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ORIGIN OF THE ALLUVIAL AQUIFER'S GROUNDWATER IN WADI BISKRA (ALGERIA)

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ABSTRACT

The alluvial aquifer of wadi Biskra is located just upstream of Biskra city (city of the Algerian Sahara). This aquifer has an area of 5km² and an average thickness of 20m; the volume of alluvium deduced from geophysics being 100 hm^3. The porosity calculations carried out using the curves of the groundwater piezometers yielded an average value of ϕ = 30% for an alluvium volume of 100 hm^3 and a stored volume of exploitable water of approximately 30 million m^3

Currently 14 boreholes with an average depth of 40m capture water from this aquifer and the exploited flow rates are in total of 1409 m^3/h. The flood's surface water of the wadi (four to five floods per year) and the low rainfall average (125 mm/ year) cannot explain the non-drying up of the alluvial aquifer.

The use of several approaches; hydrogeological (by hour-by-hour monitoring of the variation in the piezometric level), hydrochemical (analysis of groundwater and hour-by-hour monitoring of the variation in groundwater and air temperature), hydrological (study of the variation relationship piezometric levels depending on precipitation in the watershed) and structural (analysis of fracturing) highlighted the existence of a third source of supply; this is deep mesothermal water which rises towards the water table and brings to the aquifer a quantity greater than that supplied by flood waters. The presence of this water source explains why the water table does not dry up during the long dry summers and periods of drought.

Keywords: Algeria, Alluvial aquifer, Biskra, mesothermal water, Piezometry, Temperature.

INTRODUCTION

Alluvial aquifer is an underground water table that accompanies the course rivers, wadi and streams. The waters often circulate at low depth through alluvium (sands, gravel, pebbles) deposited by the stream.

They are supplied at the same time: by the water which infiltrates at the level, the alluvial plain and its borders, by the transfer of water from the stream through the banks and the bed, by groundwater flows from aquifers that eventually drain the territories located on both sides of the valley.

The region of Biskra is located in the South-East of Algeria. From a geological point of view, the region presents itself as a country of structural and sedimentary transition between two domains; Atlas in the North and Saharan in the South.

Alluvial aquifers are traditionally exploited in the Zibans (the geographical name of the region is the Zibans which is the plural of Zab) and are even at the origin of certain palm groves which were supplied directly from the sources and from the many traditional wells. In this category we classify the alluvial water table of Wadi Biskra upstream of the city.

Indeed, from the plain of El Outaya in the north to the limit of the town of Biskra in the south, the El Haï-Biskra wadi winds over a thick layer of alluvium formed by sands, gravels, pebbles, deposited by the stream from the beginning of the Quaternary (Haouchine et al., 2010). Being very permeable and porous, alluvium stores water thus forming a mass of groundwater known as the alluvial water table of wadi Biskra. The marly and impermeable Miocene subsoil on which it rests forms the substratum of this water table.

The flow rates extracted by pumping from this aquifer (over 1,400 m^3/h) are much higher than the inflows by infiltration during the rare floods of the Wadi and annual precipitation that does not exceed 125 mm/year.

MEANS AND METHODS

Geological aspect

Hydrogeological studies concerning the alluvial aquifer of Wadi Biskra are extremely rare. The only study is that carried out in 1967 by the “Société Centrale pour l'Equipement du Territoire (SCET-COOP)”. No other detailed study has been carried out since.

The aquifer is elongated in shape and has a north-south general direction (Fig 2). This form was shaped by the flow of the wadi which is dug in the impervious marls of the Miocene and backfilled by alluvial deposits.

The lithological nature of this aquifer is gravelly, characterized by the presence of pebbles, gravel, sands and conglomerate formations. The calculations of the porosity carried out on the curves of the piezometers of the water table provided an average value of $\phi = 30\%$, that is to say for a stored volume of exploitable water of about 30 million m^3, a volume of alluvium of 100 hm^3 deducted from geophysics (SCETCOOP, 1967).

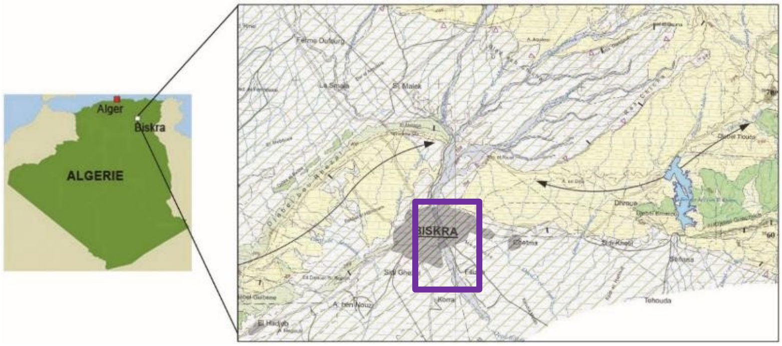

Figure 1: Situation of the alluvial aquifer

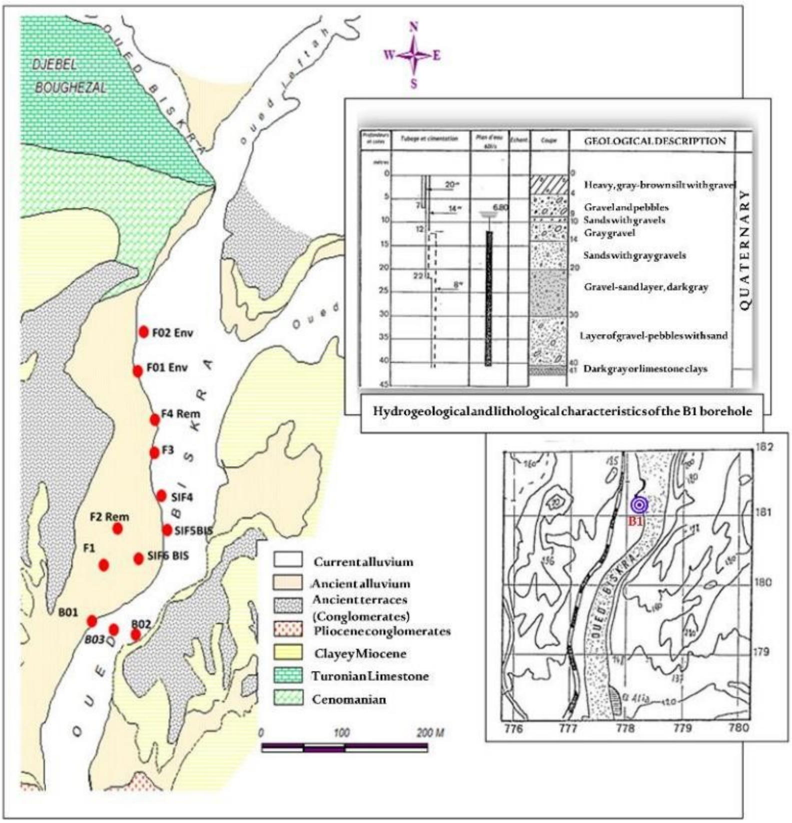

Figure 2: Geological sketch of the alluvial aquifer (R.C. 1967)

Hydrological aspect

Like a capricious climate, the rivers feeding the Biskra region have a very irregular periodic flow (4 to 5 floods per year). The most important wadis originate in the Aurès (southern slope), where rainfall is in the order of 400 to 500 mm / year (Haouchine et al. 2010).

The irregularity of the flows of the wadis, accentuated by the weakness (if not the absence) of hydrometric equipment, makes it extremely difficult to quantify the flows at different levels of the wadis.

The use of old surveys carried out at the Djemorah station (main wadi feeding the alluvial aquifer) during the period 1971-78 provides an average flow of 0.68 m^3/s. Nevertheless, we note that during this period, the wadi experienced two extreme flow values; the first of 55.8 m^3/s on 11/04/1972 and the second of 15.1 m^3/s on 11/30/1972 (Labadi and Meddi, 2008).

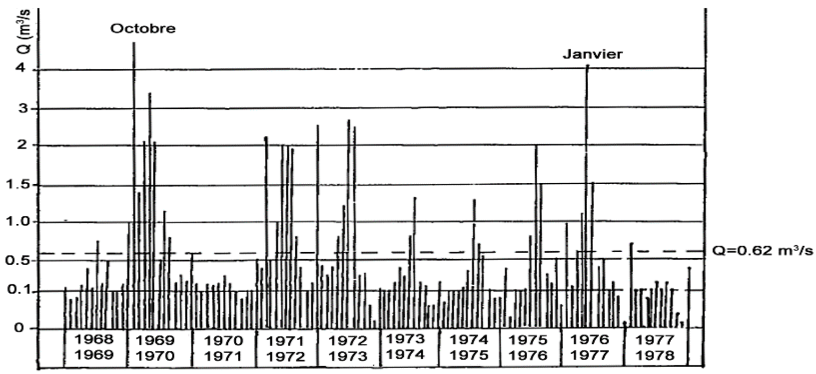

Figure 3 : Monthly flows measured at El Kantara station (1968-78)

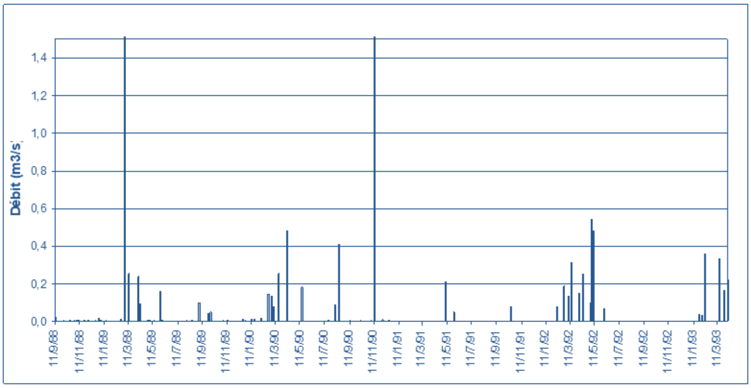

Figure 4 : Monthly flows measured at El Kantara station (1988-93)

The period 1988-1993, for its part, presents three extreme events; the first on May 25, 1989, the second on November 11, 1990 and the third on November 7, 1992 with 3.12, 2.77 and 5.69m^3/s respectively. The other values hardly exceed 1m^3/s. These values once again demonstrate the influence and magnitude of stormy fall and spring precipitation on surface waters.

Hydrogeological aspect

14 boreholes are operating currently with a flow rate of over 1400 m^3/h (Directorate of hydraulics of the wilaya of Biskra). In order to follow the variation of the piezometric level in the wadi Biskra catchment field, our choice fell on two boreholes; B1 and SIF4 (Table 1).

The use of two TD-Diver (VanEssen brand pressure and temperature sensors) enabled us to monitor, hour by hour, during the period from 05/22/2018 to 11/12/2018, the variation in the piezometric level and groundwater temperature.

Table 1: Borehole B1 and SIF4 characteristics.

Borehole's name	location	Location information	Year	Depth (m)		Static level (m)	Dynamic level (m)	exploitation flow (l/s)	
				Initial	current			Initial	current
B1	Wadi Biskra	05°44'06,70" 34°52'49,80"	1954	41	37.10	25	30.20	130	46
SIF4	Wadi Biskra	05°44'32,80" 34°53'10,40"	1970	37	30.40	24.37	/	30	/

RESULTS AND DISCUSSIONS

The variation of the piezometric level

Data on variations in absolute pressure (Patm + water depth) and groundwater temperature were obtained from the TD-Diver installed in boreholes B1 and SIF4. After treatment and compensation of the pressure values so that only the hydrostatic pressure remains, we obtained the diagrams of Fig 5 and 6 in which we observe the variation of the water level with respect to the borehole head (compensated pressure).

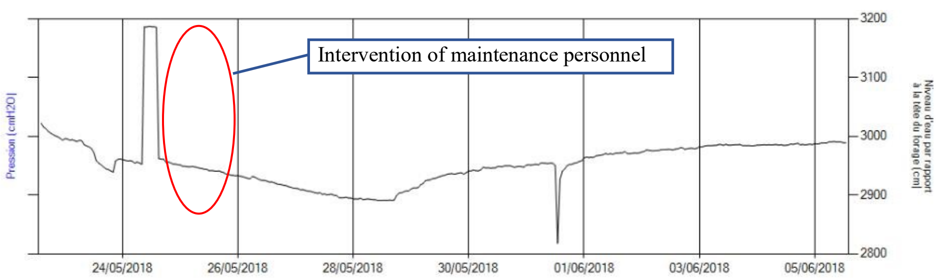

Figure 5: Water level variation compared to the borehole B1's head

Figure 6: Water level variation compared to the borehole SIF4's head

To properly observe the fluctuation of the water table, and for the graphs to be more explicit, we replaced the variation in the depth of the water level from the borehole head with the variation in the height of the water. This transformation resulted in Fig 7.

At first glance, we can see a difference in the evolution of the piezometric levels between the two boreholes. What is remarkable is that the level in B1 increased by 1.30 m while in SIF4 the increase was only 0.95 m, although the distance between them is only of 925m. This phenomenon is most likely due to the fact that the B1 zone has a much greater permeability than the SIF4 zone and the B1 is close to the feeding zone. In addition, the increase in B1 occurs while the pumping is on (46 l0 l/s).

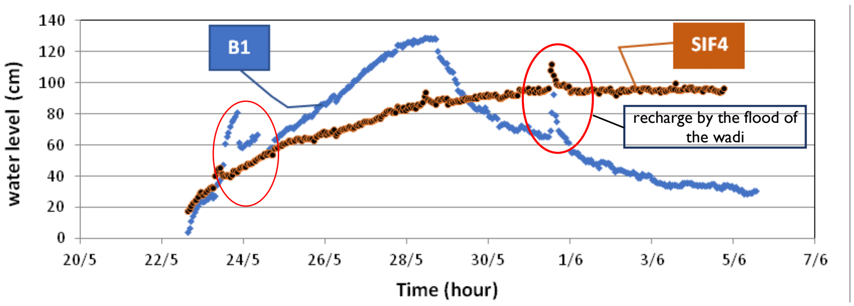

Figure 7: The water table's fluctuation at boreholes B1 and SIF4.

On May 28 at 11 a.m., B1 began to recede with a steeper slope than the flood, thus signaling that the extracted flow (outgoing) had become greater than the incoming flow (flow feeding the water table), while in SIF4 we observed an equilibrium phase with stabilization of the water level. It should also be noted that the appearance of a slight increase in the water level in the two boreholes on May 31 at 9 am, followed after a few hours by a decline. The time of this episode is 40 hours. This is a phase of recharge of the alluvial table by the flood of the wadi during this period. This sequence is, in our opinion, proof that the share of Wadi Biskra in feeding the alluvial water table during periods of flooding is very minimal.

Variation in water temperature

The water temperatures in the alluvial water table range from 25 to 31 °C, which is unusually high considering the static level is just 25 meters below the ground surface.

Fig 8 clearly illustrates an increase in SIF4 water temperature during the period from May 22 to June 9, coinciding with a rise in the water level in the borehole. This event indicates that, in the absence of floods, the groundwater is primarily replenished by hot water sources.

We attribute the 5 °C temperature difference between SIF4 and B1 to the continuous pumping in the latter. Unlike the relatively quiescent waters of SIF4, the waters in the B1 zone undergo perpetual regeneration. Consequently, the pumping consistently utilizes the hot water from the water supply zone, leading to this temperature variation.

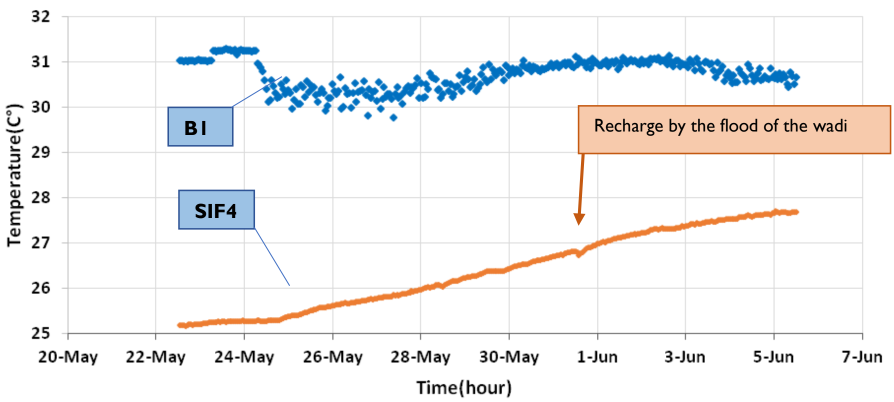

Figure 8: Temperature variation of B1 and SIF4.

Over a period of 7 months, continuous measurements were conducted with a one-hour time interval, revealing no significant correlation (coefficient of determination = 0.24) between the groundwater temperatures within the alluvial water table (ranging from 25 to 31°C) and air temperatures (ranging from 7 to 48°C), as shown in Fig 9.

During the summer season, when air temperatures soared to 48°C, the groundwater temperature remained relatively stable, fluctuating between 30 and 31°C. This stability underscores the lack of influence exerted by high air temperatures on the aquifer's water temperature, further confirming their independence.

However, a significant event occurred on October 18 when the groundwater temperature suddenly dropped from 31°C to 27°C. This abrupt 4°C decrease was attributed to the influx of surface water into the aquifer. This observation underscores the importance of recharging the hot water table, highlighting its greater significance compared to recharging with cold water sources.

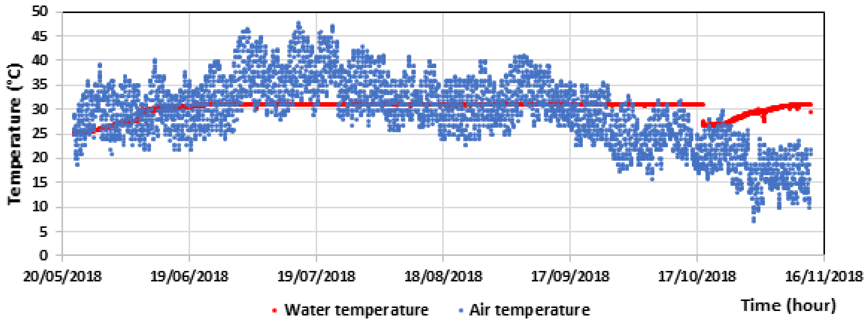

Figure 9: Groundwaters' temperatures' variation in the borehole SIF4 and the air temperature.

Rainfall and piezometric variation

Based on hypotheses regarding the origin of the water in the aquifer, the synchronous readings of the piezometric level are compared with the recorded rainfall heights at the Biskra station, as well as the Menaa and Bouzina stations upstream of the watershed. (Fig 10).

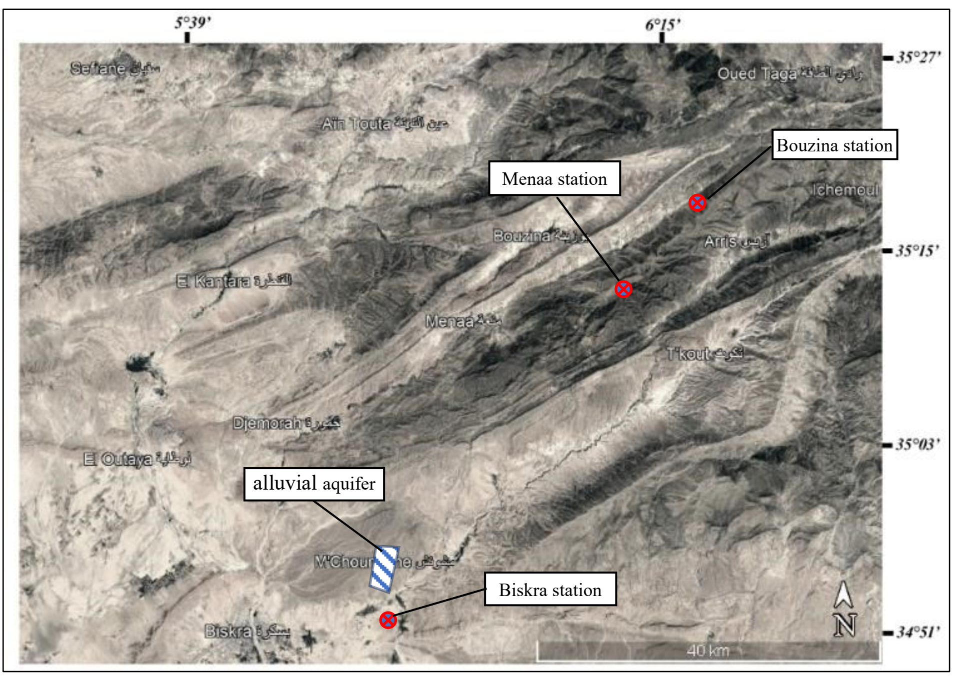

Figure 10: The geographic location of the three rainfall stations

In general, the continuous recording of the groundwater level in the SIF4 borehole, during this period has a dominant downward trend (Fig11).

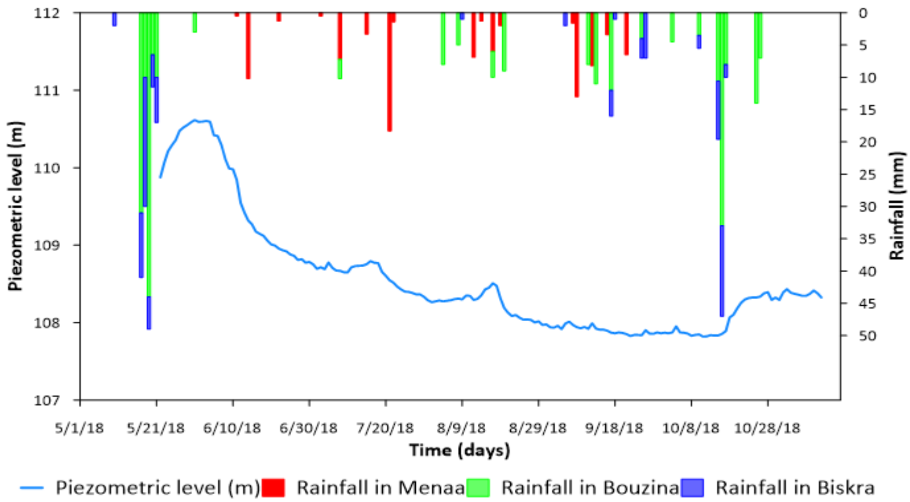

Figure 11: The piezometric level evolution at the SIF4 borehole.

Analysis of the graph in Fig 11 clearly shows that precipitation in the Biskra region has no influence on the variation in the piezometric level since there is no immediate response from the latter. We can see that the increase from May 22 to 28 (of 0.95 m) is a delayed response to the fairly significant rainfall episodes (100 mm) recorded upstream of the watershed at the Bouzina and Menaa stations.

The piezometric level of the water table, at the level of SIF4, begins to gradually decrease from June 6, following the start of pumping in the SIF4R borehole (replacement) with a flow rate of 10 l/s. This indicates that the flow extracted by pumping has become greater than the incoming flow (flow feeding the water table).

The resumption of the increase in the piezometric level was noted on October 16, which corresponds to rainfall inputs recorded upstream (Bouzina and Menaa) and in the Biskra region, and in addition this increase of 0.45 m took place following at the passage of a flood in the wadi.

This increase is very significant, it could reflect a groundwater recharge with a fairly large flow and could also mean that the infiltration of water during this flood was distributed along the reservoir.

Hydrochemistry of alluvial water

The chemical facies of all the points is sodium chloride with a conductivity which varies between 3400 and 4090µS/cm thus reflecting strong mineralization of the aquifer (table.2). This aquifer being essentially made up of gravel, pebbles, sand and clay and very few gypsiferous levels, leads us to argue that these high concentrations of water cannot come only from the alluvial aquifer itself and that the origin of this mineralization is to be looked further upstream.

Table 2: Concentrations of chemical elements in alluvial aquifer drilling

Forage	Ph	T (°C)	CE (mS/cm)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)
ENV 02	7,19	24,2	4,06	***168***	82,56	***640,40***
ENV 01.	7,25	25,1	4,02	160	***86,4***	608,07
F4.	7,22	24,6	4,09	161,6	82,56	608,07
F3	7,28	25	3,96	151,2	76,32	618,85
SIF.4	7,19	24,7	3,43	156,8	72	575,74
F2 BIS	7,25	25,1	3,61	155,2	72,96	640,40
SIF 5	7,31	25	3,57	152	78,72	597,30
SIF 6 BIS	7,34	25,5	3,51	147,2	69,12	532,64
B1	7,22	25,1	3,84	152	78,72	608,07
B1 BIS	7,24	24,8	3,68	161,6	73,92	597,30
B3 BIS	7,24	25	3,40	152	79,68	586,52
F1	7,22	27,3	3,70	158,4	75,84	618,85

Forage	K (mg/l)	Cl (mg/l)	SO_4 (mg/l)	HCO_3 (mg/l)	NO_3 (mg/l)
ENV 02	***13,18***	809,4	501	226,92	14,61
ENV 01.	12,27	795,2	456	212,28	14,57
F4.	12,27	781	522	219,6	14,06
F3	11,81	***837,8***	504	219,6	14,61
SIF.4	11,36	646,1	507	209,84	***14,99***
F2 BIS	11,36	717,1	531	207,4	14,87
SIF 5	11,81	660,3	507	***229,36***	14,35
SIF 6 BIS	11,81	674,5	483	224,48	14,68
B1	11,81	752,6	504	224,48	14,31
B1 BIS	11,81	674,5	498	219,6	14,57
B3 BIS	11,36	631,9	519	209,84	14,52
F1	12,27	759,7	***558***	217,16	14,43

Turonian carbonate aquifer

In the region, the Turonian formation is characterized by dense limestone masses, measuring 300 to 400 meters in thickness, interspersed with occasional marly layers (as noted by R. Laffite in 1939). This limestone layer is overlaid by predominantly marly formations from the Senonian period, totaling more than 900 meters in thickness. The Turonian formation, which acts as the primary source of groundwater, is visible from Djebel Metlili in the North, which serves as the feeding zone, to Djebel Bou Rhezel in the South. This geological formation takes the shape of an anticlinorium with two distinct outcrops: the first one at Draa Ezzemla in the vicinity of Sidi El Hadj, where a thermal spring is present, and the second one at the western periclinal termination of the Djebel

El Azereg anticline (refer to Fig 10). Additionally, it is worth mentioning the existence of a Triassic diapiric intrusion located south of Draa Ezzemla in the Outaya locality (see Fig 12).

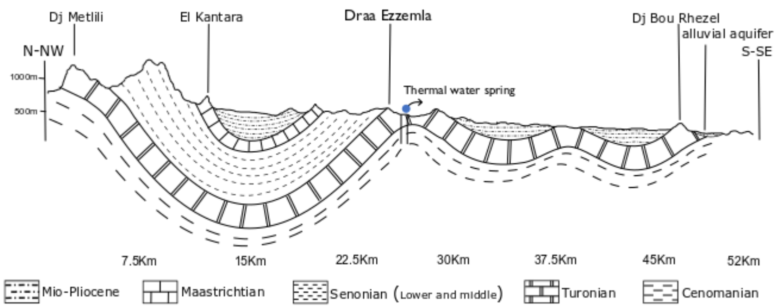

Figure 12: Geological section.

The analysis of the fracture network on the Draa Ezzemla massif (shown in the circular histogram of fracturing in Fig 13a) and Bou Rhezel (presented in the histogram in Fig 13b) revealed two main directions of lineaments:

- The first direction is observed in the northern part, with lineaments oriented NE-SW (N050E), aligning with the major faults in the region, commonly referred to as the "Atlasic direction". These faults, perpendicular to the predominant stress caused by the Atlas compression, are not of significant hydrogeological interest. However, the large fractures oriented NW-SE (N110E and N140E), parallel to the Atlas stress, facilitate significant water circulation. Thermal springs in the vicinity of Sidi El Hadj indicate substantial water flow along these structures, which serve as the primary conduits for karstification.
- The second direction is observed at Djebel Bou Rhezel, where the majority of fractures fall within the directional interval of N120 to N130. This change in the main direction of fractures, which allows favorable water circulation and has considerable lengths, is influenced by the bending of the Bou Rhezel massif.

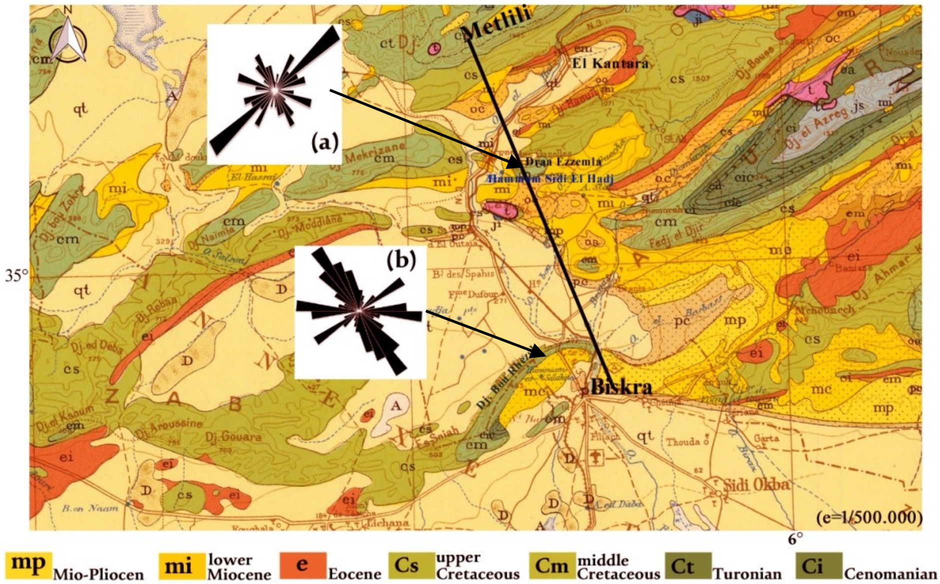

Figure 13 : Geological map of the study region

Furthermore, the alluvial formations of the Biskra wadi aquifer are situated atop impermeable Miocene marls and connect with the Turonian limestones of Djebel Bou Rhezel in their northern part. We believe that the contact surface between the Turonian aquifer and the alluvial aquifer serves as the zone supplying water to the alluvial aquifer (Fig 13).

CONCLUSION

We are dealing with an alluvial aquifer where the volumes extracted through pumping significantly exceed those from infiltration during infrequent floods (approximately 5 to 6 floods per year) and an average annual precipitation of 125 mm. Despite continuous pumping from 14 boreholes, the aquifer is not depleting, indicating the probable existence of a third water source.

To understand the origin of water in the Oued Biskra alluvial aquifer, we have employed various hydrological, hydrogeological, and structural approaches. The utilization of digital water level recorders in boreholes B1 and SIF4 proved invaluable, providing a series of hourly measurements. These measurements revealed several hydrogeological phenomena, including:

- Low water supply to the aquifer through floods.
- Extremely limited recharge due to local precipitation.

- A delayed response of the water table to precipitation on the Aurès massif, as recorded further north at the Bouzina and Menaa stations.

The physicochemical analysis of the alluvial aquifer waters indicates a contribution from mesothermal waters (31°C) originating from the Turonian carbonate aquifer. These waters seep through the contact surface between the Turonian and alluvial layers at Djebel Bou Rhezel.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

BUSSON G. (1971). Principles, methods, and results of a stratigraphic study of the Saharan Mesozoic. Doctoral Thesis, University of Paris, 441p. (In French)

CORNET A. (1964). Introduction to Saharan Hydrogeology. National publishing and distribution company (SNED), Algiers, Algeria, 572p., Cornet and Gouscov, 1952. (In French)

FABRE J. (1976). Introduction to the Geology of the Algerian Sahara. National Publishing and Distribution Company, Algiers, Algeria, 422p. (In French)

HAOUCHINE, A., ABDERRAHIM, B., HAOUCHINE, F.Z., NEDJAI, R. (2010). Mapping of potential aquifer recharge in arid zones. Case study of the El Outaya Plain, Biskra, Algeria. European Journal of Scientific Research, ISSN 1450-216X Vol. 45, Issue 4. (In French)

LABADI, A.S., MEDDI, M. (2008). Impact of the construction of the Fontaine des Gazelles dam on the alluvial aquifer of the Biskra River. National Seminar «Water in its Environment », Blida, Algeria, June 08 and 09, 2008. (In French)

LABADI A.S. (2013). Contribution of hydrochemistry to the understanding the structure and functioning of aquifers in the Northern Sahara. Doctoral Thesis, University of Biskra. (In French)

LAFFITTE, R. (1939). Geological study of the Aurès. Bulletin of the Geological Survey of Algeria, 2nd Series, Stratigraphic Description of the Region, N° 15, 451 p. (In French)

LATER F., LABADI A., KADDOURI M.T. Contribution of piezometry and temperature to the determination of the origin of groundwater from the alluvial aquifer of Oued Biskra (Algeria). Colloquium on Water Resources, Environment, and Climate Change (STEE'2018), Hammamet, Tunisia, October 22nd, 23rd, and 24th, 2018. (In French)

R.C (1967). Oued Biskra Groundwater, Study of exploitable resources using electrical network analyzer. Urban and Rural Water Exploitation Company of the Sahara

(S.O.D.E.X.U.R.). Hydrology Department of the Central Company for Territorial Equipment (S.C.E.T./COOPERATION). (In French)

UNESCO (1972). ERESS Project. Study of Water Resources in the Northern Sahara and report on the results of Project REG-100, UNESCO, Paris (1972). (In French)