

# THE NORTH-WESTERN SAHARA AQUIFER SYSTEM

JOINT MANAGEMENT OF A TRANSBORDER BASIN

**MAIN RESULTS**

**JUNE 2003**



SAHARA AND SAHEL OBSERVATORY

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## NORTH WESTERN SAHARA AQUIFER SYSTEM

### *Shared management of a cross-border basin*

The North Western Sahara Aquifer System (NWSAS)\*, shared by Algeria, Libya and Tunisia contains considerable reserves of water, that are however little renewable and are not exploitable in totality. During the last thirty years, the drilled wells abstraction passed from 0,6 to 2,5 billions of m<sup>3</sup>/year. This exploitation is confronted today to many risks :waters salinisation, disappear of the artesian flow, outlets drying up, interferences among countries.

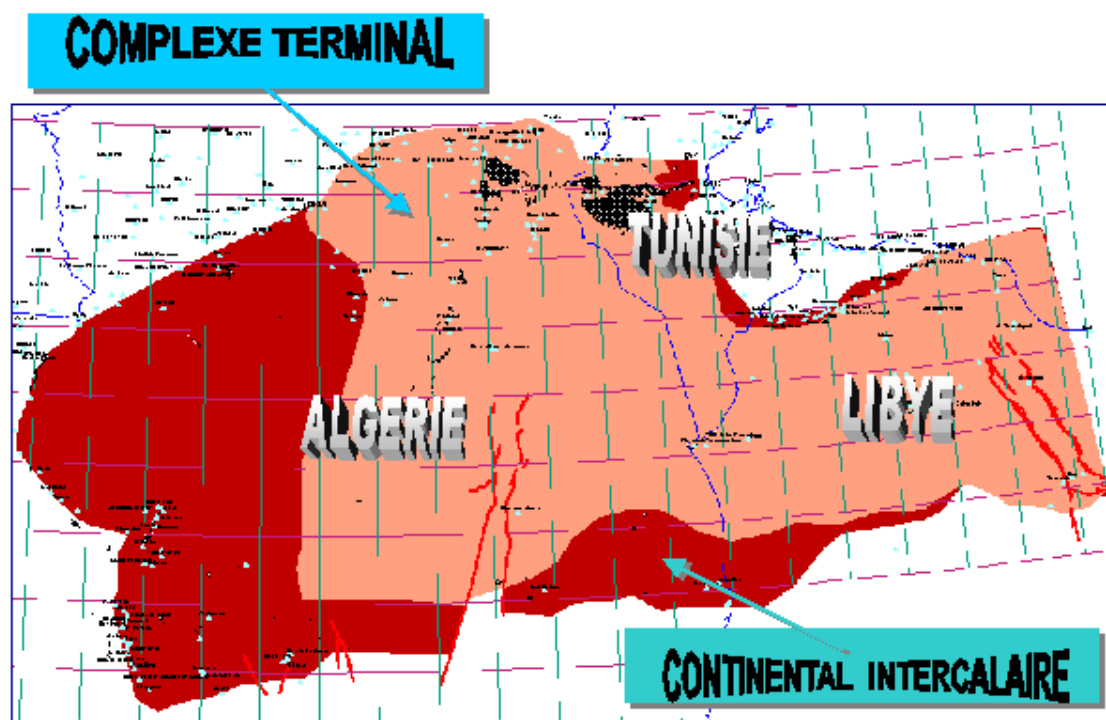
The simulations carried out on the Model have highlighted the areas where shared resources appear to be the most vulnerable. They also permitted to identify new withdrawals zones that permitted to increase the actual exploitation while assuring the mastery of the risks through a reinforced concentration between the three countries.

The present document sets out the principal results obtained through the implementation of the various components of the NWSAS project: Acquisition, Analysis and Synthesis of Hydrogeological Data; Elaboration of the Shared Database and of the Information System; Development and Exploitation of the NWSAS Mathematical Model; and Installation of the Dialogue Mechanism concerning the basin's shared management.

### 1- THE NORTH WESTERN SAHARA AQUIFER SYSTEM PROBLEM

The Sahara Aquifer System points out the superimposition of two principal deep aquifers: a) formation of the Continental Intercalary (CI), the deepest; b) that of the Complex Terminal (CT). This System covers an area of more than one million square kilometers, 700,000 of which is situated in Algeria, almost 80,000 in Tunisia, and 250,000 in Libya.

Fig. 1 : Area of NWSAS formations

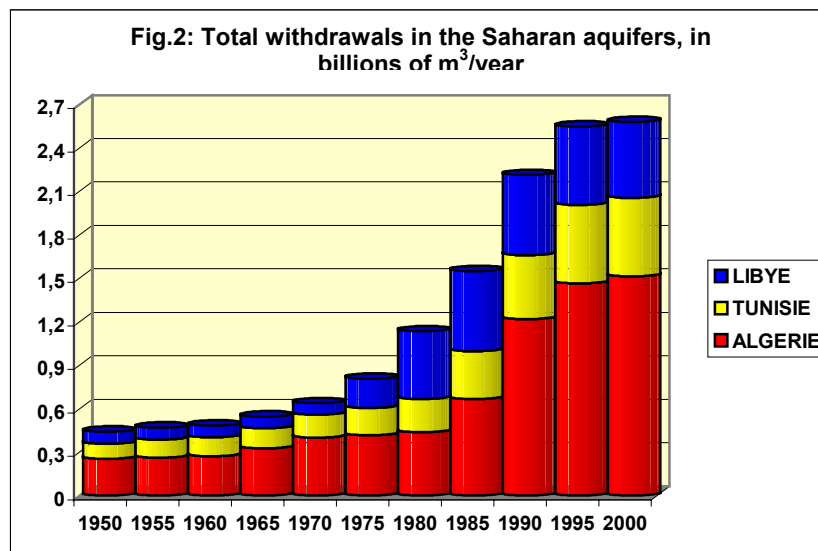


Given the Saharan climate conditions, these formations are only slightly recharged around **one billion m<sup>3</sup>/year** in total, infiltrating mainly into the piedmonts of the Saharan Atlas in Algeria, as well as into the Jebel Dahar in Tunisia and the Djebel Nafusa in Libya. Nevertheless, the expanse of the system and the thickness in aquifers have supported the accumulation of considerable reserves.

Then, how, within the framework of a lasting management, might the Saharan aquifers be exploited, beyond their rate of resupply, drawing from the accumulated reserves?

How might a maximum of withdrawals of water for the best development of the region be secured, without at the same time risking the irreparable deterioration of the state of the resource? It is in these terms that the definition of the exploitable resources of the North Western Sahara Aquifer System lands today.

The Saharan Aquifer System is acknowledged and exploited by almost 8,800 water points, drillings, and sources: 3,500 in the Continental Intercalary and 5,300 in the Complex Terminal. These points are allocated by country, as follows: 6,500 in Algeria, 1,200 in Tunisia, and 1,100 in Libya. The increasing of the drilled wells number and their system of exploitation indicates extremely strong growth during the course of the last 20 years: today, this exploitation reaches 2.2 billion m<sup>3</sup>/year, (in other words, 1.3 billion in Algeria<sup>1</sup>, 0.55 in Tunisia, and 0.33 in Libya). If this development, shared among three countries, were to be prolonged, undoubtedly, there will be serious reasons for concern about the future of the Saharan regions, where one may already note the first signs of deterioration of the state of water resources.



Intense development in the exploitation of NWSAS aquifers has profoundly changed the perspective that one might have going forward concerning this exploitation, one that is confronted by a certain number of **major risks** due to the simple fact of its development: **strong interferences among countries, water salinization, disappearance of artesian flow well drilling, outlets drying up, excessive drawdown in pumping wells**. The three countries concerned with the future of the system, thus, are constrained, in the short term, to come together in finding a certain form of joint management of the Saharan Basin.

The three countries authorities are well aware of these risks, and they have decided to take on a large program of joint studies, of which the supervision and financial research has been entrusted to the OSS. In 1998, with the assistance of the three countries, the OSS obtained support from Swiss cooperation, the FIDA and the FAO for a first phase of three years which continued up until December 2002.

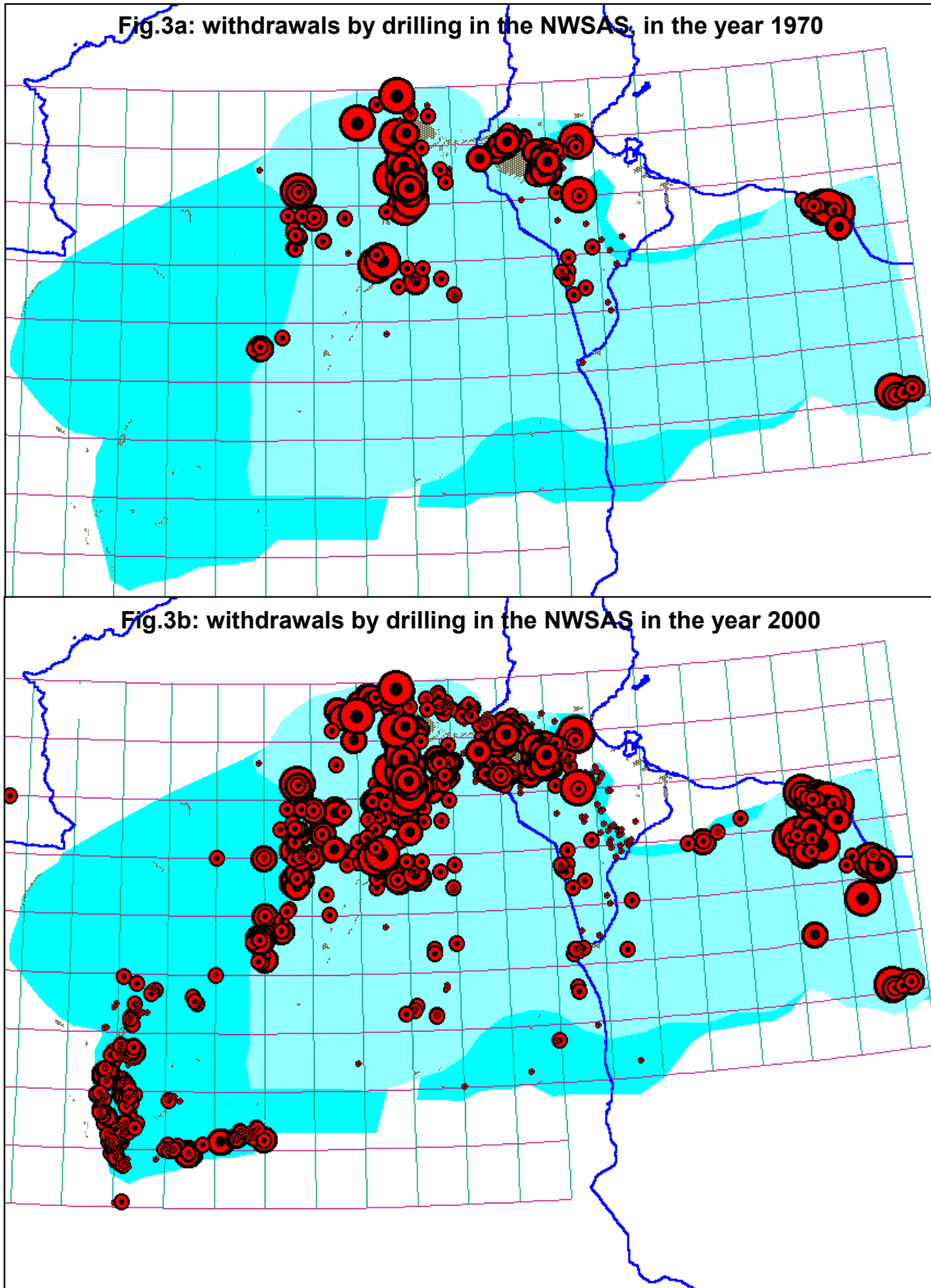
The objectives and activities of the NWSAS project involve several components: hydrogeology, an information system, a mathematical model, and a Consultation mechanism.

<sup>1</sup> Expressed in m<sup>3</sup>/second, the NWSAS withdrawals by drillings in the year 2000, settled at 70.1m<sup>3</sup>/second, allocated, as follows: 42.1m<sup>3</sup>/second in Algeria (21.1 in the CI and 20.9 in the CT); 10.8m<sup>3</sup>/second in Libya (3.4 in the CI and 7.4 in the CT); and 17.2m<sup>3</sup>/second in Tunisia (2.7 in the CI and 14.5 in the CT).

## 2- THE OBTAINED RESULTS

### 2.1- Knowledge of the Aquifer System

The NWSAS project has made it possible to improve geological and hydrogeological knowledge of the basin as a whole, thanks to recent surveys and new hydrogeological prospects, in particular, a historical fifty-year study (1950-2000) of the *piezometry* (the water level coast), water salinity, and its exploitation.



The results of this sharp knowledge of the basin's hydrogeology is a schematization of the aquifers with a view to realizing a mathematical model. The Saharan basin is a large multilayered, sedimentary entity. The adoption of a simultaneous representation of the collective aquifers – aquiferous and semipermeable – makes it possible to account for the hydraulic and chemical connections and exchanges among all of the basin's aquifers and thus, the performance of the system in the medium and long terms.

## 2.2 – The NWSAS Database

The elaboration of the Information System has involved a diagnosis of the existence, the conception, the realization, and the implementation of a shared Database, with the objective of carrying out implementation simultaneously at the project's head offices and with the respective administrative authorities for water within each of the three countries.

The scale of the task is measured by the diversity and the multiplicity of the operations carried out at the 9,000 inventoried water points: collecting, homogenizing the systems for classification and identification, reviewing, detecting faulty data, correcting, and validating.

The information system obtained authorizes the updating and adding of new data, statistical requests, graphs, and links with the Model. This system comprises all of the basic elements to constitute the **instrument panel for the follow-up and the exploitation of basin water**. **A management tool of very good quality for each of the three countries and that is functional within each administration** is now available for use.

## 2.3 – The NWSAS Model

Management with full factual knowledge of the Aquifer System assumes the availability of a mathematical model that allows for the carrying out of simulations and the formulation of predictions. The reference period chosen for the adjustment was the historical period 1950-2000, with the situation assessed in 1950, as an initial condition.

### The Exploratory Simulations:

A reference pattern, named a scenario zero was defined. It consists in holding constant the withdrawals from drilled wells carried out in the year 2000, and calculating the system's corresponding evolution to the year 2050.

Many patterns are defined

- **In Algeria**, two patterns :
  - A so called "**strong**" representing an additional withdrawal of **101 m<sup>3</sup>/s**, which would carry Algerian withdrawals from 42 to 143 m<sup>3</sup>/s between the year 2000 and the year 2030 ;
  - A so-called "**weak**" assumption for an additional withdrawals of **62 m<sup>3</sup>/s**, which would carry the withdrawals from 42 to 104 m<sup>3</sup>/s.
- **In Tunisia** : the contemplated pattern anticipates that the savings realized from improvement in the efficiency of irrigation will compensate for the additional demand of the new irrigated perimeters, which corresponds to the maintenance of the present withdrawals.
- **In Libya** : the exploratory simulations concern two programmes of the Great Manmade River Project (GMRP): the pumping field of Ghadames-Derj, with an additional flow of 90 km<sup>3</sup> /year, and the collecting field of Djebel Hassaounah.

### Results of the Exploratory Simulations :

#### Scenario Zero :

**for the CI**: the scenario zero will involve important drawdowns more than 40 meters within the Algerian Sahara lower part; in Tunisia, they are approximately 20 to 40 meters around the Chott Fedjej; in Libya, the drawdowns back are approximately 25 meters.

**for the CT:** in Algeria and in Tunisia, the drawdowns exceed 30 meters around the chotts; in Libya they reach 60 meters. The disappearance of all artesian flow in the Algerian-Tunisian chotts region, with the risk of waters intrusion from the chotts recharge into the CT's aquifer and probable salt contamination, is notable. *From this perspective, the continuation of the current rhythm constitutes a major potential danger within the region.*

**Scenario « Strong hypothesis » :**

With respect to the CI, the drawdowns are 300 to 400 meters within the Algerian Sahara lower part, with the complete disappearance of artesian flow; Libya has not been affected by this pattern; with respect to Tunisia, the drawdowns are from 200 to 300 meters and the disappearance of artesian wells and the Tunisian outlet are notable. Concerning the CT, there is no effect in Libya, there are no important drawdown in Algeria, and the chotts are in the position of resupply.

**Scenario « weak hypothesis » :**

In Algeria, as well as in Tunisia, the effects are very strong and quite unacceptable with respect to the CI, as well as the CT.

**Libyan scenarios of the GMRP :**

In Ghadames, the drawdowns in the CI are 100 meters to the collecting field, around 50 meters within the deep southern region of Tunisia and in Deb Deb, Algeria. As for the collecting field of the jebel Hassaounah, its impact on the CI remains negligible.

**These exploratory simulations have highlighted the harmful effects and the risks to which water resources in this basin are exposed.** Continued exploitation of the CI and CT aquifers will require the minimizing and management of these risks, which may be summarized, as follows:

- a) *the disappearance of artesian flow*
- b) *excessive drawdowns in pumped wells*
- c) *the drying up of Tunisian outlet*
- d) *excessive interferences of drawdowns among countries*
- e) *potential re-supply by the Chotts.*

**Research of New Patterns:**

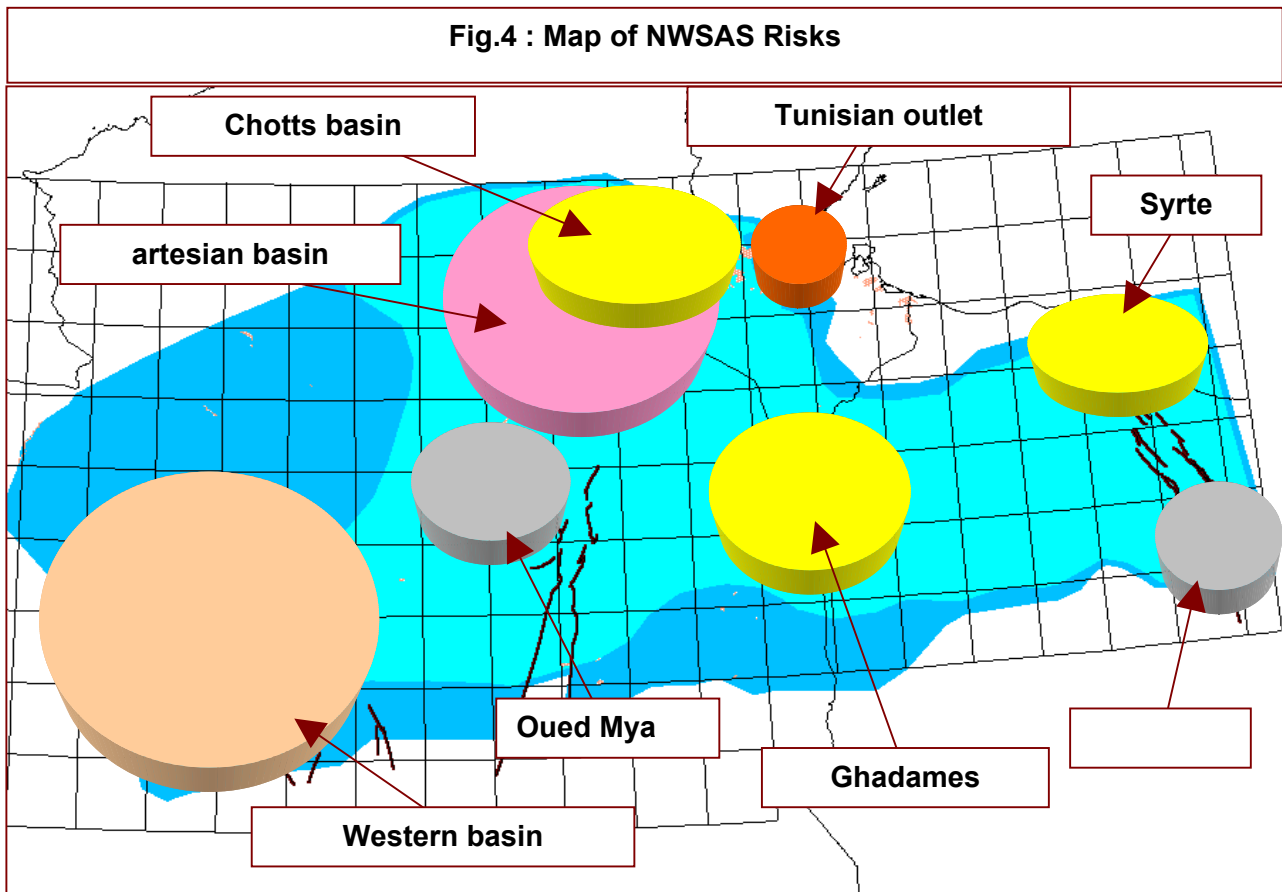
At the completion of the exploratory simulations, the adopted principle has been to dismiss the research of development patterns based solely upon predictions of the demand for water and to seek ***the building of patterns having a hydraulic basis, founded upon NWSAS output capacities and minimizing the identified risks of harmful effects***, at the sites as close as possible to the places where present or future demand might be expressed, without refraining from the prospecting of favorable sectors that would be distant but could prove to be favorable for exportation. The first stage for such a process has consisted in making inventory of all the potential sites for pumping. The NWSAS Digital Model, which is committed to such a function, has been used to simulate the newly identified patterns.

**Control of the Risks and Durable Management of the NWSAS:**

The simulations concerning the future and that have been carried out on the NWSAS Model have highlighted **the most vulnerable regions:**

- a) With respect to the **Artesian Basin** of the CI aquifer, the anticipated additional drawdowns will exceed 100 meters; verification is easy there: deep drillings and very few in number.
- b) The flow, present and future, of the CI's **Tunisian Outlet** is of great importance, as it contributes to the supply of the Djefara coastal aquifer which itself has been heavily exploited. Now, this flow from the Tunisian outlet will have to be decreased, even if the withdrawals at their current level must be blocked.





- c) In the CI aquifer, the **Ghadames Basin** presents risks of excessive, drawdowns of approximately 200 meters; however, these risks occur in the medium term, and from a technical standpoint, their controlling is easy.
- d) The sector most exposed is the Algerian-Tunisian **chotts basin** in the CT. This is the region where this aquifers most vulnerable. It is there where the strongest density in population can be found, where the pressure on resources will be the strongest. The calculations made on the Model have clearly shown that the simple continuation of the present rates of withdrawals, by the year 2050, would bring about additional drawdowns of approximately 30 to 50 meters on each of the two aquifers, with respect to all of the four interdependent sectors – the Oued Rhir, the Souf, the Djerid, and the Nefzaoua. Such a situation would be unacceptable for the Complex Terminal: the risk of the chott's water percolation toward the layer would be inevitable for the latter in terms of salinity. The simple continuation of the existing rates, at least within the CT, thus, would be completely unacceptable for the Chotts region. There, the reduction of withdrawals must be seriously contemplated as a plausible pattern and preparation for the same must be made going forward.
- e) On the **Khoms/Zliten** coast, if the simulated pattern of filling shortages satisfies the need had to be carried out, the risk of sea invasion by the year 2050 would be seriously harmful to the Complex Terminal.
- f) At Ferjan, in the CT aquifer, additional drawdowns are anticipated to exceed 50 meters.
- g) Moreover, one of the results of the investigations performed has allowed for checking as to the possibility of bringing the level of exploitation through drilling of the NWSAS up to **7.8 billion m<sup>3</sup>/year by the year 2050**. The reaching of such a

level of development can be done only at the cost of dispersing new fields of exploitation: 80% of the additional withdrawals will have to be done within distant areas: the CI's **Western Basin** and the CT's **Oued Mya** in Algeria. This will provide a total exploitation, by country, of **6.1 billion m<sup>3</sup>/year in Algeria**, **0.72 billion m<sup>3</sup>/year in Tunisia**, and **0.95 billion m<sup>3</sup>/year in Libya**.

This possibility would cause exploitation of the NWSAS to climb to a level equivalent to eight times its renewable resources. Such an operation is realizable only by considerable drawing upon the system's reserves. Nonetheless, the necessity of confirming the results obtained must be stressed: in spite of the progress realized by the NWSAS project, uncertainties remain as to knowledge of the system, which uncertainties will require the undergoing of new investigations.

The combined exercise of hydrogeological knowledge and the model makes it possible to reach realistic conclusions as to the capacities of the NWSAS to supply appreciable quantities of water while minimizing risks concerning the resource. The results obtained show that it is advisable to manage this resource **jointly**. The intention of planning this joint use has been advocated by the OSS since the launching of the project: to promote a **basin consciousness** and to implement a "**dialogue mechanism**."

### **3- CONSULTATION MECHANISM**

The simulations carried out on the Model have highlighted the areas where shared resources appear to be the most vulnerable. Among Algeria, Tunisia and Libya, the Complex Terminal today, and the Continental Intercalary tomorrow, are in a state of exploitation such that undoubtedly, it will be necessary one day in the future to consider collectively controlling, if not reducing, the flows from pumpings. How can these flows be controlled within the framework of the States's will to mutually contribute toward the guaranteeing of the region's future, notably, by way of a concerted policy for safeguarding the water resources?

#### **Sharing Information – An Exercise in Solidarity That Is Impossible to Circumvent:**

Among the reasons for encouraging dialogue, the management of crises and especially, the risk of deteriorating the resource as a consequence of overexploitation, is a major one. Moreover, the practice of partnership throughout the NWSAS project has progressively forged a mutual confidence among the technical teams, the conviction that common action increases the effectiveness of solutions, and the certainty that information exchange, which forms the foundation of all solidarity, at the NWSAS project's end, has become an activity that is not only possible but necessary.

As such, the OSS, through the NWSAS project, has henceforth allowed for considerable projections: the elaborate Database, containing all present and historical information on all water points, their levels, and their flows, is operational and accessible to the three countries. In this respect, the goodwill of the three water authorities in the communication of information has been exemplary.

Moreover, the NWSAS Model is henceforth available and operation within each of the three countries. An effective form of dialogue might first consist of guaranteeing the maintenance, the development and the permanent updating of two tools – the Database and the Simulation Model.

#### **From the NWSAS Study to the Mechanism Project:**

The three countries favor the creation of a permanent tripartite mechanism for dialogue at the NWSAS level. The starting point is the requirement of maintaining and developing the shared NWSAS database, as well as all other systems for the regular exchange of data and information. The data exchange must then serve as a basis for the formulation of common policies and strategies.

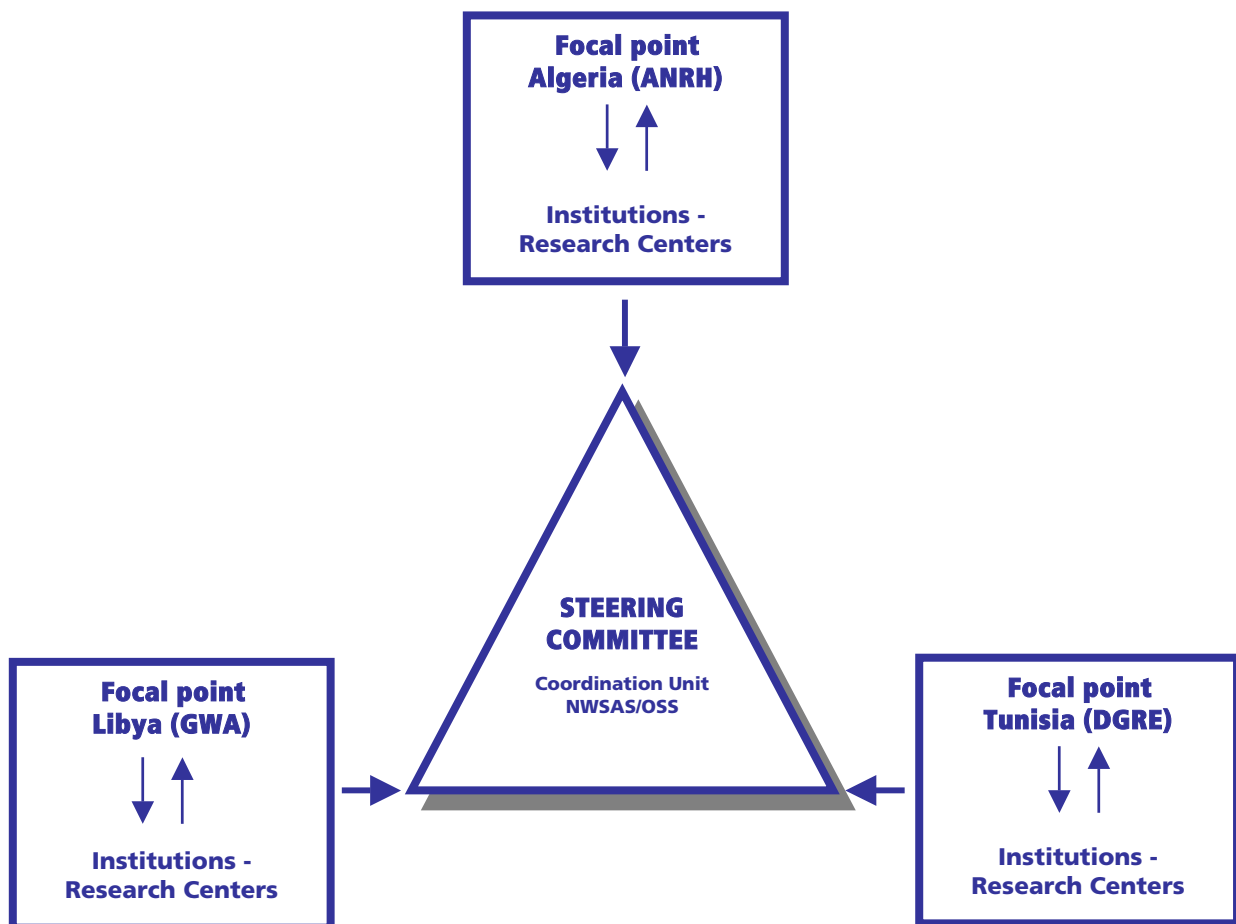
Preparation of the mechanism was elaborated during the course of three national workshops held in Tripoli, Tunis and Algiers, respectively, in November 2002. From these three

workshops came a certain number of points of convergence and consensus bearing on the following:

- a) the necessary continuation of the NWSAS project's work, bearing on improving knowledge of the system and of its exploitation
- b) the setting up of a mechanism for dialogue and its institutional anchoring in its first phase within an international organization – the OSS
- c) the progressive and evolutionary nature of the Mechanism, of a lean and efficient structure, toward an elaborate body equipped with more considerable attributions at full term

These options were approved during the Regional Workshop on synthesis which took place at the FAO's head offices, Rome, Italy, in December 2002, and they have been officially confirmed by the three countries to the OSS.

**Fig.5: Sketch of the first step of Consultation mechanism**



### Characteristic of the Consultation Mechanism

*The Objective* is the coordination of a concerted management of the NWSAS water resources.

*The structure of the Consultation Mechanism is composed of the following:*

- **a Steering committee** composed of the national structures in charge of water resources, serving as national focal points
- **a coordination unit** managed by and housed under the OSS
- **an ad hoc scientific committee** for scientific evaluation and orientation

*The Main Attributions are the following:*

- the management of tools developed by the “NWSAS” project
- the setting up of and following up on observation networks
- the analysis and the validation of data concerning the resource
- the development of databases on the socio-economic activities and the uses of water
- the production and publication of indicators concerning the resource and its uses
- the promotion and carrying out of studies and research conducted in partnership
- the development and implementation of training and improvement programmes
- the updating of the NWSAS model
- reflections on the mechanism’s evolution

#### **4- CONCLUSIONS : DURABLE MANAGEMENT OF THE NWSAS**

Constraints are exercised upon the aquifers making up the North Western Sahara Aquifer System (the “NWSAS”) that limit the ability to exploit their potential. These constraints, of course, have an economic character, but the environmental risks today cause the constraints to be most overriding. The problem is complicated by the existence of three countries sharing the same resource, but not necessarily, *a priori*, the same outlook as to the future of the Saharan aquifers.

Thanks to thorough knowledge of the hydrology of the region, together with the constitution of a shared database, the elaboration of a mathematical model and at full term, the carrying out of simulations, the results of the project show the following:

- the simple continuation of the present tempos of withdrawals can constitute a serious danger for the Complex Terminal’s layer within the chotts region
- outside of the chotts region, the Tunisian outlet and the Syrte gulf, slight increases in the tempos of exploitation can still be endured without serious damage
- simulations based upon strong assumptions lead to an unacceptable situation
- appreciable increasing of the present withdrawals is possible, however, it is at the cost of dispersing additional pumping fields to distant areas: the Western Great Erg and the confines of the Eastern Erg
- in spite of the efforts made through the project, uncertainties remain concerning knowledge of the system, as well as defining the options for development, which will require the undergoing of new investigations

In conclusion, this initial, first phase presents a rather optimistic outlook concerning the exploitation of water within the Northern Sahara, if by any chance one takes into consideration the collaborative manner of the observations and results emanating from the model and one takes into account from now on, all of the risk factors highlighted by the NWSAS study within the framework of the OSS.

Insofar as ignorance of the effects allows for behavior and shared information reinforces solidarity, one may conceive the NWSAS Model as a powerful teaching tool and an instrument of dialogue and objective mediation around which dialogue can be organized.



# NORTH WESTERN SAHARA AQUIFER SYSTEM

JOINT MANAGEMENT OF A TRANSBORDER BASIN

## MAIN RESULTS

Serving as a driving and facilitating force, OSS, in carrying out the SASS Programme, relies first and foremost on the expertise available in specialised, well experienced institutions of the three countries as well as on broad international partnership.

The North-Western Sahara Aquifer System, (NWSAS), shared by Algeria, Tunisia and Libya, has considerable water reserves that cannot be totally exploited and are only very partially renewed. The NWSAS stretches over a million km<sup>2</sup> and is composed of two major water-bearing layers, the Continental Intercalary and the Terminal Complex. Over the last thirty years, abstraction by drilling has risen from 0.6 to 2.5 billion m<sup>3</sup>/yr. This rate of abstraction involves many risks: strong impact on neighbouring countries, salinisation, elimination of artesianism, drying up of outlets, etc. Simulations on the NWSAS Model have enabled OSS to pinpoint the location of the most vulnerable areas and map the risks facing the aquifer system. The three countries concerned by the future of the NWSAS will need to work together to develop a joint management system for the basin. A consultation mechanism needs to be instituted and gradually put into operation.

The present document sets out the principal results obtained through the implementation of the various components of the NWSAS project: Acquisition, Analysis and Synthesis of Hydrogeological Data; Elaboration of the Shared Database and of the Information System; Development and Exploitation of the NWSAS Mathematical Model; and Installation of the Dialogue Mechanism concerning the basin's shared management.

## PARTNERES



Agence Nationale des Ressources Hydrauliques  
(ANRH, Algeria)



Direction Générale des Ressources en Eau  
(DGRE, Tunisie)



General Water Authority  
(GWA, Libya)



Fonds International de  
Développement Agricole



Département du Développement  
et de la Coopération Suisse



UNESCO



Organisation des Nations-unies  
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Allemagne (GTZ)



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