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# Hydrodynamic Characteristics of the "Complex Terminal" aquifer in the Region of Oued Righ North (Algerian Sahara).

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**ABSTRACT/RESUME**

***Abstract:*** *Accessibility of fresh water, the nature's gift wheels the foremost part of the world economy. The sufficient supplies of water are essential for agriculture, human intake, industry as well as regeneration. The Oued Righ region is located in Algeria's South-East, specifically in the North-East of the Sahara, on the Northern edge of the Grand Erg Oriental and the Southern border of the Aures massif. This area appears as a lower Sahara synclinal basin and is part of a broad North-South trending ditch.*
*It is famous for its date palms, the development of the date culture in this region is attributed not only to the population's efforts, but above all to the particular climatic conditions, the favorable soil characteristics and the existence of significant groundwater. The aim of this study is to understand the results obtained from using different approaches of water hydrodynamics in the Complex Terminal aquifer. The aquifer's hydrodynamic characterization was carried out using hydrodynamic parameters and piezometry. As a result, the transmissivity and permeability obtained data using traditional Cooper-Jacob method showed that the flow capacities of the aquifer environment and the productivities of the structures are important in the studied zone where, the highest value of transmissivity equal 2.36× $10^{2}$-$m^2/s$ is found in the central part of the study area in El-Meghair. The establishment of piezometric maps reveals a flow direction oriented toward the chott.*

## I. Introduction

The arid Saharan zone occupies two-thirds of Algeria's land area. Despite its hyper-arid climate, the Oued Righ area is part of one of the world's largest deserts it is one of the most important geothermal zones, with extensive underground water reserves. These waters are found in aquifers containing geological horizons of different depths and thicknesses. Two famous reservoirs met in the great Algerian Sahara; from bottom to top, we have the Continental Intercalary (CI), which is very deep in the North Eastern basin with warm waters that are also very mineralized, the second is the Terminal Complex (CT), which is shallower but saltier; these two aquifer systems have several layers of water superimposed on each other. Numerous studies were applied in this system aquifer of Oued Righ valley such as Belksier et al 2018[1]; Guendouz et al 2003[2] and Bettahar et al 2017 [3, 4]. The water potential of these various aquifers is currently being extensively exploited for domestic, industrial and palm grove irrigation. The present study is part of the problematic of the Terminal Complex aquifer characterization involved in quantitative studies of ground- water problems. This research work aims to summarize the data collected in the area and to define the

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hydrogeological, piezometric and hydrodynamic aspects for evaluating the geometry
and characterizing the hydrodynamic functioning and operating conditions of the Terminal Complex aquifer system in the agricultural and urban environment.

## II. Description of the study area

The study area is part of one of the largest deserts in South-East of Algeria, specifically the Northeastern Sahara, enclosed to the North by the Saharan Atlas, to the South by the wilayas of Tamanrasset and Illizi, to the North-West by the province of Djelfa, to the West by the wilaya of Ghardaia and to the East by Tunisia and Libya. It begins in the South by the Blidet amor village of El Goug (Touggourt) and ends at a distance of 150 km further North to the village of Oum Thiour (100 km from Biskra) passing by the Merouane Chott which is considered to be the lowest altitude in the North of Africa at minus 31m below the sea level[5],it is situated 500 Km South –East of the capital Algiers, at latitude 32◦ 49' to 34◦ 3' North and longitude 05◦10' to 06◦ 14' East.
Morphologically, this area is considered to be at low pressure area and is bordered to the West by the Mio-Pliocene plateau and to the East by the major dune alignments of the Oriental Erg[6], which seems far too immense (15 to 30 km) wide [7].

The climate of the Oued Righ region is similar to that of the Saharan climate which is characterized by low rainfall levels, high temperatures, a significant evaporation and excessive solar radiation. The agricultural domain which was once the main activity of the region[8], it covers almost 16,000 hectares of palm groves[9].
Governmentally, the valley of Oued Righ belongs to two wilayas: Ouargla and El-Oued. Due to the abundant extension of the study area, this study is limited to the territory of El-Oued wilaya; Oued Righ North comprising daïra of Djamaa and Meghaier. From a geographical perspective, this study area is none other than the North Oued Righ Valley, defined geographical entity as shown in figure 1.

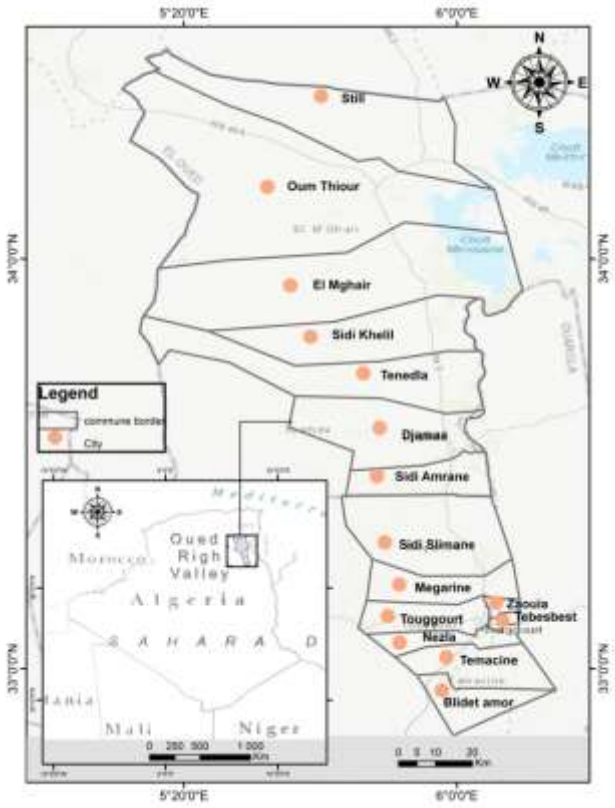


***Figure 1.*** *Localization of the study area.*

## III. Geological and Hydrogeological context

Structurally, Algerian territory is divided into two main geological domains; Alpine domain to the North and Saharan platform domain to the South. The study region is part of the lower Sahara which is limited to the North by the South Atlas accident and the first foothills of the Aures mountains, to the South by the Southern cliff of Tinhert, to the East by the Cretaceous outcrops of Dahar, and to the West by the Mzab ridge. It is therefore between the Northern edge of the Hoggar and the Southern edge of the Saharan Atlas that the large sedimentary basin of the Lower Sahara is located. Geologically, the lower Sahara is formed by two structural units; the Precambrian socle composed of igneous and metamorphic rocks, prevailed by thousands of meters of sedimentary layers from Cambrian to Quaternary in which the Paleozoic lands outcrop in the South, between the Tadmait and Tinhert plateau and the Hoggar massif, the Mesozoic and early Cenozoic terrains make up a large portion of the edge outcrops and Tertiary and Quaternary continental deposits occupy the center of the basin. The study area range from the Barremian to the Quaternary which are characterized by the absence of major tectonic deformations as shown in Figure 2.

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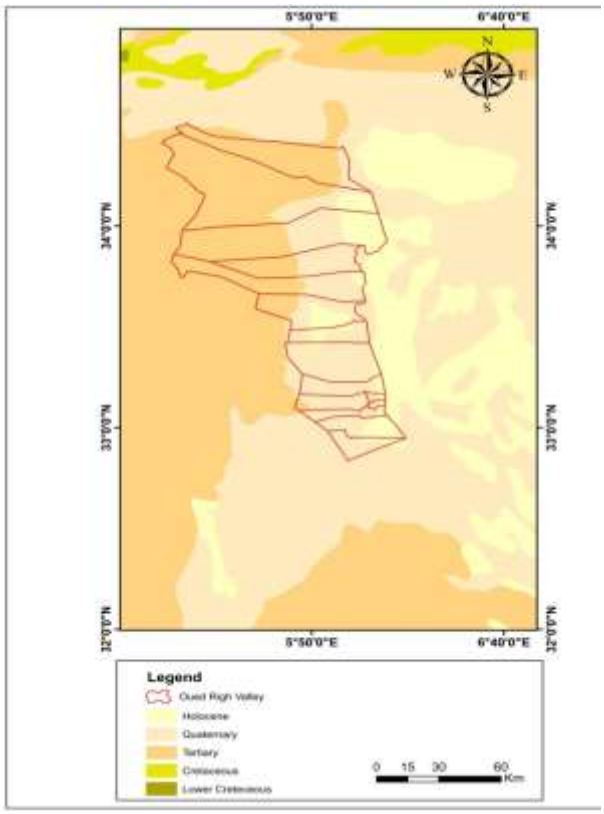


***Figure 2.****Geological map of Oued Righ valley taken from the geological map of Eastren Sahara 1/1.000.000.*

From a hydrogeological point of view, the Northern Sahara basin is composed of a number of wide ranging heterogeneous formations, separated by impermeable formations, known as non-renewable resources represented by the two large aquifers: the Intercalary Continental and the Terminal Complex. In the study area, the following three layers from bottom to top are encountered:

- The Continental Intercalary aquifer.
- The Complex Terminal aquifer which is the subject of our study.
- Phreatic aquifer.

Since the Holocene, the current level of aquifers reflects the result of a pure drying up as reported by[11].

In the Oued Righ region, there are three aquifers were well differentiated in the Complex Terminal: The first and second layers of Mio- Pliocene sands followed by the limestone of the Eocene inferior as presented in Figure 3. From the figure it's understood that the continuity of the underground flow passing from one zone to another area[12].

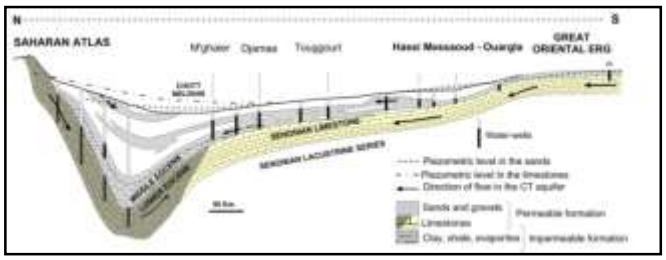


***Figure 3.****Hydrogeological transversal cutting of the Complex Terminal aquifer (UNESCO, 1972).[13]*

## IV. Materials and methods

In this study several long-term pumping tests were carried out on four operating wells, the contribution of this work was to increase the variability on the distance scale of the drillings points. To conduct these tests a submersible pump, a flexible hose, a bucket, stopwatchand apiezometric probe were used during this study. The interpretation of these tests result based on C.E. Jacob's method; the following are the basic requirements for using this technique:

- Darcy law validity: laminar flow in a homogeneous and isotropic environment.
- Full well, capturing the aquifer's entire thickness, reaching the substratum, and being screened over its entire height.
- Wells properly developed and equipped.
- Sub-horizontal piezometric surface.
- Constant pumping rate.
- Smallest possible well radius.

The determination of the hydrodynamic properties of the Terminal Complex aquifer by estimating the Transmissivity and the Permeability; were calculated using the following formula:

$$T = Kb \qquad (1)$$

Where:

T is Transmissivity ($m^2/s$).
K is Permeability (m/s).
b is aquifer Thickness(m).

Generally the study area consists of pumping water from the aquifer initially at the point of rest and following the evolution of drawdowns and direct observation of the exploitation effect on the aquifer. In this study, the maps were produced using ArcGIS software and the pump test was performed with AquiferTest software.

## V. Results and discussion

### V.1. Hydrodynamic context of the region

#### V.1.1.Piezometric map

The piezometric map (see Figure 4) has been established from the piezometric relieved of 10 drilling wells using ordinary Kriging method. Note

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that the operation of groundwater is related to the geology and geometry of the reservoir rock.
On the piezometric map of the Complex Terminal aquifer in Oued Righ, arrows show the position of groundwater and its movements, the general flow directions are given below:

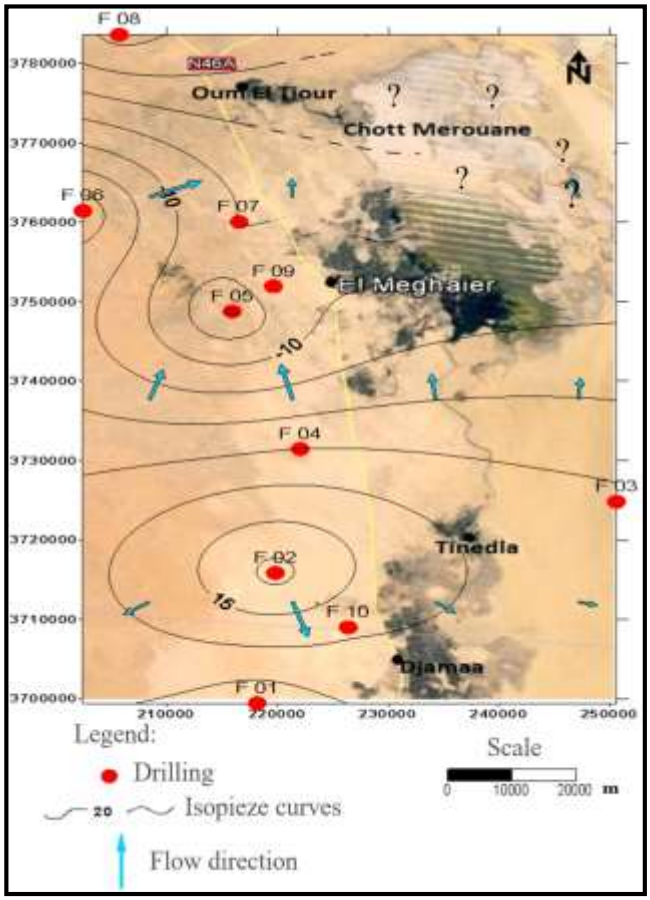


***Figure 4.*** *Piezometric map of the complex terminal in Oued Righ North.*

⋆ In the Southern part (Djamaa):
The curves forma dome at F02 drilling related to a feeding zone, from which the water flows in all directions. This dome is caused by the piezometric level being elevated at this level.
⋆ The central part and the Northern part:

The flow in the El-Meghair area shows that a depression has been occurred at the borehole Number 05, the lowest load water is that of the borehole F08 in Oum Thiour where the piezometric level is equal to -44.7 meter. In general, the flow direction oriented from South to North toward the area of Chott Merouane.
The piezometric curve spacing is a function of the hydraulic gradient, which is all weak ($I = 4.2 \times 10^{-2}$) as the curves are spaced in the Djamaa region. While the hydraulic gradient in the El-Meghair area is weaker ($I = 5 \times 10^{-2}$).

**V.1.2.The groundwater pumping properties**
The evaluation of the aquifer capacity includes the determination of different hydrodynamic parameters: Transmissivity (T) -Coefficient of storativity (S) and Permeability (K). To interpret the results of the four pumping tests performed in drilling levels of the Terminal Complex aquifer in the Oued Righ North, an automated mapping software named "AquiferTest" was used .The obtained results were based on the interpretation made by the method: CE Jacob. These tests in the areas of Djamaa, Sidi khlil, El-Meghair and Oum Thiour.

***Table 1.*** *Hydrodynamic criterion.*

| Region / Parameter | Djamaa F01 | Sidi khlil F04 | El-Meghair F07 | Oum Thiour F08 |
|---|---|---|---|---|
| **X** | 6º 01' 02" E | 05º 55' 47" E. | 05º 55' 58" E. | 05º 51' 02" E. |
| **Y** | 33º 34' 57" N | 33º 50' 37" N | 33º 56' 43" N | 34º 08' 31" N |
| **Z(GPS)** | 2 1 m | 13 m | -02 m | 01 m |
| **Depth** | 172m | 221m | 221 m | 269 m |
| **Maximum Drawdown** | 9.12 m | 18.9m | 23.1 m | 19.35 m |
| **maximum dynamic level** | 18.98m | 33.51m | 34.74 m | 45.80 m |
| **Static level** | 9. 89 m | 14.65 m | 29.15 m | 26.45 m |
| **Thickness** | 30m | 50m | 47m | 60 m |
| **Duration of pumping** | 4320 min | 4320 min | 4320 min | 4320 min |
| **Constant debit** | 50 L / s | 40 L / s | 40 L / s | 44 L/ s |

**V.1.2.1.Djamaa test (6º 01' 02" E and 33º 34' 57" N)**
This test was realized in a siliceous coarse sand and anhydrite captive aquifer. All parameters of the Hydrodynamic criterion obtained results were tabulated in Table 1. On a semi logarithmic graph the pumping data, drawdown in meters and time in seconds are plotted in Figure 5. These data allow drawing a straight line where showed that all positions are representative of the test. For this test, we observe that the well begins to react after 60 seconds. The figure shows a two-part analysis. The first portion, from the 60 to 86400 seconds, indicates a gradual increase in drawdown. The second phase,

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which extends from 86400 seconds until the end of the pumping, indicates the stabilization of the drawdown.

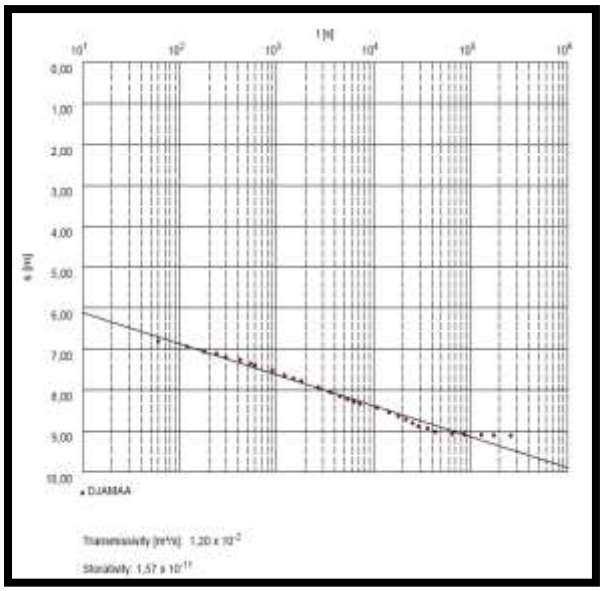

***Figure 5.****Pump Test long duration in Djamaa by the method of Cooper-Jacob descend.*

**V.1.2.2.Sidi khlil test (05° 55' 47" E and 33° 50' 37" N)**

This test was realized in the captive aquifer with young coarse sand, white coarse sands and clays young. The hydrodynamic criterions of this test are shown in Table 1. Pumping data, drawdown in meters and time in seconds are plotted on a semi logarithmic graph (Figure 6).The drawdowns in this pumping structure recorded an increase until the pumping stopped.

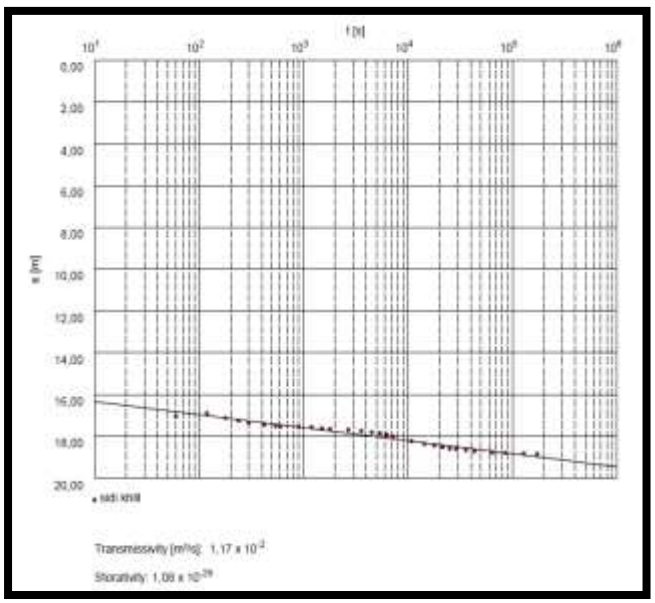

***Figure 6.****Pump Test long duration in Sidi Khlil by the method of Cooper-Jacob descend.*

**V.1.2.3.El -Meghair test (05° 55' 58" E and 33° 56' 43" N)**

The test was realized in a captive aquifer of coarse sands yellow and clays. The hydrodynamic criterion's parameters of this test are given in Table 1.The data for the pump, drawdown in meters and time in seconds are all shown on a semi logarithmic scale (Figure 7). We note that the drawdown exhibits an increase in behavior until the pumping stops.

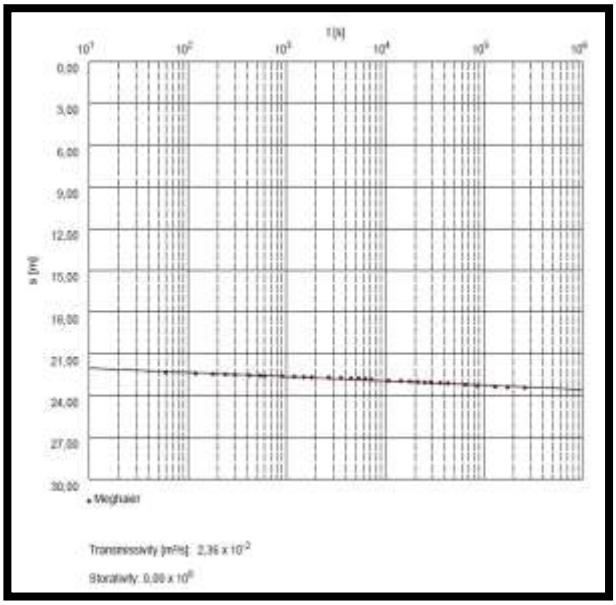

***Figure 7.****Pump Test long duration in El -Meghair by the method of Cooper-Jacob descend.*

**V.1.2.4.Oum Thiour test (05° 51' 02" E and 34° 08' 31" N)**

The test was realized in a captive aquifer made up of siliceous white sand with some gravel and yellow and brown plastic clay. The parameters of the hydrodynamic criterion are described in Table 1. The pump's data drawdown in meters and time in seconds are both plotted on a semi logarithmic graph (Figure 8). This test's drawdown evolution can be divided into three parts. The first section which lasts for the first 60 seconds is akin to the curve with a pseudo-stabilization caused mostly by the presence of water in the well. Then at 120 seconds it continues to increase till 4500 seconds. The third part indicates a stabilization of the drawdown from 4500 seconds until the pumping stops.

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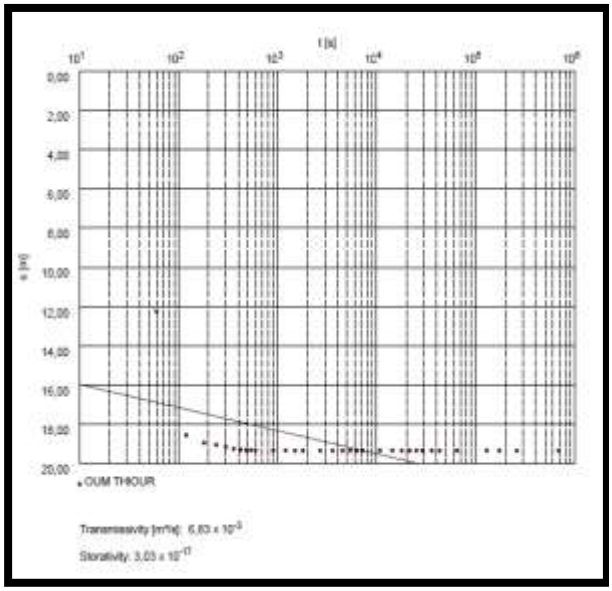


***Figure 8.*** *Pump Test long duration in Oum Thiour by the method of Cooper-Jacob descend.*

**V.1.3.Evaluation of hydrodynamic parameters**

From an "aquifer evaluation" perspective, determining the hydrodynamic characteristics of an aquifer system needs the determination of transmissivity and permeability.

The following Table summarizes the characteristics of these four tests:

***Table 2.*** *Hydrodynamic parameters*

| **Region** | **Transmissivity ($m^2/s$)** | **Permeability (m/s)** |
|---|---|---|
| **Djamaa** | $1.20\times 10^{-2}$ | $4 \times 10^{-4}$ |
| **Sidi Khlil** | $1.17\times 10^{-2}$ | $2.34 \times 10^{-4}$ |
| **El-Meghair** | $2.36\times 10^{-2}$ | $5.02 \times 10^{-4}$ |
| **Oum Thiour** | $6.83\times 10^{-3}$ | $1.13 \times 10^{-4}$ |

The pumping test results showed that transmissivity and permeability are significant parameters in the hydrodynamic analysis of Oued Righ's Complex Terminal aquifer as shown in Table 2.

- The transmissivity values were increased in the central part of the study area in El-Meghair.
- The spatial distribution of permeability was shown with a variance range of $1.13 \times 10^{-4}$ to $5.02 \times 10^{-4}$ m/s.

## VI. Conclusion

In view of increasing urbanization, water resources in the valley of Oued Righ are subject to strong quantitative pressures, this study described the hydrodynamic behavior of the Terminal Complex aquifer and the establishment of piezometric map that allows for understanding and studying the groundwater level while accounting for flow direction to ensure sustainable groundwater usage and management.

The flow behind the South to the North was drawn on the piezometric map of the Complex Terminal aquifer in the Oued Righ North, with these convergence areas showing chott Merouane region. Furthermore, the evolution of the piezometric level differs according to the situation of the boreholes compared to the irrigated sectors.

The interpretation of the constant flow drilling tests helped in the calculation of the hydrodynamic parameters. The transmissivity values varying between $6.83 \times 10^{-3}$ $m^2$ / s and $2.36 \times 10^{-2}$ $m^2$ / s and the permeability of $5.02 \times 10^{-4}$ to $1.13 \times 10^{-4}$m/s, thus the thickness of the formation captured seems to play a more important role. In general, it is estimated that these obtained values are considerable.

This work is acquired for future developments which should lead to a numerical modeling of groundwater flow that could serve as a water resources management tool.

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