6th International Conference on Water Resources and Arid Environments (ICWRAE 6): 428-436
16-17 December, 2014, Riyadh, Saudi Arabia

GIS and Database for a Groundwater Assessment and Management of the Rmel-Oulad-Ogbane Aquifers (Larache, Morocco)

[1]Mohamed Jalal El Hamidi, [1]Abdelkader Larabi, [1]Mohamed Faouzi and [2]Rachid Essafi

[1]Regional Water Center of Maghreb, LIMEN, Mohammadia School of Engineers, Rabat, Morocco
[2]Direction of the Research and the Planning of water (DRPE),
Delegate Ministry of Water, Rabat, Morocco

Abstract: The majority of urban and rural centers of Morocco are generally located on the coast and the coastal plains. The increase in water demand, due to demographic and agricultural development, is accompanied by pressure on groundwater abstraction. This situation causes significant drops of the groundwater level and may eventually cause a deficit water balance of the aquifer as well as a degradation of the freshwater quality by seawater intrusion; and consequently concern the decision makers responsible for the management and planning of water resources. The study area of Rmel-Ouled Ogbane aquifers, with a surface of approximately 303 km^2, is located in Low-Loukkos basin in northern Morocco (south of Larache city). This area is delimited to the west by the Atlantic Ocean, to the east by succession of hills of prerifan aquifer and to the south by marl outcrops from Mio-Pliocene. The analysis of data from different sources and provided on different media, have been processed and organized in a common database with spatial referenced coordinates. A Visual BASIC application has been developed for a better use of this database on GIS (Geographical Information System). Hence, several thematic maps of reservoirs and water resources have been produced to be used by the decision maker. These products of GIS database allowed, updating the water balance and constructing the conceptual model of these aquifers. This database will also be used to support a set of groundwater simulations based on Visual MODFLOW code; and to develop a mathematical model in steady state and transient flow, pollutant transport and seawater intrusion in these aquifers. These models also associated with GIS database will help to better plan, manage and control the groundwater resources of this aquifer system.

Key words: Database · Visual BASIC application · GIS · Rmel and Oulad Ogbane · Aquifers

INTRODUCTION

The study area of Rmel-Ouled Ogbane aquifers, with a surface of approximately 303 km^2, is located in Low-Loukkos basin in northern Morocco (south of Larache city). This area is delimited to the west by the Atlantic Ocean, to the east by succession of hills of prerifan aquifer and to the south by marl outcrops from Mio-Pliocene.

To achieve the aim of developing a GIS database for a groundwater management model of the Rmel-Oulad Ogbane aquifers, it is necessary to collect available data on reservoir and water resources and complete them by other data and information through additional fieldwork and visits to various regional organizations (Hydraulic Basin Agency of Loukkos (ABHL), Direction of the Research and the Planning of water (DRPE), Regional Office of Agricultural Development of Loukkos (ORMVAL), National Office of Drinking Water of Tanger and Kenitra towns (ONEP), Mohammadia School of Engineers (EMI)).

After consulting reports and data sheets (Water Resources Index /IRE) related to the studied area, it was found that the majority of them are presented on hard copy and display disadvantages and difficulties for exploitation, especially for this study and future studies. In addition, these documents remain largely inaccessible, fragmented and unorganized and need update to ensure control, monitoring and management. Furthermore, the intersection of information resulting from different origins

Corresponding Author: Mohamed Jalal El Hamidi, Regional Water Center of Maghreb, LIMEN, Mohammadia School of Engineers, Rabat, Morocco.

is often difficult when it comes to develop thematic maps and especially when the scales are different. Currently, these databases and the Geographic Information Systems (GIS) facilitate more the studied tasks by offering the opportunity to acquire, store, organize, manage, analyze, process, update the spatial data and better represent them in digital format and in synthetic thematic maps, graphs and diagrams (elements of decision for water planning and managing).

Since then, for the needs of this study, the development of a database in GIS is a necessity to better represent the conceptual model and prepare the input data. At the same time, the model results (output data) can also be exploited and better represented in this GIS interface.

MATERALS AND METHODS

The development of a GIS database of the Rmel-Oulad Ogbane aquifers is performed in several steps:

Data Acquisition: Data acquisition is the most expensive step in the establishment of the database. It consists on collecting various aspects of data related to water resources of the studied area and integrating them into the geographic database. Thus, the data, around which revolves this database, were collected from various local and regional organizations (ABHL, DRPE, ORMVAL, ONEP-Tanger-Kenitra, EMI) and generally in hard copy (reports, data sheets, listings, tables, maps, sections). The integration of these data was performed by the input alphanumeric data, scanning maps, profiles and sections and digitizing spatial entities with which were attached their attributes and descriptive semantic data.

Spatial Reference Coordinate System: The integration of all the data collected within a geographic information model, their display, their superposition and their crossing requires a strict prior harmonization of the spatial coordinate system. All the data with a geographical character (vector objects, pictures or raster data grid) must be represented in the same spatial geographical coordinate system or projected system.

It must be highlighted that some maps and geo-location data of many collected water points were originally defined in the American coordinates system. It was therefore necessary to transform them, via specific software, to represent them in the Moroccan projection system.

The cartographic spatial coordinate system chosen for the transformation of the geographical coordinates and the integration of geographic data with respect to the studied area corresponds to '*MAROC Lambert Conformal Conic - Zone 1*' whose parameters are as follows:

MOROCCO CCL ZONE 1	
Projection	Lambert_Conformal_Conic
False_Easting	500000
False_Northing	300000
Central_Meridian	-5.4
Scale_Factor	1
Latitude_Of_Origin	33.3
Linear Unit	Meter
GCS_Merchich_Degree	
Datum	Merchich

Format of data Management: The ArcCatalog application of the ArcGIS tool lets us design databases, manage inventory of spatial data, create geo-databases, identify and organize geographic data, display and update metadata. Data format supported in the design of our GIS database of the Rmel - Oulad Ogbane aquifers are as follows:

- Vector spatial data in 'Shapefile' format (*. shp and associated files)
- Quantitative and qualitative tabular data, organized in Excel file, relative to geographic entities whose location is defined by their spatial coordinates ;
- Raster spatial data in picture format;
- Raster spatial data in data grid format (*.Grid);
- Personal GeoDataBase (PGDB) in *.mdb format which is a spatial and relational database, containing the geographic objects in a single file (points, arcs, polygons and raster) and all tabular informations associated with them.

The Geo-database established is called "Geodatabase _ Database". It includes vector objects classified according to their thematic, raster catalog and the data grids and tiles (TIN) intended for continuous data representation. In detail, the vector objects of Geo-database represent a series of *feature datasets* that include blankets of the related entities. The different *feature classes* describe the various aspects and sub-themes related to water resources in the studied area (Fig. 1).

Development of a GIS Extension: This section is the results from the development of the database to produce decisional thematic maps, providing more information layers to managers on water resources.

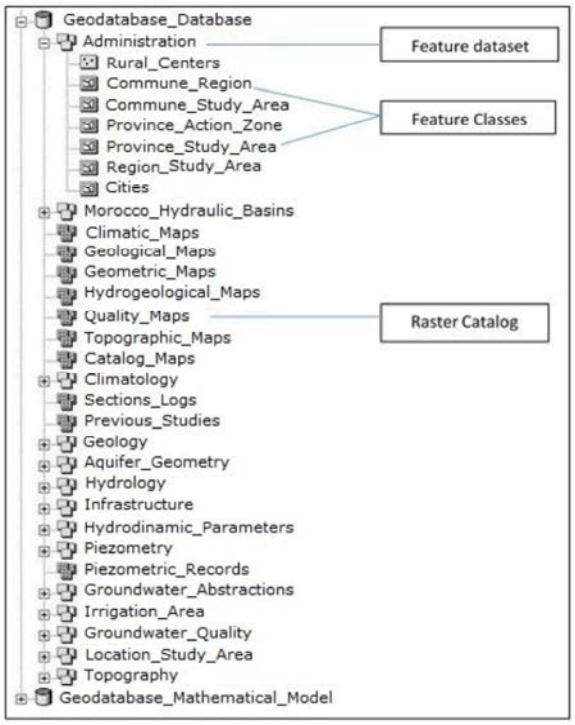

Fig. 1: Structure of the Geodatabase.

According to previous studies [1, 2], the Visual Basic scripts was chosen to develop the extension in ArcGIS. In this case, we opted for the development of a Visual Basic extension using tutorials [3, 4] to characterize the using this database in GIS.

Hence, we proceeded to implement an extension that manages, extracts and overlays the information layers and blankets incorporated into the developed database. The obtained thematic layers were organized according to the needs of managers and decision makers in menus and sub-menus. This action facilitates consultation, customization and duplication of informations in relation to the various aspects of water resources.

Presentation of MONAROO: This extension has been developed in the Visual Basic environment and is named MONAROO (MOdélisation de la NAppe Rmel & O. Ogbane). It includes customized scripts under the ArcMap interface, as integrated menus in the toolbar of the map database "DB_MONAROO.mxd". These menus customized as control buttons offer a range of additional features simple to handle and quick to execute. They allow users of different levels to consult, display and update thematic maps. The main steps for implementing the extension are summarized in Fig. 2.

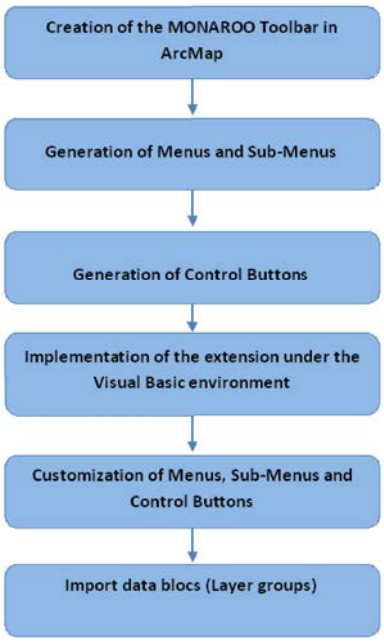

Fig. 2: Development steps of the MONAROO extension.

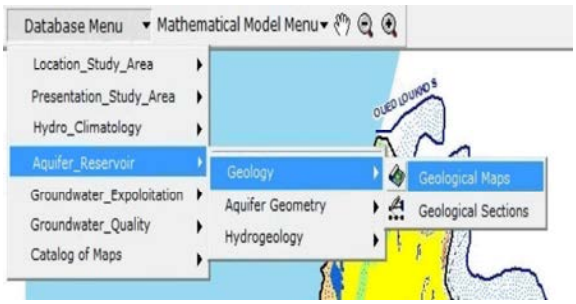

Fig. 3: Display of the 'MONAROO Toolbar'

Description of Monaroo Toolbar: Under ArcMap, the 'Toolbar MONAROO' appears on the screen display (View) of the project "DB_MONAROO.mxd". This bar has been customized according to an easy to use interface, in order to facilitate the display, consultation and exploitation of information layers grouped by theme. Indeed, the developed interface consists of a series of components (Menu Bar, Menus, Sub-menus and Control buttons) structured to reflect the different information blocs and thematics related to the characterization and exploitation of water resources of the Rmel-O. Ogbane aquifer. The developed interface contains as well the input\output data of the mathematical model of seawater intrusion in these aquifers.

In general, the 'MONAROO Toolbar' contains two menus: ' Database Menu' and 'Mathematical Model Menu', each of which includes menus, sub-menus and control buttons as shown in Figure 3.

RESULTS AND DISCUSSION

Exploitation of MONAROO Database: In this section, we present some examples of thematic maps that summarize and synthesize the updated knowledge on the geology of the studied area. It informs as well on the hydrodynamics and functioning in space and time of the Rmel-O. Ogbane aquifers and the quality of its water. These maps, derived from various data treatments, are available to managers and to the different actors in the field of water resources of the Rmel-O. Ogbane area. They facilitate the decision-making on integrated management and implementation of the protection and monitoring policies.

These maps can be viewed via the *'Database Menu'* from the *'MONAROO Toolbar'* project "DB_MONAROO.mxd" (Fig. 4, 5, 6 and 7).

Hydrogeology: The *'Sub-Menu: Hydrogeology'* in *'Menu: Reservoir Aquifer'* includes maps and data which allow to understand the spatio-temporal functioning of the Rmel-O. Ogbane aquifers. It contains the hydrodynamic parameters maps of the aquifer, the piezometric maps, the piezometric records and groundwater level.

For the groundwater piezometry, it is viewable under the *'Class: Piezometry'* through three types of control buttons: piezometric network, piezometric maps and piezometric records (Fig. 8).

The assembled data of the piezometric maps integrated to our database allow analyzing the piezometric situation at different periods. It gives as well a choice between different piezometric states dating from 1961/1962 to the present: 1961-1962 [7], 1972 [8], 1985 [9] 1992 [10], 1999 [11], 2000 [12].

For instance, Fig. 9 illustrates the situation of the piezometric surface of the groundwater, in average low water of 1961-1962. The examination of this piezometric map shows that the general flow of the groundwater is carried out from south-west to north-est (towards the Loukkos River), with an estimated hydraulic gradient of 3 to $7x10^{-3}$ at the central area of Rmel and at the alluvial area boundary to the East. This gradient is quite large ($1.5x10^{-2}$) in the South-west of Oulad Ogbane, where the groundwater flows through the silty and marly pebbles. In the Western area (coastal area), the groundwater flow becomes East-West (towards the ocean) with a hydraulic gradient of $4.5x10^{-3}$.

Two domes of the groundwater are observed, one in the North and North-East (between Sakh-Sokh and Smid El Ma Wadis). Along the wadis and embankments (eastern edge), the groundwater is constantly drained; demonstrated by the presence of springs and swamps known locally as the Merjas.

At South-West of the Rmel area, the rising of the impermeable Mio-Pliocene bedrock to form a shoal come out as a groundwater divide line of groundwater. This marly bedrock outcrops along the western boundary of Oulad Ogbane. The superposition of the piezometric map of the average low-water of 1961-1962 [5] and a relatively recent (1997) geological map (1/50.000) [6] and [7] allowed correcting the imperfections of the piezometric line at the outcrop areas of marls in the South-East of the study area (Fig. 10).

Water Balance: The development of GIS database was used to calculate, evaluate and estimate a water balance of the Rmel-O. Ogbane in 1963 (Table 1 & 2); based on, the global and detailed inventory of all pumping points (wells, boreholes and springs), weather data relatively accurate that we have on the study area and calculate lateral flow estimated in 1963.

Organization of the Different Information Layers: Organize the different information and overlay them in the form of thematic maps and bloc layers (Fig. 11) allowed us to develop a conceptual model of the Rmel-O. Ogbane aquifers. This model is a platform for developing a mathematical model of the variable density flow and of the seawater intrusion in the study area. In general, the information layers containing spatial entities to which are associated attribute data, quantitative/ qualitative data and spatio-temporal data, include various aspects of the aquifer and water resources in the Rmel-O. Ogbane area.

Further Work: In summary, this work consisted of:

- Development of the Rmel-O. Ogbane Database,
- Implementation of the MONAROO extension,
- Customizing a ' *MONAROO Toolbar* ' with *'Database Menu'*

Based on the results of this database, future work will involve the development of a conceptual model of the aquifer, a hydrodynamic model in steady and transient state andq finally a seawater intrusion model of the Rmel-O. Ogbane aquifers. The simulation results will be integrated progressively into the database and the data / thematic maps will be consulted and viewed through the *'Mathematical Model Menu'* of the *'Toolbar MONAROO'*, already prepared in advance.

Table 1: Estimated water balance of Rmel aquifer in 1963.

Input	Q (l/s)	Output	Q (l/s)
-rain infiltration	1660.5	Pumping	
-Return of irrigation	68.4	-Drinking water for Larache	0
		-Groundwater pumping for irrigation	285.4
		Natural Flow	584.2
		-To ocean	86
		-To alluvial aquifer	4,3
		-To O. Ogbane aquifer	
		-Rivers, springs and swamp	769
Total	1729	Total	1729

Table 2: Estimated water balance of Oulad Ogbane aquifer in 1963.

Input	Q (l/s)	Output	Q (l/s)
-rain infiltration	227	Pumping	0
		-Rural drinking water	0
		-Groundwater pumping for irrigation	157
		Natural Flow	70
		-Drainage by rivers	
		-To alluvial aquifer	
Total	227	Total	227

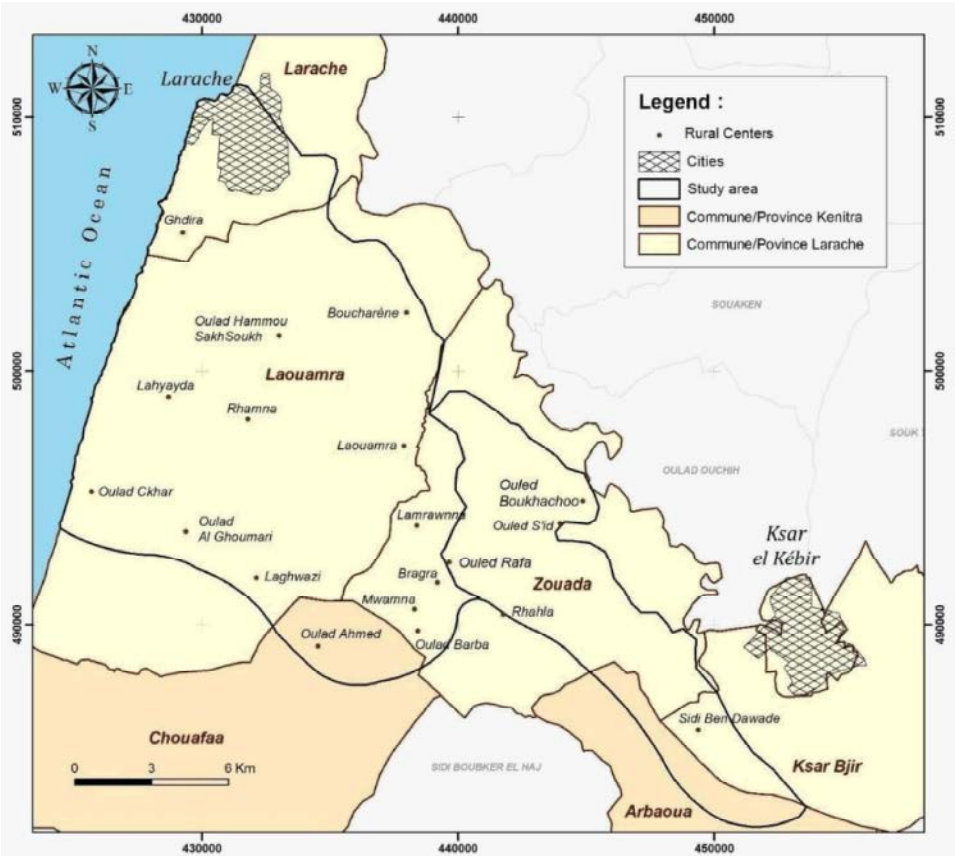

Fig. 4: Administrative map of the study area.

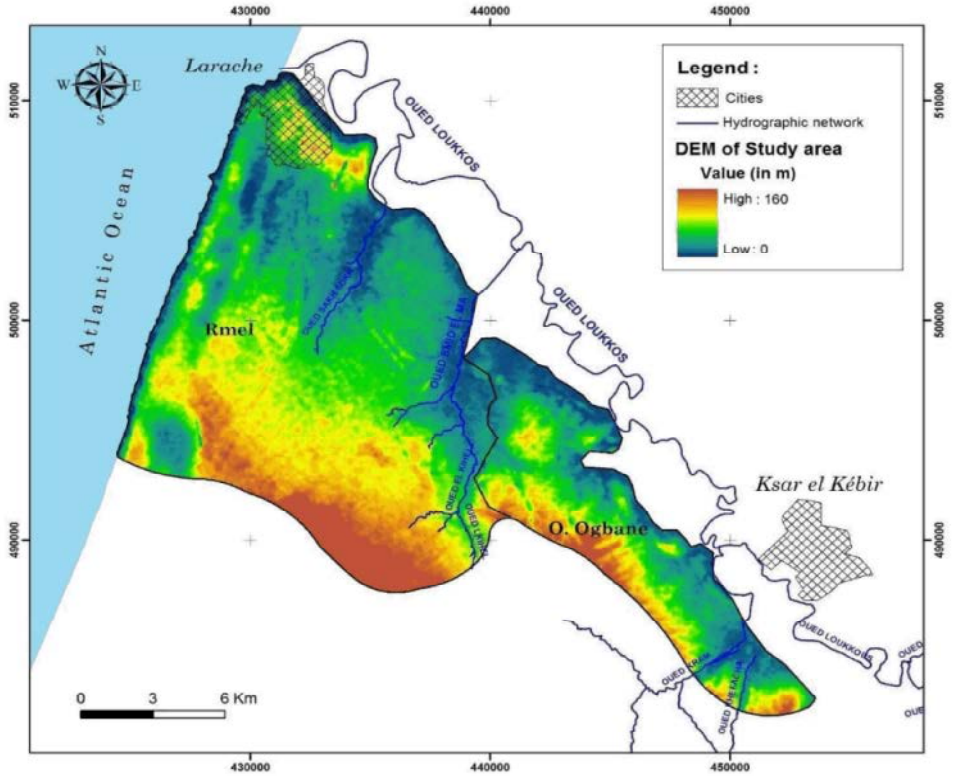

Fig. 5: Digital Elevation Model (DEM) of the study area.

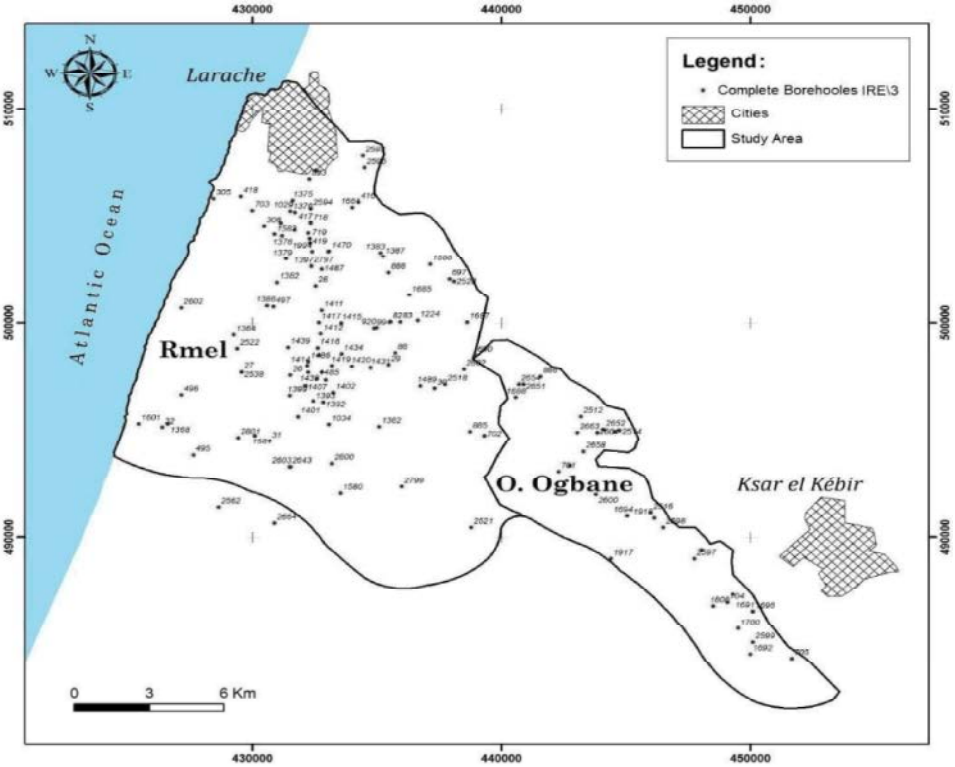

Fig. 6: Distribution map of the complete boreholes of the study area.

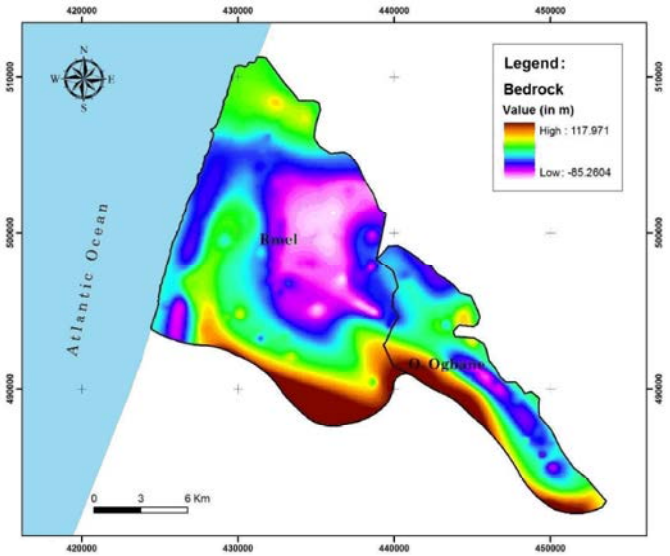

Fig. 7: Map of the bedrock Aquifer.

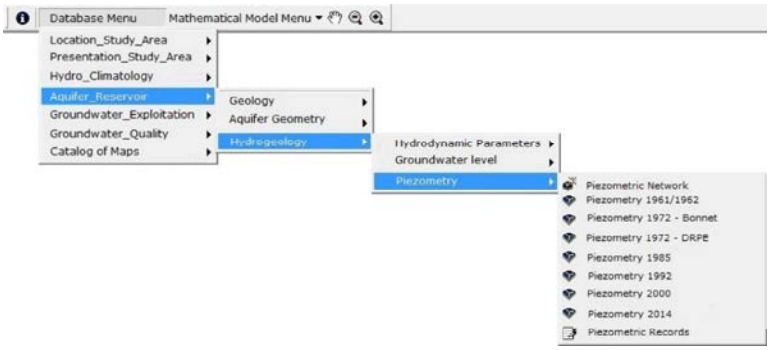

Fig. 8: Control buttons displayed from the 'Class: Piezometry'

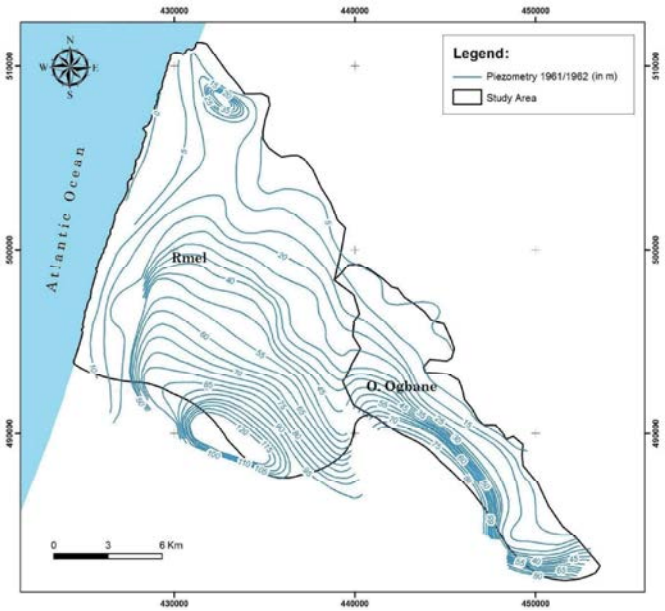

Fig. 9: Piezometric Map of the study area 1961-1962 (modified).

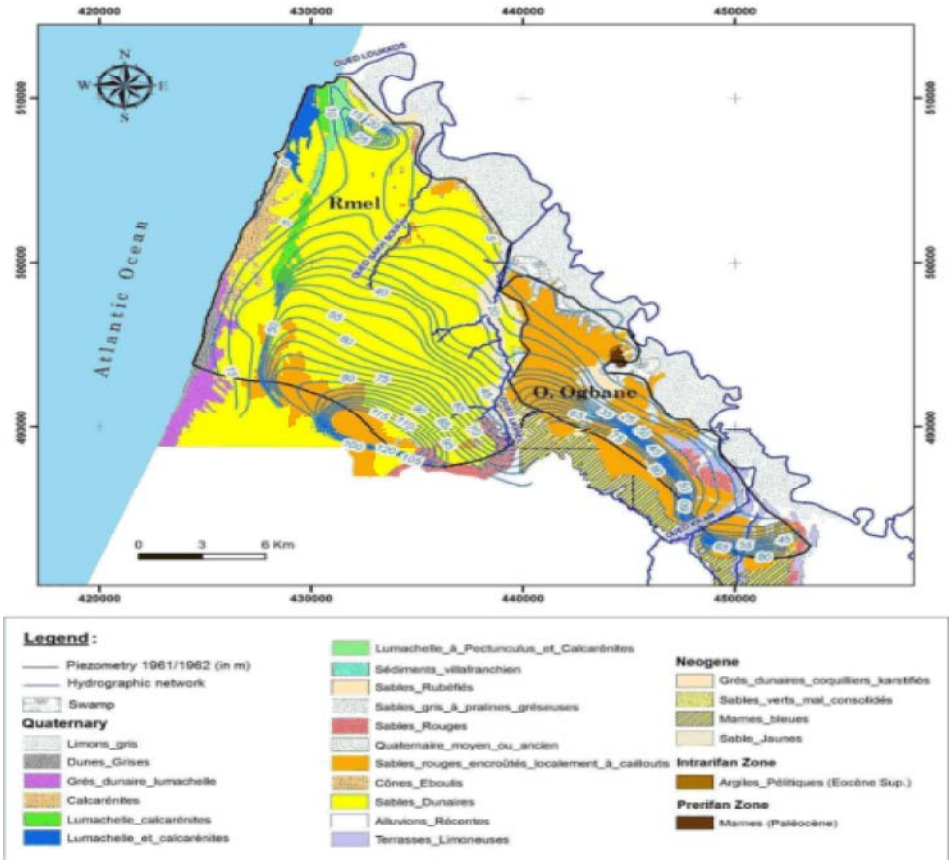

Fig. 10: Overlap of the new geological map (1999) and the piezometric map of 1963.

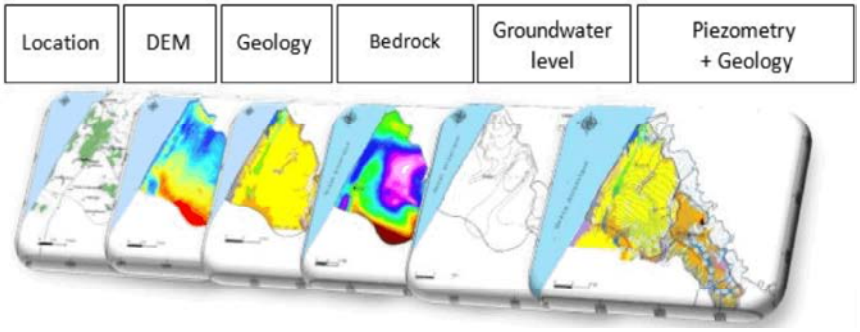

Fig. 11: Examples of produced thematic maps of the Rmel-O. Ogbane aquifer.

CONCLUSIONS

The development of the GIS database of the Rmel-O. Ogbane aquifers was performed following several steps. It started with collecting data from different sources and different supports. They have been thereafter validated, organized and structured as information layers according to the assigned objective. Finally, an application has b een developed in Visual-Basic environment ('MONAROO' *extension*). The latter was designed to make easier the exploitation of the database for managers and makers, as well as the visualization of thematic/synthetic maps which are valuable tools for making decisions.

This database contains all the updated information on the aquifer and water resources in the study area; topography, hydrology, climatology, geology, aquifer geometry, hydrogeology, use of water resources, water quality, etc. These data are, thus, centralized at the

Delegate Ministry for Water of Morocco. They may be made available to managers for the implementation of socio-economic projects or to conduct studies on the impact on water resources.

This information will form the framework for the construction of conceptual model and hydrodynamic models, of seawater intrusion and management, to help decision makers to better plan, manage and control the ground water resources in the study area.

REFERENCES

1. Kinuthia, J., A.J. Rodrigues and R. Oluoch, 2006. Wildlife GIS: Spatial Analysis and Visualisation in Masai Mara (Kenya), Map Africa. Geospatial Media and Communications Pvt Ltd, India. Available at: http://www. geospatial world.net.
2. Naiha, S., A. Larabi, *et al*., 2006. Development of a geographic information system to aid in the exploitation of water resources in the coastal aquifer Souss-Chtouka (Agadir, Morocco). PhD Thesis, Mohammadia School of Engineering (EMI), Rabat, Morocoo.
3. Burke, R., 2003. Getting to know Arcobjects - Programming ArcGIS with VBA. 1st Edition, ESRI, pp: 133-390.
4. ENSG - Ecole Nationale des Sciences Géographiques, 2003. Introduction to Programming in VBA under ArcGIS. Centre d'Etudes et de Recherches en SIG (CERSIG), France. unpublished.
5. Messaoud, M., 1963. Hydrogeological report of Lower-Loukoss basin (Larache_Ksar-El-Kébir), Report of Service des ressources en eau, Centre Régional de Tanger, Morocco. unpublished.
6. ESGM - Editions du Service Géologique du Maroc, 1999. Geological map of Arbaoua - Mechr Bel Ksiri (Scale/50.000). Ministry of Energy and Mines, Direction of Geology, Notes et mémoires no 391, Rabat, Morocco.
7. ESGM - Editions du Service Géologique du Maroc, 1997. Geological map of Larache (Scale 1/50.000). Ministry of Energy and Mines, Direction of Geology, Notes et mémoires no 382, Rabat, Morocco.
8. Bonnet, M. and A. Buffet Rais, 1978. Study by Mathematical Model of Rmel Larache. 1st Report, Document serie no 34-1982, BRGM, PhD Thesis, National Polytechnic Institute of Lorraine, Nancy, France.
9. DRPE - Direction de Recherche et de Planification de l'Eau, 1987. Hydrogeological study of the Rmel aquifer (City of Larache, Morocco), Report no. 8, 87 / DRH / 003 / SHG. Direction de la Région Hydraulique du Loukkos, Tetouan, Morocco. unpublished.
10. Larabi, A. and B. Bouhmadi, 2001. Hydrogeological characteristics of the study sites: Aquifer System of Rmel -Larache, Report of the Integrated Action Moroccan-Spanish 59/PR/99 Cooperation and Research between the University of Granada (Spain) and the Mohammadia School of Engineers (Rabat) on 'the joint exploitation of surface water and groundwater in coastal aquifers (comparative study between Moroccan and Spanish case), internat report, Ecole Mohammadia d'ingénieurs, Rabat. unpublished
11. Arbai, A., 1999. Hydrogeological study and modeling of Rmel. Msc thesis, Hassania School of Public Works, Casablanca, Morocco. unpublished.
12. ONEP - Office National de l'Eau Potable, 2002. Strengthening of Drinking water of the city of Larache - Study of the quality of the Rmel aquifer, Final Report no. 71-6-0060/1, unpublished.