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Assessing the hydraulic connectivity between polluted surface water and shallow groundwater and its role in preserving palm groves in the Oued Righ valley, Algeria

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ABSTRACT

In recent years, the degradation of palm groves due to the rise of hypersaline groundwater has increased. This research aims to assess the hydraulic connectivity status between the Oued Righ channel and the adjacent aquifer. For this purpose, a piezometric network with 20 monitoring wells was installed, and the channel's water and bottom levels were measured in April and September of 2019 at 12 gauging stations, then the soil samples of the banks and the bottom were collected from the channel. The results showed the predominance of silty loam formation, which has reflected the weakly values of hydraulic conductivity of the clogging layer, with values ranging from 5.51×10^{-5} to 6.74×10^{-6} m/s, and according to the results of the hydraulic head differences between the channel and phreatic water for both periods, we found two types of water return statuses: hydraulically connected in the sections (22.5–25.5 km and 36–42.5 km), and hydraulically disconnected in the sections (23.5–24.5 km and 38.5–42 km). The study's findings are critical for water resources management, in order to preserve palm groves' wealth, which is the most important economic resource for the population.

Keywords: Oued Righ channel; Shallow groundwater; Hydraulic connectivity; Palm groves; Clogging layer

1. Introduction

The Oued Righ valley is located in the northeastern Algerian Sahara. Agriculture, particularly the exploitation of date palms, has long been the main activity in this region, which consists of more than 50 oases with at least 2 million palm trees [1]. In this valley, drainage is through an artificial channel that evacuates drainage water and wastewater without pre-treatment for 130 km before discharging into the chott Merouane downstream [2]. Since the first drilling in Tamlaht in 1954 [3], the drilling of the Albien and the Terminal Complex has provided increasing flows each year to satisfy the needs of drinking water and, in particular, for palm grove irrigation. Indeed, due to the basin's situation in this region, the superficial aquifer absorbs excess irrigation water, raising the hypersaline water table, and the malfunction of the Oued Righ channel contributes to the escalation of this problem [3]; many palms die and palm groves decline due to asphyxia and high salinity of soil caused by evaporation (Fig. 1) [4].

Previous research on different water resources in this region, specifically on the Oued Righ channel and the water table, has focused on: the impact of the Oued Righ

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channel on the surrounding chotts, existing groundwater and their impacts on the environment [5], while Lembarek and Remini [6] measured the hydraulic characteristics of the channel and the evolution of its water flow, as well as Belmnouar [7] who studied flow regime of Oued Righ, also points of connection of a drainage discharge and sewage discharge and their effects on phreatic water contamination [1]. Benhamida [8] identified the different parameters that contribute to the rising water table phenomenon, as well as established a water balance for the Oued Righ collector channel, and Serrai [9] evaluated the effects of irrigation and drainage systems on the oasis environment in the Oued Righ region. While Mohammed and Boualem [10] estimated the amount of salts that had been deposited downstream of the Oued Righ channel, Benhaddya [11] studied the physico-chemical quality and the trace elements in the waters of the channel, and Hammadi et al. [12] based their research on the influence of the geological aquifer formation on salinization of the phreatic water.

The functional links between the groundwater and the surface water depend on the geological formation, for example the presence of an aquiclude or aquitard, the clogging layer sediments permeability [13], and the relative water levels between the water bodies and the aquifer [14] for this, the clogging layer characteristics were highlighted for the first time in this region as a determining factor in the nature of the relationship between the channel and the adjacent aquifer, we aim in this research to study the hydraulic connectivity situation between the right bank of the Oued Righ channel and the phreatic water, based on three approaches: the connectivity index, hydraulic conductivity, and the hydraulic head differences; by evaluating the sediment permeability of the clogging layer as well as the flow directions between the Oued Righ channel and the phreatic water at the end of wet period (April) and at the end of dry period (September). Knowledge of such a relationship is required better to understand the phenomenon of the rising water table in general and to identify the areas vulnerable to the channel's water return to the adjacent aquifer in particular in our study area, this preliminary assessment study will aid in quantifying and estimating the risk of shallow aquifer contamination caused by wastewater return in future research in order to preserve the wealth of palm trees.

2. Study area

2.1. Site description

The Oued Righ valley (Fig. 2) is located in the south-eastern part of Algeria and is one of the world's largest and driest deserts. It is divided between two wilayas Touggourt and Meghaier, and is bounded to the north by large chotts and the Zab piedmonts, to the west by the plateaus of dorsal Mozabite and Daias, to the south by the Ouarglie sandy regs, and to the east by the Grand Erg Oriental dune belt. The valley is covering a total area of more than 6,000 km^2 [15] with a population of 0.5 million inhabitants.

2.2. Climatic, geologic and hydrogeologic description

The Oued Righ region has a hyperarid climate with high summer temperatures and low annual precipitation. With the exception of a few violent storms that generate runoff [16], rainfall is low and irregular, averaging 83.30 mm/y, and plays no role in direct aquifer recharge. In terms of humidity, the wettest month is December, which has high humidity and low insolation, and the driest month is July, which has low humidity and high insolation. Aridity is visible not only in the lack of rain, but also in the high evaporation caused by insolation, which is caused by the low precipitation and humidity of the air [17].

To better understand the geology of Oued Righ valley, we will extend the field of investigation to the entire Lower Sahara, due to the extent of the geological, stratigraphic and tectonic structures characterizing the region. We distinguish from bottom to top, three sets: Paleozoic terrains can be found to the south, between the Tademait and Tinghert plateaus as well as the Hoggar massif. The Mesozoic and Cenozoic terrains are the main outcrops of the lower Sahara borders. The center of the basin is occupied by continental deposits from the end of the Tertiary and Quaternary. In this research, we will focus mainly on the post Paleozoic sedimentary cover, which contains the main aquifers of the Sahara, the geological series contains two important hydrogeological units called: Continental Intercalaire at the base and Terminal Complex at the top, present throughout the northeastern Sahara [18].

The Intercalary Continental (IC) and the Terminal Complex (TC) represent two multi-layer aquifer systems

Fig. 1. Palm groves affected by salt accumulation.

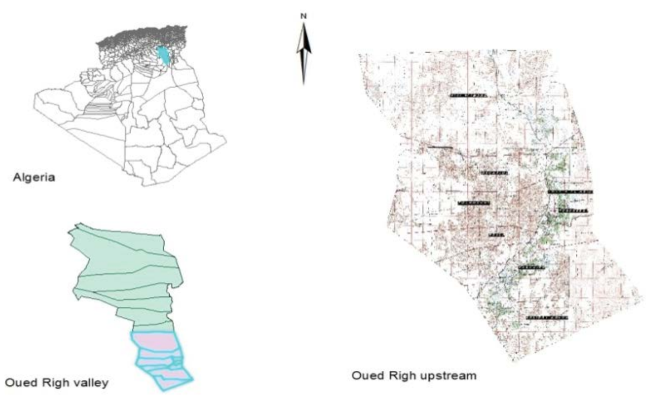

Fig. 2. Location map of study area.

(Fig. 3), which contain considerable water reserves at over 30 trillion m^3 [19], which are currently poorly replenished. Its reserves were formed during the rainy periods of the Quaternary. The Chotts region is the natural outlet for these hydraulic complexes [20]. The phreatic aquifer is present in all the oases of the valley. It is contained in the fine to medium sands, of the quaternary age, containing gypsum crystals. It stretched from south to north and its average power is about twenty meters. It is characterized by waters of high salinity, the analyses of the waters of this aquifer show that they are very salty, the electrical conductivity is of the order of 4.91 mS/cm and passes to 13.44 mS/cm [21].

3. Methods

3.1. Network of monitoring wells

To better configure groundwater contours and determine flow directions, a network representative of the entire groundwater table was chosen, using existing wells in the study area and adding new piezometers (Fig. 4). The new wells were dug by hand to the saturated zone, with drilling depths ranging from about 3 m near the Oued Righ channel to about 1 m near the Sebkhas and Chotts [22]. Moreover, to build those wells, a 63 mm diameter polyvinyl chloride (PVC) pipe perforated 1 m long at the bottom end was used, and the spacing around the pipe was filled with gravel to prevent perforation clogging, the rest of the borehole was full of excavated soil.

Monitoring the evolution of piezometry over time and space allows one to identify the general direction of flow while also identifying some hydrodynamic parameters (hydraulic gradient and flow rate); the latter provide information about the residence time of seepage waters in the aquifer layer, as well as the degree of geochemical exchanges between the water and the rock.

We should mention that the measurements were taken with a 100 m long piezometric probe equipped with dual sound and light signals, in April and September of 2019.

3.2. Water stage and bottom level measuring

Because the Oued Righ channel is quite shallow (Fig. 5a and b), we only used a leveling staff with the topographic device to determine the water level and bottom. Furthermore, the rate of distances between suggested stations for measuring level, was between 5 and 10 km depending on the possibility of entering the site because the relief is extremely dangerous, necessitating the use of bridges in

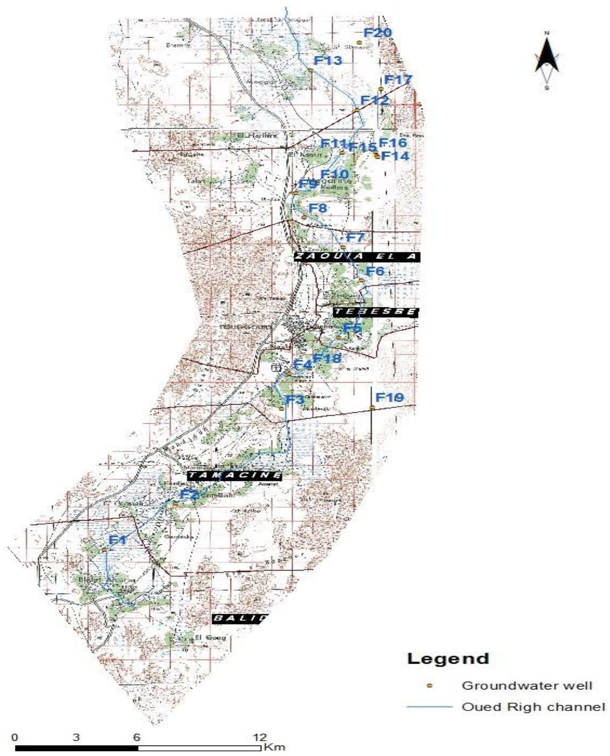

Fig. 4. Water table wells locations map.

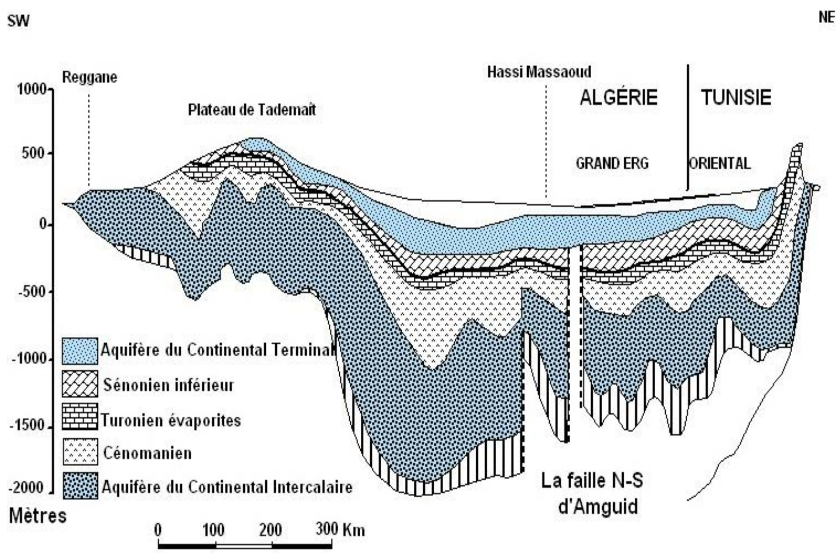

Fig. 3. Synthetic hydrogeological section across the septentrional Sahara by UNESCO 1972 [22].

Fig. 5. (a,b) Photos of Oued Righ channel.

the difficult points. Also, we should point out that the elevations of the water and the channel bed, were determined using the topographic map of the study area (Fig. 6).

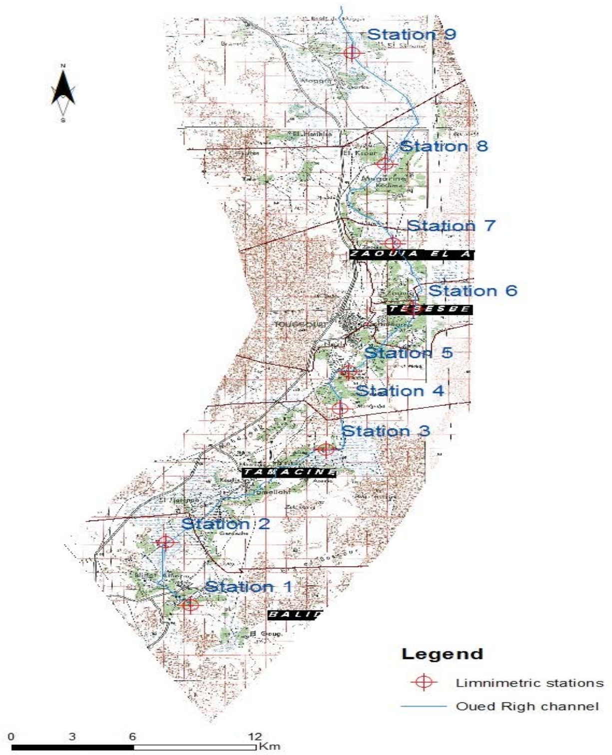

Fig. 6. Location of stations map.

3.3. Sediments sampling and analysis

Manual corers were used to collect bottom and right banks sediments samples from the Oued Righ channel in 08 locations (Fig. 7). Samples were taken every 20–30 cm from the soil surface to below water level in the bare banks, and the materials were sampled in the bottom of the bed in 03 sections (the channel is not very wide and generally does not exceed 20 m in width), with 3–5 samples per section. We followed NF EN ISO 5667-15 for sludge and sediment sample preservation and treatment, and ISO 5667-12 for sediment sampling.

We note that access to this channel has been difficult in some sections due to its dangerous morphology, also the banks being fragile and the water level not allowing us to navigate in the channel. Consequently, these factors influenced the selection of sampling sites.

The coarse fraction's particle size (greater than 2 mm) was determined by dry sieving on a column of mesh sieves ranging from 10 to 0.08 mm (NF ISO 3310-1). In the geotechnical and environmental laboratory in Ouargla city, we conducted particle size analyses.

3.4. Connectivity index approach

The connectivity index was conceptualized by Ransley et al. [23]. This is a straightforward method for determining the connectivity between surface water and groundwater, and it takes four factors into account: water table depth (D), river channel sediments (S), geology (G), and geomorphology (GM). Based on the conditions, each factor is assigned a score. Each parameter is given a weight (Table 1), and the connectivity index is finally calculated using Eq. (1):

$$CI = 3D + 5S + 5G + 2GM \tag{1}$$

The depths of the water table were determined in the current study by taking measurements at wells along the channel, most of which were located within 500 m of the channel. In this study, this distance is deemed adequate for channel-aquifer connectivity analyses. Laboratory particle size analysis was used to identify the type of channel's bottom and banks sediments. Field observations and previous geological maps of study area were used to obtain geological the lithology, and Google Earth and topographical maps were used to obtain geomorphological features. According to Lower Sahara geological studies, the Oued Righ valley is a depositional environment. Oyarzún et al. [24] proposed the following CI classification criteria: $-78.5 < CI <- 24$, low connectivity, $-24 < CI < 53$, moderate connectivity, and $53 < CI < 75$, high connectivity.

3.5. Hydraulic conductivity using Slitcher Equation (1899)

Slitcher developed the formula [Eq. (2)] below while quantitatively describing the permanent underground flow field in response to a well of discharge [26].

$$K = \frac{g}{\upsilon} \times 10^{-2} n^{3.287} d_{10^2} \tag{2}$$

This formula applies to sand types with effective diameters of grain (d_{10}) ranging from 0.01 to 5 mm. Here *K*: hydraulic conductivity (m/s); Uc: coefficient of uniformity and is defined as Uc = d_{60}/d_{10}; υ: viscosity kinematic, is dependent on the temperature of a channel water, 25°C was measured during our tests in the field. υ was set to 0.884 × 10^{-6} m^2/s in the computation of *K*; *n*: porosity, is derived from the empirical relationship between porosity and the coefficient of uniformity [27].

$$\eta = 0.255\left(1 + 0.83^{Uc}\right) \tag{3}$$

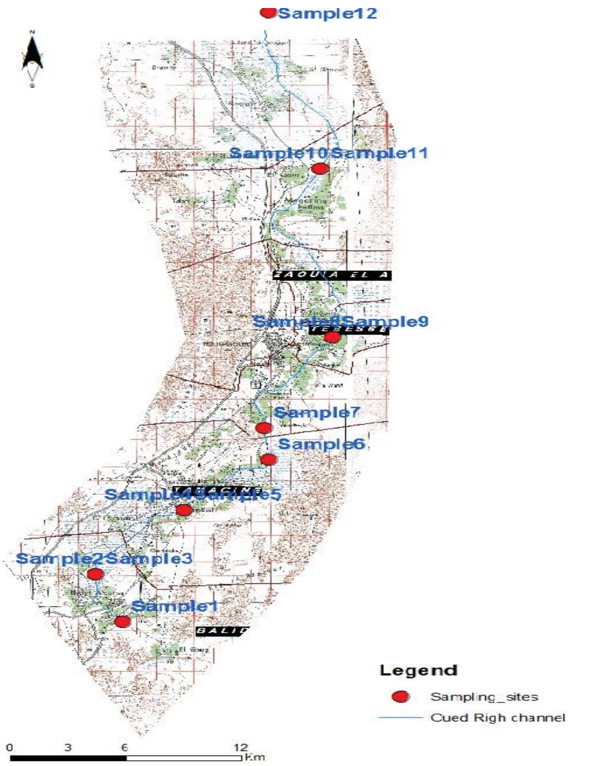

Fig. 7. Map of sampling sites.

Table 1
Parameters, class and score of connectivity index approach [25]

Parameter	Class	Score
Water table depth	<10 m	5
	10–20 m	3
	>20 m	0.5
River channel sediment	Sand/gravel	5
	Sandy loam/silty loam	3
	Silt/clay loam	–1
	Clay	–4
Geology	Gravel/sand	5
	Clay/sand	3
	Clay	–4
Geomorphology	Erosional environment	5
	Depositional environment	1
	Hill top	0

We chose Slitcher's formula because we found it most suitable to apply to our soil types.

4. Results and discussion

4.1. Piezometric profile of phreatic water

The results of the piezometry of the phreatic table for April and September of 2019 (Fig. 8) enabled the creation of a fluctuation profile for the two seasons, upstream of the Oued Righ valley.

Both curves are quite similar, with the greatest fluctuations occurring upstream of the water table and reaching 0.55 m. These fluctuations vary between 0 and 0.30 m in the middle and downstream of the water table. The slight fall in the water table between the two periods can be explained by a single main factor, the effect of which is the high evaporation in the summer period. In addition, these profiles show that the underground flow is generally oriented southwest towards the northeast, and the groundwater drainage axis coincides significantly with the Oued Righ channel, which drains the groundwater, drainage, and sewage to chott Merouane downstream.

4.2. Oued Righ channel stage

The longitudinal profile of the Oued Righ channel (Figs. 9 and 10) for both periods, can be divided into three sections, the first of which the water level in the channel does not generally exceed 2 m on average over a length of 15 km, the second is at a height of the water stage between 2 and 5 m over a length of 35 km, and the last section where the water level in the channel is too low with 0.5 m in height until it overflows on the ground surface

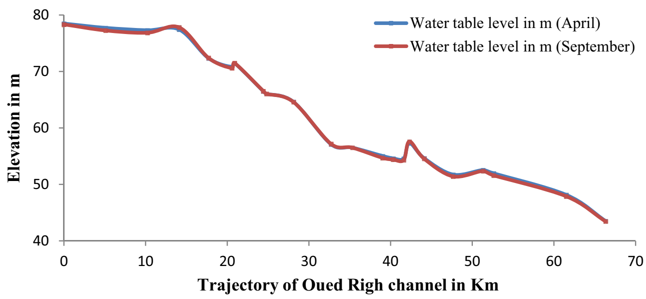

Fig. 8. Piezometric profile of phreatic water.

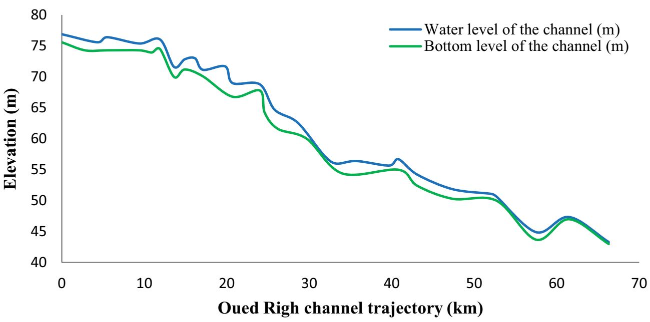

Fig. 9. Longitudinal section of Oued Righ channel (April).

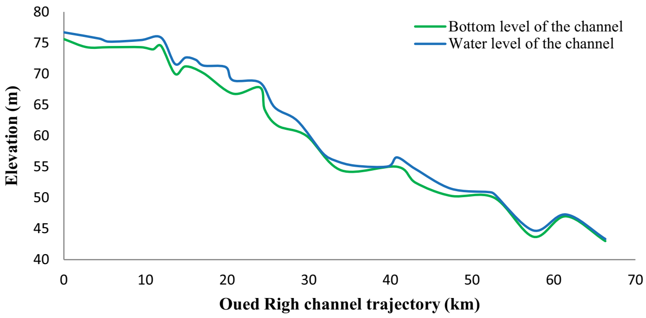

Fig. 10. Longitudinal section of Oued Righ channel (September).

Fig. 11. Dredging operation of Oued Righ channel.

in a few kilometers, then the channel recovers its natural trajectory.

The results showed that the water level curve and the channel bottom curve were almost similar along the Oued Righ channel's trajectory for both periods, and they were also identical to the topographic survey of the natural terrain of the study area. In addition, it showed abrupt elevations in the water level curve in some channel sections, which can be explained by the presence of wastewater discharge points as well as drainage collector connection points in these locations.

It should be noted that there are significant changes in the channel bed in different sections due to anthropogenic interventions such as unstudied dredging operations (Fig. 11) that have strongly influenced the stability of the banks and bottom of the channel [28]. In addition, the erosion resulting from the change abrupt of velocities and flow directions in the connection points of the drainage collectors as well as wastewater discharge [29].

4.3. Grain size distribution of analysed sediments

The types and classes of sediments can be deduced from the particle size analysis; also a sample of sediments may contain gravel, sand (coarse, medium, and fine), silt, and clay; Fig. 12 illustrates the microscopy images of analyzed sediment samples.

In addition, the diameter (D30) represents 30% finer particles and 70% coarser particles than that D30 particular size. On another hand, the diameter (D10) indicates 10% finer particles and 90% coarser particles than that specific size of D10. Then the (D60/D10) ratio is the uniformity coefficient (Cu), and the ($D30^2$/D60 × D10) ratio is the coefficient of gradation (Cc). Fig. 13 displays the results of sieving analyses for 12 samples collected from the right bank and the middle at various locations, along the Oued Righ channel trajectory. And Table 2 shows the proportions of gravel, sand, silt, and clay in the samples analyzed as 0%, 12.53% to 60.11%, 36.05% to 80.18%, and 1.43% to 9.95%, respectively, with sand having the highest percentage. In all sections, no gravel was discovered in sediments samples.

The diameters D60, D30, and D10 were determined by the particle size distribution curves of the analyzed soils shown in Fig. 13, and Table 2 indicates that the analyzed sediments had D10 ranging from 0.080 to 0.108 mm, D30 ranging from 0.111 to 0.176 mm, and D60 ranging from 0.907 to 1.177 mm. The uniformity coefficient (Cu) ranged from 1.855 to 10.903 while the coefficient of gradation (Cc) ranged from 0.242 to 0.995.

The results of the sediments texture classification triangle shown in Fig. 14 revealed that silty loam predominated in the majority of samples analyzed, with the exception of three samples (samples 2, 3, and 6) that were sandy loam. The influence of geological formation, water erosion [30] and organic matter settling [31], all play a significant role in the dominance of fine particles in the Oued Righ channel, not to mention the dredging effect on bank and bottom stabilization.

4.4. Hydraulic connectivity assessment

4.4.1. Connectivity Index approach

Table 3 shows the results of the connectivity index approach determined for each channel reach based on geology, geomorphology, water table depth, and sediments of river channel.

In all reaches, the method gave an average connectivity condition equal to 47, the exceptions being reaches R2 and R3 with medium connectivity equal to 27 in some points. We can attribute the presence of low connectivity values in the valley's midstream (R2) and downstream (R3) to the phenomenon of settling of charged organic matter in the wastewater as well as the sediments of fine particles resulting from erosion water.

It should be noted that seasonality has no effect on the final results in terms of changes in groundwater depth [22]. For this purpose, we chose only one season (high water), because, in two seasons all monitoring wells showed water table depths below 10 m, and received a rating of 5. By comparing the depth of the channel sediments, local geology, and geomorphology when calculating the connectivity index, it can be seen that the depth of the water table was not significant. Indeed, the presence of silt and clay sediments in the channel's bottom and banks has greatly aided in achieving medium connectivity.

4.4.2. Hydraulic conductivity of clogging layer

Table 4 shows permeability coefficient values as a function of sediment grain size [32]: The infiltration capacity of the soil is estimated based on the permeability values calculated by the empirical equation of Slitcher. Based on this table, it can be concluded that the sites tested are semi-permeable formations with relatively low permeability.

Fig. 12. Microscopy images of sediment samples.

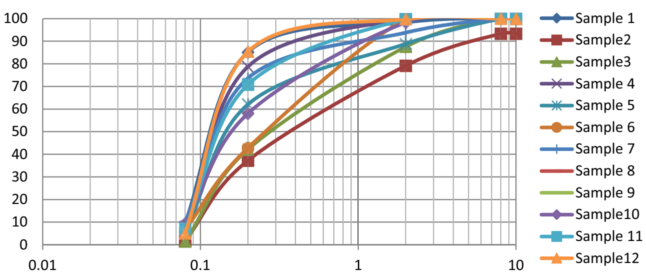

Fig. 13. Grain size distribution curves of analysed sediments.

We also present below a diagram (Fig. 15) showing the properties related to drainage (and by analogy, similar to infiltration capacity) as a function of the estimated permeability coefficient of the analyzed soil (expressed in m/s). Thus, according to this diagram, the permeability of the sediments confers to the channel properties relative to the drainage is low in general, and by analogy also a capacity of infiltration is low.

Under these conditions, in view of all these factors, it can be concluded that the sediments capacity is considered rather favourable to the infiltration of water into and from the Oued Righ channel.

4.4.2.1. Comparison between two approaches

The results of the connectivity index approach (CI) and hydraulic conductivity (Table 5) indicated that the three channel reaches of Oued Righ channel were weakly connected, based on the results of two methods for preliminary estimation of hydraulic connectivity. For more precise

Table 2
Characteristics of analysed sediments

Samples	Localization	Sand (%)	Silt (%)	Clay (%)	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc	Sediments types
Sample 1	Middle	14.78	75.62	9.60	0.160	0.112	0.081	1.984	0.979	Silty loam
Sample 2	Middle	60.11	38.05	1.84	1.177	0.176	0.108	10.903	0.242	Sandy loam
Sample 3	Right bank	57.82	40.75	1.43	0.907	0.164	0.105	8.620	0.282	Sandy loam
Sample 4	Right bank	21.24	70.56	8.20	0.168	0.117	0.083	2.023	0.982	Silty loam
Sample 5	Middle	37.93	57.01	5.06	0.195	0.133	0.090	2.16	0.993	Silty loam
Sample 6	Middle	57.16	36.05	6.79	0.743	0.157	0.090	8.19	0.367	Sandy loam
Sample 7	Middle	26.33	63.94	9.73	0.174	0.118	0.080	2.16	0.993	Silty loam
Sample 8	Middle	30.82	60.76	8.42	0.181	0.123	0.083	2.19	0.995	Silty loam
Sample 9	Right bank	12.53	77.52	9.95	0.157	0.111	0.080	1.96	0.978	Silty loam
Sample 10	Right bank	41.93	49.00	9.07	0.286	0.131	0.082	3.48	0.731	Loam
Sample 11	Middle	29.15	63.73	7.12	0.179	0.123	0.085	2.10	0.988	Silty loam
Sample 12	Middle	14.54	80.18	5.28	0.162	0.117	0.087	1.855	0.971	Silt

Table 3
Connectivity index results

Reach	Water level measurement well	Distance of well to the channel (m)	Water level depth (m)	Water table depth score	River channel sediment score	Geology score	Geomorphology score	CI	Connectivity category
Upstream	F1	32	1.76	5	3	3	1	47	Medium
	F2	126	0.77	5	3	3	1	47	Medium
Midstream	F3	138	1.53	5	3	3	1	47	Medium
	F4	13	1.67	5	3	3	1	47	Medium
	F5	105	1.32	5	–1	3	1	27	Medium
	F6	55	1.4	5	–1	3	1	27	Medium
	F7	85	1.03	5	–1	3	1	27	Medium
	F18	140	1.95	5	3	3	1	47	Medium
	F19	5,068	2.5	5	3	3	1	47	Medium
	F8	67	1.6	5	3	3	1	47	Medium
Downstream	F9	34	2.26	5	3	3	1	47	Medium
	F10	56	4.17	5	3	3	1	47	Medium
	F11	86	1.37	5	3	3	1	47	Medium
	F12	25	1.27	5	–1	3	1	27	Medium
	F13	32	1.47	5	–1	3	1	27	Medium
	F14	1,688	2.24	5	3	3	1	47	Medium
	F15	1,760	2.65	5	3	3	1	47	Medium
	F16	1,452	2.25	5	3	3	1	47	Medium
	F17	4,580	1.5	5	–1	3	1	27	Medium
	F20	3,050	1.5	5	–1	3	1	27	Medium

measurements of hydraulic connectivity, isotopic analyses will be essential.

4.4.3. Hydraulic head differences between the channel and the phreatic water

Groundwater discharge (gaining channel) refers to the upward flow of water from the aquifer to the channel, while groundwater recharge (losing channel) refers to the downward flow of water from the channel to the aquifer.

The results of hydraulic head differences (Figs. 16 and 17) showed that the groundwater discharge status is dominant throughout the channel trajectory; this situation is considered the natural function of the Oued Righ channel, which allows to lower the piezometric level of the water table and to evacuate excess irrigation water and wastewater to the chott Merouane downstream.

There are two cases of groundwater recharge: the first is hydraulically connected, where the water table level is below the channel water level [33], these cases appeared in four sections as follows: sections (22.5–25.5 km, and 36–42.5 km) in April, then the sections (23–25.5 km, and 38–43 km) in September, of the channel's starting point, and the second is hydraulically disconnected, where the water table level is below the bottom of the channel [34], which occurs in the sections (23.5–24.5 km, and 38.5–41.5 km) in April, then the sections (23.5–24.5 km, and 38–42 km) in September, from the Oued Righ channel's starting point. These depression areas are characterized by the appearance of surface water bodies [35] such as lakes, sebkhas "Playa" (Fig. 18), and chotts (Fig. 19), which confirms the hypothesis of the effect of the water return from the channel on these regions.

Our research only looked at the right bank of the channel, but it may be necessary to include the left bank as well. In fact, including the left bank would allow us to better understand the nature of the relationship between the Oued Righ channel and the adjacent aquifer, allowing us to diagnose better the phenomenon of rising water tables in this region.

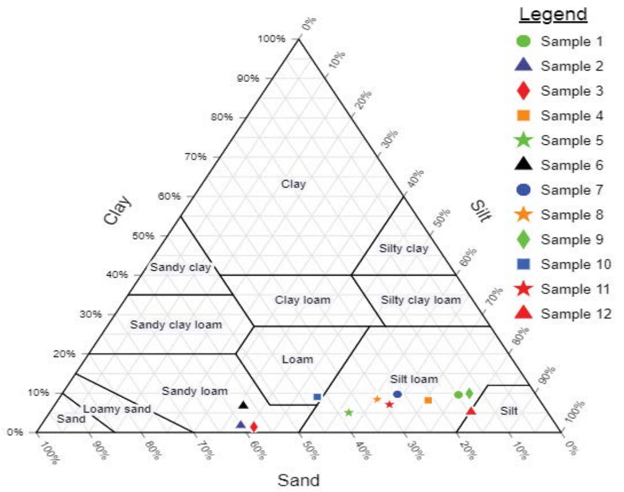

Fig. 14. USDA classification of texture sediments.

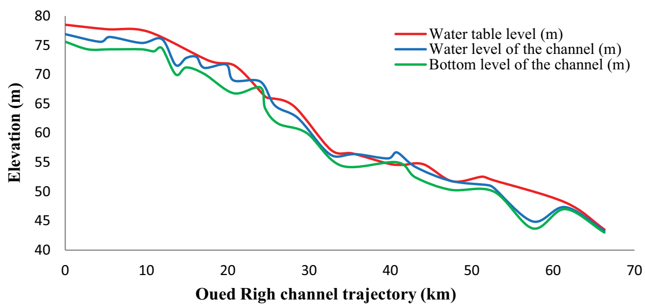

Fig. 16. Hydraulic head differences between the two compartments (April).

Table 4
Parameters of analysed sediments

Samples	D60 (mm)	D10 (mm)	Cu	N (%)	K (m/s) × 10^{-5}	Permeability (°)	Types of formations
Sample 1	0.160	0.081	1.984	43.12	4.54479821	Poor	Semi-permeable
Sample 2	1.177	0.108	10.903	28.84	2.17386124	Poor	Semi-permeable
Sample 3	0.907	0.105	8.620	30.62	2.51181326	Poor	Semi-permeable
Sample 4	0.168	0.083	2.023	42.99	1.41997846	Poor	Semi-permeable
Sample 5	0.195	0.090	2.16	42.54	1.11218051	Poor	Semi-permeable
Sample 6	0.743	0.090	8.19	31.04	0.6738186	Poor	Semi-permeable
Sample 7	0.174	0.080	2.16	42.53	1.81553472	Poor	Semi-permeable
Sample 8	0.181	0.083	2.19	42.46	1.80546765	Poor	Semi-permeable
Sample 9	0.157	0.080	1.96	43.18	1.90727074	Poor	Semi-permeable
Sample 10	0.286	0.082	3.48	38.83	2.04159687	Poor	Semi-permeable
Sample 11	0.179	0.085	2.10	42.74	2.30156657	Poor	Semi-permeable
Sample 12	0.162	0.087	1.855	43.55	5.50633516	Poor	Semi-permeable

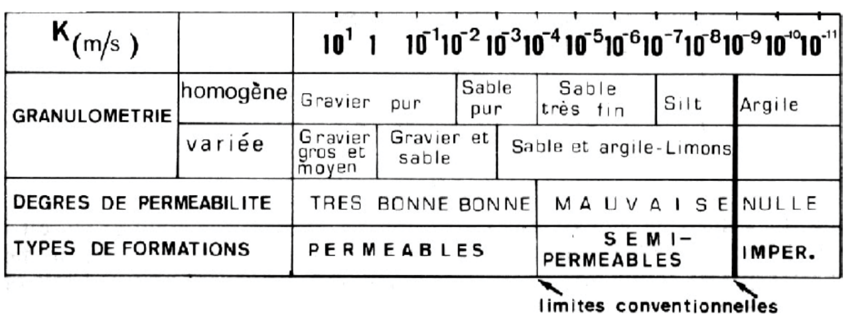

Fig. 15. Permeability coefficient values based on grain size [32].

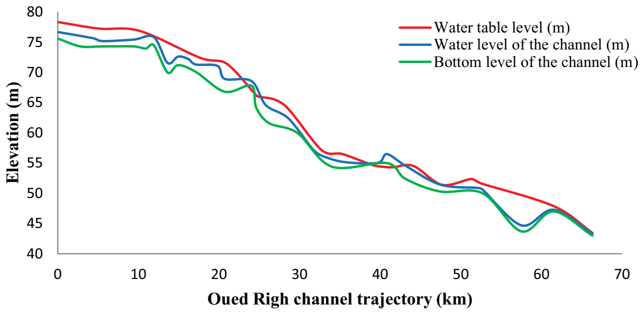

Fig. 17. Hydraulic head differences between the two compartments (September).

Fig. 18. Sebkha in the valley downstream.

Fig. 19. Chott in the valley upstream.

Table 5
Comparison between two methods

Reach	Connectivity index	Hydraulic conductivity	Results
Upstream	Medium	Poor	Low
Midstream	Medium	Poor	Low
Downstream	Medium	Poor	Low

5. Conclusion

The natural function of the Oued Righ channel has changed due to the intervention of several factors, causing the rise of phreatic water in this area. In this paper, we attempted to define the various states of hydraulic connectivity between the Oued Righ channel and the adjacent shallow aquifer, and the results showed the poor permeability of the clogging layer due to silty loam formation predominated in the majority of samples analyzed, also revealed two cases of water back from the channel in some sections: the first was hydraulically connected, where the piezometric surface of the phreatic table was below the channel water level, and the second was hydraulically disconnected, where the piezometric surface of the water table was below the bottom of the channel. Moreover, the connectivity index approaches, and hydraulic conductivity results showed that these methods for estimating the connectivity of surface water and shallow groundwater were appropriate.

This study is useful for the rational management of water resources in this area by implementing an appropriate irrigation system and maintaining the drainage network to protect palm groves from the decline caused by the rise of polluted waters. This is a preliminary study, and further researches based on isotope analysis and simulation should be conducted in the future for greater precision.

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