treated wastewater for non-potable use (WW1, score 3.8)

The raising of a dam (gSW5) and the rehabilitation of the network (NR1) obtained a score of 3.6 points. Compared to the options listed above, they are therefore assessed a little less positively. Concerning the raising of dams mainly because of the considerable social and environmental risks and concerning the rehabilitation of the network due to the relatively modest volume mobilized.

The reuse of wastewater and wastewater (WW1) is likely to bring relatively large volumes of water with relatively moderate costs. This option should be integrated as a local resource that is not vulnerable to climate change in the water supply of the Marrakech region in order to strengthen the water resources of the Rocade Canal and reduce drinking water the city of Marrakech.

Providing coastal cities with desalinated water and freeing water at the Al Massira complex for the city of Marrakech is a promising option, as it significantly reduces transport losses, all the more so that it is an option that is not vulnerable to climate change. This option should therefore be further developed, including its cost, taking into account international experience and the potential to cover high electricity consumption with renewable energy (eg wind or solar energy). In this context, the institutional arrangements required for these water exchanges and the necessary financial arrangements should also be developed.

Water transfer options or the transfer of water transferred from the north to the Al Massira complex and from there to Marrakech get an economic score of 3.5 points because the costs of transfer from the north to the Al Massira dam are not taken into account (see discussion of cost-effectiveness of options above). Overall, transfer options are therefore less favorable than desalination, not only because of their high costs, but also because of their environmental risks and their vulnerability to climate change.

The rainwater harvesting options (RW1 and RW2), the gray water reuse of the hotels (WW3) and the urban landscape design (DM1) are relatively low. These options produce a relatively low volume of water at a high cost.

The prioritization of options does not depend solely on the results of the financial and economic analysis. It will also depend on the cumulative volume of water to be released by the options - depending on the expected needs - and at what time these volumes and the various water resources will be available. In this context, the rehabilitation of the distribution network of RADEEMA (NR1) should be carried out as soon as possible, as it can generate considerable volumes of drinking water in a short time. The same holds true for recharge of groundwater by infiltration (GW3) using retention thresholds that can be built relatively quickly.

Description of the main challenges with the implementation of the options

Generally it must be said that the implementation of technical options must be accompanied by institutional measures. Moreover, this study does not represent a sufficiently detailed and solid basis for the realization of the options. In a next step, the technical, economic, institutional, environmental and social aspects of options and combinations of options need to be studied in more detail in feasibility studies, taking into account challenges in a broader framework. To do this, the following two aspects should be explored:

Adaptability: The framework of the conditions for the supply of drinking water for Marrakech may develop in a not or partially planned direction (eg unanticipated variations of climate change, migration, economy, etc.).). Modular options and / or limited service life and / or adaptable features have an advantage in this regard.

Competition: Various options for water supply use certain water resources and require space. Often these same resources are used by other users (eg other cities, agriculture, industry). These competing uses vary in their degree of complexity (eg in the number and organization of users). Options that utilize resources that are not challenged by other uses have an advantage from this point of view.

The figure below illustrates an initial assessment of the challenges for options arising from this broader framework. A few explanations of this assessment for individual options are given in the following.

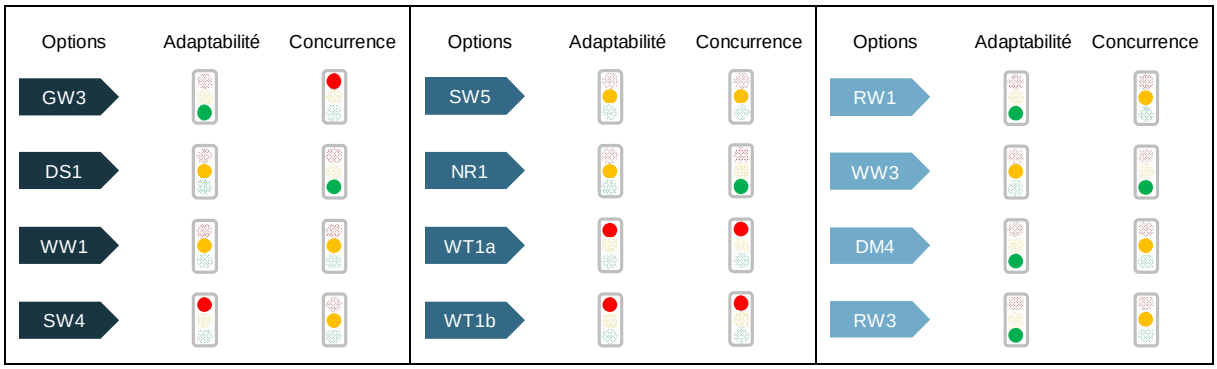

Fig. 8.4 : Appréciation des défis pour les options provenant du cadre élargi. Sens des feux : rouge = grands défis, jaune = moyens défis, vert = peu de défis

- Construction of new dams to store surface water (SW4): The cost of the project represents a challenge and the construction of the Ait Ziat dam is an important strategic and financial choice for the agency of the hydraulic basin of Oum Er Rbia, knowing that by 2030, about 30% of the capacity of this dam will be destined for the supply of drinking water to the city of Marrakech. The environmental and socio-economic impact of this project is significant and costly, in particular the loss of hundreds of hectares of agricultural land upstream of the dam as well as loss of income and employment in a region or the poverty is already important. From a technical point of view, the risk of siltation of the dam must be considered.
- Increase in the storage capacity of existing dams (SW5): The raising of the Sidi Driss dam presents no major challenges. On the other hand, the resources at this dam are vulnerable to

the impact of climate change, which would result in a reduction in the regularized volume estimated to be close to 10% compared to the PDAIRE. Despite this climatic vulnerability, the Sidi Driss dam, which will be managed in an integrated manner with the Hassan 1 complex, the Ait Ziat dam and the Al Massira dam, could play a fundamental role in the supply of drinking water to the city of Marrakech. From a technical point of view, the risk of siltation of the dam must be considered.

- Recharge of groundwater by infiltration (GW3): The feasibility of this option presents a technical challenge due to the risks of erosion, clogging and vulnerability to climate change. Indeed, the surface water supplies of the various wadis where the infiltration thresholds will be realized can undergo a reduction of the flow and the volume of infiltrated water in the aquifer estimated at nearly 20%. The option also represents a challenge in terms of competition for groundwater uses. Indeed, recharge of the groundwater could promote a return to irrigation of green spaces from the groundwater or excessive exploitation by farmers in the region.
- Inter-basin water transfers or transbassin diversions (WT1): The challenge of the impact of climate change on water availability is not negligible for the transfer of water from the north via the Al Massira or Kasba dam Tadla to Marrakech. It is sufficient that a transfer chain basin suffers from a succession of dry years for the system to be disturbed. However, the allocation provided for in the municipal water represents only 3% of the total resource. This option would therefore strengthen the resilience of Marrakech's drinking water supply to climate change, which is not the case for irrigation water supply.
- The high investment and energy costs of the transfer to Marrakech require a long-term financing strategy and a distribution of investment and operating costs between the various institutional actors (ABHT, ABHOER, ONEE, MDCE), donors international and private (OCP, concessionaires). Financing problems could lead to considerable delays with the completion of the northern transfer.
- Competition from allocations due to scarcity of water resources and economic development (irrigation and municipal and industrial water supply in the urban poles) constitutes a major technical and political challenge. Such situations must be resolved by the supervisory ministry in consultation with the regional councils which have the competence to promote economic development.
- Rainwater harvesting (RW1 and RW3): Based on the new water law, which generally strengthens the legal framework for rainwater recovery, the collection and reuse of rainwater requires prior place and in force of a specific regulatory mechanism. In addition, awareness-raising campaigns for the population, the developers and the authorities in charge are necessary. These campaigns should focus on the quality of the rainwater, the implementation of collection schemes and the use of these waters, and help promote the acceptability of this solution in civil society.
- Re-use of treated wastewater for non-potable use (WW1): From a legal point of view, there is a lack of regulatory text setting out the modalities for granting financial aid for the reuse of treated wastewater.

  The financial burden of extending the existing WWTP requires a possible financing strategy with a PPP partnership or shared funding among public and private investors. The existing contracts between RADEEMA and golf operators are not yet guaranteed success and must be improved in order to generalize the use of treated wastewater for the irrigation of golf courses and green spaces.

  The WWTP, after its extension, will be able to supply a quantity of 60 Mm3 / year of which about 35 Mm3 / year will be necessary and sufficient for the irrigation of the golf courses and

green spaces of Marrakech. This volume will reduce the pressure on the water table and will release an equivalent drinking water supply from the Canal de Rocade. However, in order to be able to liberate more drinking water and to make water exchanges effective, a partnership between the ONEE, the ORMVAH, the ABHT and the RADEEMA should be instituted.

- Reuse of gray water in hotels (WW3): The new water law strengthens the legal framework for waste water recovery and regulates their reuse for irrigation. However, the adaptation of the institutional and regulatory framework and the provision of standards for the internal re-use of gray water are still lacking.

  From a technical point of view, it is necessary to accompany hotel managers in setting up the necessary facilities for the re-use of greywater, and to set up incentives in partnership with the AUM, the Ministry of Tourism and the Marrakech. The re-use of gray water requires separate sanitary facilities for wastewater from toilets and greywater. For this, the option is feasible more easily in new hotels equipped from the beginning with the sanitary facilities required.

- Desalination of seawater by reverse osmosis (DS1): The new water law has established the legal framework for desalination of seawater. However, the regulatory framework for concession contracts with the desalination plant operator is not yet sufficiently established. This option is dependent on the efficiency of the feeding of the towns of El Jadida and Safi from two desalination plants. On the institutional level, the involvement of the councils of the two Casablanca - Settat and Marrakech - Safi regions is necessary to define the institutional arrangements for this exchange of water, the conditions for financing, realization and exploitation.

  The costs of operating and maintaining desalination facilities are considerable, including electricity costs. In this context, the feasibility of an operation of desalination plants with renewable energy (eg wind and solar energy) needs to be studied.

- Network Rehabilitation, Leak Detection and Accompanying Measures (NR1): By reducing the volume of water purchased from ONEE, improving the efficiency of the water system will help to the RADEEMA. However, significant investments in service improvements (extension of WWTP and networks) and pricing constraints make it difficult to self-finance these measures. Grants from the state, the contribution of the municipality and international donors may be requested to finance this option. On a technical level, the introduction of appropriate information and communication technologies (ICTs) such as SCADA systems and geographic information systems is necessary to ensure the efficiency and sustainability of this option. This also requires a strategic approach and vocational training programs.

- Urban landscaping (DM4): The city of Marrakech is a national model for improving the quality of life and the substantial increase in green spaces. The landscaping of the city is important and has allowed to green and beautify the urban space while fighting against the islands of heat. These spaces must remain attractive and in harmony with the image of the city and its tourist attractiveness while limiting their water consumption. To this end, awareness-raising work is needed to involve the various actors involved in the urban space, including civil society.

ANNEX XIII - References

ABHOER, 2017: Assistance technique pour l'intégration et l'évaluation des risques climatiques (ERC) dans la planification et le développement des ressources en eau au niveau du bassin de l'Oum Er Rbia

ABHT, 2010 : Rapport d'ABH du Bassin Hydraulique de Tensift

ABHT, 2014 : Gestion participative des ressources en eau souterraines, contrat de la nappe du Haouz-Mejjate. Communication orale de l'ABH Tensift

Abourida A., 2007: Approche hydrogéologique de la nappe du Haouz (Maroc) par télédétection, isotope, SIG et modélisation. Thèse Université Cadi Ayyad, Marrakech, Maroc AFD, 2012: Agence française de développement; Gestion de la demande en eau : étude de cas du Maroc

Alston J.M., 1986: An analysis of growth of U.S. farmland prices 1963-1982, American Journal of Agric. Economics, 68, 1

Angrill S., R. Farreny, C. M. Gasol, X. Gabarrell, B. Viñolas, A. Josa and J. Rieradevall, 2011: Environmental analysis of rainwater harvesting infrastructures in diffuse and compact urban models of Mediterranean climate, Int. Journal Life Cycle Assessment, DOI 10.1007/s11367-011-0330-6

ANSES, 2016: Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail - Risques sanitaires liés à la recharge artificielle de nappes d'eau souterraine

Arfanuzzaman, Atiq Rahman, 2017: Sustainable water demand management in the face of rapid urbanization and groundwater depletion for social-ecological resilience building, Global Ecology and Conservation 10, 9–22

Bahri, 2012: Integrated Urban Water Management. Stockholm: Global Water Partnership

Belghiti M., 2009: Le plan national d'économie d'eau en irrigation (PNEEI): une réponse au défi de la raréfaction des ressources en eau, Revue HTE N°143/144

Berkamp, G., et al. 2000: *Dams, Ecosystem Functions and Environmental Restoration* Thematic Review II.1 prepared as an input to the World Commission on Dams, Cape Town, www.dams.org

Blumenthal U.J. and Peasey A., 2002: Critical review of epidemiological evidence of the health effects of wastewater and excreta use in agriculture, London School of Hygiene and Tropical Medicine

Boinon et Cavailhes, J., 1988 : "Essai d'explication de la baisse du prix des terres'', dans "La terre, succession et héritage", Études rurales, 110-111-112, Ed. EHESS, Paris, avril-décembre.

Bolaky, B. and C. Freund, 2004: Trade, Regulations, and Growth; World Bank eLibrary http://elibrary.worldbank.org/doi/abs/10.1596/1813-9450-3255

Brears R.C., 2017: Urban Water Security, Wiley & Sons, UK, ISBN: 9781119131724

Caziot P., 1930: « Le capital foncier et les capitaux d'exploitation », Revue d'Économie Politique, XLIV, pp.8-19

CSEC, 2001: Plan directeur pour le développement des ressources en eau du bassin du Tensift, 9e session. Conseil Supérieur de l'Eau et du Climat, Direction de l'Hydraulique, Rabat, Maroc

Daniell, Katherine, Jean-Daniel Rinaudo, Noel, Chan, Celine Nauges and R. Quentin Grafton, 2015: Understanding and Managing Urban Water in Transition

Doukkali R. and C. Lejars, 2015: Energy cost of irrigation policy in Morocco: a social accounting matrix assessment. International Journal of Water Resources Development, Volume 31, 2015 - Issue 3: Special Issue: http://www.tandfonline.com/doi/abs/10.1080/07900627.2015.1036966: Water-Food-Energy-Climate nexus in Global Drylands: the epitome of 21st century development?

Doukkali R. M. and J.G. Grijsen, 2015: Contribution économique de la surexploitation des eaux souterraine au Maroc ; World Bank Working Paper, Rabat, Maroc

ECA et al, 2015: Economic Consulting Associates, Trémolet Consulting Limited, Waman Consulting - Economic Analysis: Reducing Morocco's Urban Water Gap. Final Report commissioned by the World Bank

EPA, 2013: Water audits and water loss control for public water systems; https://www.epa.gov/sites/production/files/2015-04/documents/epa816f13002.pdf

EU, 2013: Sustainable Water Integrated Management - Support Mechanism (SWIM- SM) - Review and analysis of the status of the implementation of strategies and/or action plans for wastewater; National report for Morocco; http://www.swim-sm.eu/files/EXECUTIVE_SUMMARY_MOROCCO_ENGLISH.pdf

Facchini, F., 1997: Politique agricole en France et prix de la terre. « Politique agricole et prix de la terre », Politiques et Management Public, 1997, décembre, vol.15, numéro 4.

Falkenmark M. and G. Lindh, 1976: Water for a Starving World, Westview Press, 1976 - Technology & Engineering

Falter C.M, 2017: Greenhouse Gas Emissions from Lakes & Reservoirs: The Likely Contribution of Hydroelectric Project Reservoirs on the Mid-Columbia River https://www.chelanpud.org/docs/default-source/default-document-library/chelan-pud-mid-columbia-river-hydro-project-greenhouse-gas-emissions.pdf

FAO and WWC, 2015: Towards a water and food secure future. Critical Perspectives for Policy-maker; http://www.fao.org/3/a-i4560e.pdf

García-Valiñas, 2005: Efficiency and equity in natural resources pricing: A proposal for urban water distribution service. Environmental and Resource Economics 32, 183–204

GIZ, 2016: Élaboration de la convention GIRE du Bassin de Haouz-Mejjate, Diagnostic du bassin global

Grijsen J.G., 2011: Sustainability of the Chambal River Water Resources, Chambal - Bhilwara Water Supply Project; report prepared for the World Bank Water Anchor and Water Expert Team

GWI, 2009: Municipal water reuse markets 2010. Oxford, UK: Media Analytics Ltd.

GWI, 2016: Desalination and water reuse, Media Analytics Ltd., Oxford, UK

Global Water Partnership, 2000: La gestion intégrée des ressources en eau, TAC Background Papers # 4

GWP, 2011: Global Water Partnership: http://www.gwp.org/en/GWP-CEE/about/why/what-is-iwrm

Hati H. and K. Kounhi, 2012: Essai d'amélioration du système de distribution d'eau potable à la ville de Marrakech

Hollweg, C. H., D. Lederman, D. Rojas, and E. R. Bulmer, 2014: Sticky Feet: How Labor Market Frictions Shape the Impact of International Trade on Jobs and Wages; Directions in Development; Washington, DC: World Bank.doi:10.1596/978-1-4648-0263-8

IEA, 2012: Water for energy; is energy becoming a thirstier resource? http://www.worldenergyoutlook.org/media/weowebsite/2012/WEO_2012_Water_Excerpt.pdf

ILO, 1998: Migration and population distribution in developing countries: Problems and policies. In: United Nations (Ed.), Population distribution and migration. Proceedings of the United Nations expert group meeting on population distribution and migration, Santa Cruz, Bolivia, January 18–22, 1993

IPCC, 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (Eds.);.Cambridge, UK and New York, NY: Cambridge University Press.

IPCC, 2014: Summary for policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32; http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf

IWMI, undated: Chapter 2, Global Wastewater and Sludge Production, Treatment and Use; http://www.springer.com/cda/content/document/cda_downloaddocument/9789401795449-c1.pdf?SGWID=0-0-45-1493735-p177017059;

JICA, 2008: Étude du Plan de gestion intégrée des ressources en eau dans la plaine du Haouz, Maroc

Khomsi, K., Mahe, G., Tramblay, Y., Sinan, M., and Snoussi, M., 2016: Regional impacts of global change: seasonal trends in extreme rainfall, run-off and temperature in two contrasting regions of Morocco, Nat. Hazards Earth Syst. Sci., 16, 1079-1090, doi:10.5194/nhess-16-1079-2016

Kuper M., Bouarfa S., Errahj M., Faysse N., Hammani A., Hartani T., Marlet S., Zairi A., Bahri A., Debbarh A., Garin P., Jamin J.-Y., Vincent B., 2009: A crop needs more than a drop: towards new praxis in irrigation management in North Africa. Irrigation and Drainage

Kurtze J., M. Morais, E. Platko, H. Thompson, 2015: Advancing Water Management Strategies in Morocco - https://web.wpi.edu/Pubs/E-project/Available/E-project-101615-040211/unrestricted/IQP-Sponsor_Edition.pdf

Lautze, J.; Stander, E.; Drechsel, P.; da Silva, A. K.; Keraita, B. 2014: Global experiences in water reuse. IWMI - CGIAR Research Program on Water, Land and Ecosystems (Resource Recovery and Reuse Series 4): http://www.iwmi.cgiar.org/Publications/wle/rrr/resource_recovery_and_reuse-series_4.pdf

Lazarova V. et Brissaud F., 2007: Intérêt, bénéfices et contraintes de la réutilisation des eaux usées en France ; http://www.ecoumenegolf.org/XEauXLAZAROVA.pdf; N° 299 - L'eau, l'industrie, les nuisances

Luo, T., R. Young, P. Reig, 2015: Aqueduct Projected Water Stress Country Rankings, Washington, D.C.: World Resources Institute; http://www.wri.org/publication/aqueduct-projected-water-stress-country-rankings

Martins R. and A. Fortunato, 2007: Residential water demand under block rates - a Portuguese case study. Water Policy 9, 217–230

Molle, 2017: *Conflicting Policies:* Agricultural Intensification *vs*. Water Conservation in Morocco, Institut de Recherche pour le Développement, UMR-G-Eau

OECD, 2012: Environmental Outlook to 2050: The consequences of Inaction - Key Findings on Water; https://www.oecd.org/env/indicators-modelling-outlooks/49844953.pdf

ONEE-IEA, 2014: Water sector management in Morocco. Pillar of sustainable development; Mahmoud Hafsi - Mediterranean water forum; https://www.holanda.es/media/72108/m.%20hafsi.pdf

ONEMA & BRGM, 2013 : Recharge artificielle des eaux souterraines: État de l'art et perspectives

ONEP/ABHT, 2010 : Mission I, Inventaires des établissements touristiques [...]

ORMVAH, 2011 : Office régional de mise en valeur agricole de la région de Haouz - Gestion des réseaux d'irrigation dans les périmètres du Haouz. Document interne.

Palrecha A., N. Sakhare, S. Patkar, S. Sule, S. Sebas and M. Ramola, 2016: Wastewater Irrigation in Maharashtra, IWMI-Tata Water Policy Program

PNE, 2015 : Plan Nationale d'Eau, Rapport Général, juillet 2015

PNUE/UNEP, 2001 : Dessalement de l'eau de mer dans les pays méditerranéens : Évaluation des impacts sur l'environnement et lignes directrices proposées pour la gestion de la saumure. Plan d'action pour La Méditerranée, UNEP(DEC)/MED - WG.183/Inf.6

Pope C.A., 1985: « Agricultural productive and consumptive use components of rural land values in Texas », American Journal of Agricultural Economics, 1, pp.81-86

Qadir, M., B.R. Sharma, A. Bruggeman, R. Choukr-Allah and F. Karajeh, 2007: Non-conventional Water Resources and Opportunities for Water Augmentation to Achieve Food Security in Water Scarce Countries, Agricultural Water Management 87-1 (2007); http://www.sciencedirect.com/science/article/pii/S0378377406001065

Razoki, B., 2001 : Mise en place d'un système de gestion de base de données pour la gestion des ressources en eaux souterraines de la plaine du Haouz (Meseta occidentale, Maroc). Thèse Université Cadi Ayyad, Marrakech, Maroc

Ricardo D., 1951: The Works and Correspondence of David Ricardo: On the Principles of Political Economy and Taxation; Cambridge University Press.

Salama, Y., Chennaoui, M., Sylla, A., Mountadar, M., Rihani, M., & Assobhei, O., 2014: Review of Wastewater Treatment and Reuse in the Morocco: Aspects and Perspectives. International Journal of Environment and Pollution Research, 2(1), 9-25; http://www.eajournals.org/wp-content/uploads/Review-of-Wastewater-Treatment-and-Reuse-in-the-Morocco-Aspects-and-Perspectives.pdf

Satoa T., M. Qadir, S. Yamamotoe, T. Endoe, Ahmad Zahoor, 2013: Global, regional, and country level need for data on wastewater generation, treatment, and use; Agricultural Water Management 130 (2013) 1–13, Elsevier; http://www.sciencedirect.com/science/article/pii/S0378377413002163

Schultz, B., 2002: Role of Dams in Irrigation, Drainage and Flood Control. Water Res. Development 18(1)

Siegel S., 2015: Let there be water – Israel's solution for a water-starved world, ISBN 9781-250-073952

Sinan M. et al, 2003: Utilisation des SIG pour la caractérisation de la vulnérabilité et de la sensibilité à la pollution des nappes d'eau souterraine. Application à la nappe du Haouz de Marrakech, Maroc, 2nd FIG Conférence Régional, 2-5 décembre, Marrakech, Maroc

Skinner, J. et al, 2009 : Partage des bénéfices issus des grands barrages en Afrique de l'Ouest. Série Ressources Naturelles no. 19. Institut International pour l'Environnement et le Développement

Statzu and Strazzera, 2009: Water demand for residential uses in a Mediterranean region: Econometric analysis and policy implications

Todaro, M., 1997: Urbanization, unemployment and migration in Africa: Theory and policy; Policy Research Division Working Paper No. 104, Population Council, New York

UNDESA, 2015: The 2015 Revision of World Population Prospects, Key findings and Advance Tables https://esa.un.org/unpd/wpp/Publications/Files/Key_Findings_WPP_2015.pdf

UNDP, 2006: Human Development Report 2006 - Beyond scarcity: Power, poverty and the global water crisis; http://hdr.undp.org/sites/default/files/reports/267/hdr06-complete.pdf

UNEP, 2008: Desalination Resource and Guidance Manual for Environmental Impact Assessments. United Nations Environment Program, Regional Office for West Asia, Manama, and World Health Organization, Regional Office for the Eastern Mediterranean, Cairo

UN-Water, 2010: Climate Change Adaptation: The Pivotal Role of Water. Available at: http://www.unwater.org/downloads/unw_ccpol_web.pdf

UN-WATER, 2013: Water security and the Global Water Agenda – a UN Water Analytical Brief www.unwater.org/downloads/watersecurity_analyticalbrief.pdf; definition based on UNESCO's International Hydrological Program's (IHP) Strategic Plan of the Eighth Phase.

UN-Water, 2014: Partnerships for improving water and energy access, efficiency and sustainability; http://www.un.org/waterforlifedecade/water_and_energy_2014/pdf/water_and_energy_2014_final_report.pdf

WHO-UNICEF, 2000: Global Water Supply and Sanitation Assessment, 2000 Report; http://www.who.int/water_sanitation_health/monitoring/jmp2000.pdf

WHO, 2003: State of the art report on health risks in aquifer recharges using reclaimed water; http://apps.who.int/iris/bitstream/10665/83800/1/WHO_SDE_WSH_03.08.pdf; No. WHO/SDE/ WSH/ 03.08, Geneva

WHO, 2006: WHO Guidelines for the safe use of wastewater, excreta and grey water (Volume IV: Excreta and grey water use in agriculture); http://www.susana.org/en/resources/library/details/1004

World Bank, 2004, Seawater and Brackish Water Desalination in the Middle East, North Africa and Central Asia; A Review of Key issues and Experience in Six Countries

World Bank, 2012: Integrated Urban Water Management Case Study: Buenos Aires. Washington, DC

World Bank, 2016a: Mainstreaming Water Resources Management in Urban Projects: Taking an Integrated Urban Water Management Approach; World Bank, Washington, DC https://openknowledge.worldbank.org/handle/10986/24430

World Bank, 2016b: Cost of desalination for domestic water supply in the MENA Region, White Paper

World Bank, 2016c: Évaluation du coût de la dégradation de l'environnement, Pôle de Compétences Mondiales de l'Environnement, Bureau régional Moyen-Orient et Afrique du Nord, Rapport N° 105633-MA Royaume du Maroc