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IMPACT OF RELEASES FROM THE KEF EDDIR DAM ON THE RECHARGE OF THE OUED DAMOUS AQUIFER

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ABSTRACT

Artificial recharge is a good way to mobilize water in aquifers and recharge groundwater. Dam release is one of the techniques used for groundwater recharge. The periodic releases programmed by the Kef Eddir dam make it possible to recharge the Damous wadi aquifer located in the coastal wilaya of Tipaza in Algeria, whose overexploitation lowers the level of its water and causes a marine intrusion that pollutes it. In this work, to estimate the impact of these releases on aquifer recharge, we followed the releases of March 2020 and May 2021. The piezometric levels of groundwater were measured before the releases, during flow caused by them, and after them. These measures concern 13 wells located along the Damous wadi watercourse for the first year and 18 wells for the second year. These two years have seven wells in common. It allowed us to compare piezometric levels and recharges between 2020 and 2021. In the absence of releases on our return in May and June 2022, we measured the depth of water presence and took samples from 6 wells to measure the water conductivity. These measurements allow us to evaluate the piezometry of the water table over these three years, and the conductivity will indicate the degree of salinity of its water.

Keywords: Artificial recharge; Kef Eddir dam; Oued Damous aquifer; Piezometric level; Releases.

1 INTRODUCTION

Arid and semi-arid countries suffer from the scarcity of rainfall, and when it occurs, the mobilization of the water it brings becomes an important issue. With the periods of drought that can be experienced even in humid countries, the concern for collecting runoff water and reusing wastewater to replenish the groundwater becomes major, particularly with the excessive exploitation of these. Indeed, in 2010, an annual withdrawal of 1000 km^3 is estimated, representing nearly 10 % of groundwater [1]. This overexploitation can lead to the drying up and degradation of groundwater, and coastal aquifers can suffer from the phenomenon of marine intrusion.

We know that 67 % of groundwater withdrawals are intended for irrigation, 22 % for domestic needs, and 11 % for industry [1]. When estimated that by 2050 environmental flow limits will be reached for approximately 70 % of catchments in which there is groundwater pumping worldwide [2], one understands the need to preserve this resource for sustainable development and protection of the ecosystem.

Artificial recharge allows the replenishment of groundwater or the storage of water in it, it also helps to fight against marine intrusion into coastal groundwater. The Korba-Mida groundwater, Cap Bon in Tunisia, has seen its waters degraded by marine waters, but thanks to artificial recharge by wastewater, water quality improved again [3]. Even though the purposes of charging are different, it is still widely used around the world. In the United States, to fight against marine intrusion into the coastal aquifers of California and their drawdown, the first artificial recharge facilities appeared in 1895 [4]. In the Netherlands, 5 % of drinking water needs are met by recharging [5], while those of Berlin (Germany) are met at 60 % [6]. In Tangier (Morocco), infiltration basins allow the storage of 1 million m^3/year [4]. In Algeria, the Mitidja plain aquifer, very exploited and subject to marine intrusion, is the object of various means of recharge: injection wells, infiltration basins, spreading, dam releases, and use of sewage [7].

Among the techniques used to recharge aquifers, dam releases are a good way. Indeed, in Tunisia, between 1988 and 1996, 70 million m^3 were released by the large dam built on the Zeroud wadi to recharge the Kairaouan plain aquifer [8]. In Algeria, the Ghrib and Deurdeur dams recharge the alluvial aquifer of wadi Cheliff, while the Boukerdane dam recharges the aquifer of wadi Hachem [7].

The construction of the Kef Eddir dam on the wadi Damous stream retains water, and the many wells for irrigation are lowering the level of the water table. This overexploitation, seen in all aquifers on the Algerian coast, causes the Damous wadi aquifer to be contaminated by seawater [9], [10]. The flow, naturally toward the sea, is reversed in certain areas, and the sea water spreads several kilometres inland. Releases from the Kef Eddir dam scheduled throughout the year can replenish the aquifer and reduce the degradation of its waters. The objective of this study is to assess the impact of these releases on the recharge of this aquifer.

2 STUDY REGION AND WORK METHODOLOGY

2.1 Presentation of the site

Damous is a town in the wilaya of Tipaza located in northern Algerie, 68 km west of Algiers (Figures 1 and 2). Tipaza is a coastal wilaya with an agricultural vocation. The climate is of Mediterranean type with a warm season from May to September and a rainy and humid season from October to April [11]. The average annual rainfall is 567.30 mm, and the average annual temperature is 17 °C [12].

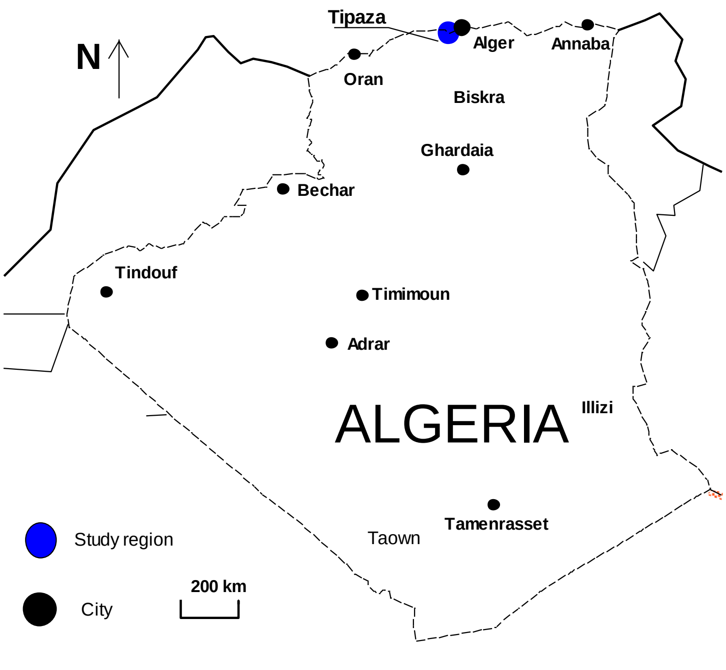

Figure 1. *Situation of the la wilaya of Tipaza*

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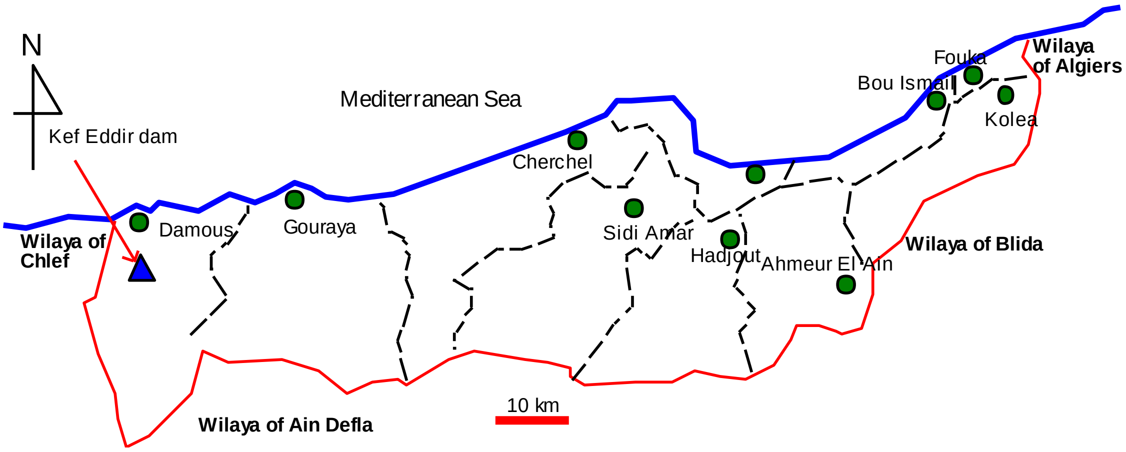

Figure 2. *The town of Damous*

The geomorphology of northern Algeria is dominated by reliefs, with steep slopes and an essentially marly lithology with little or no permeability, which disadvantages it in terms of groundwater except for the vast plio-quartenary alluvial plains [9]. These formations cover the alluvial terraces of the main wadis of the wilaya of Tipaza (Mazafran, El Hachem, Nador, Messelmoune, and Damous). The alluvial deposits of the wadi Damous aquifer referred to in this study are of carbonate origin; the geophysical study by the electrical method of 1966 showed a thickness of 50 to 60 m in the north with resistivity indicating a fine material, in the centre, the thickness is 20 to 30 m while in the south, the alluvium is coarse and resistant. The part that constitutes the most interesting aquifer is north, at the mouth of the wadi [12].

The Kef Eddir (Figure 3) is an earth dam built on the Damous wadi. The dam has a capacity of 125 million m^3 and regulates 57.4 million m^3 annually [13]. It is intended to meet the drinking and irrigation water needs of the wilayas of Tipaza, Ain Defla, and Chlef [13].

Figure 3. *Kef Eddir dam in the wilaya of Tipaza*

The dam watershed has an area of 482 km^2 [13] and an average slope of 2 %. The drainage density is 2 km/km^2 [14].

2.2 Methodology

For the good management of the Kef Eddir dam, and in order to evacuate the stored mud and avoid blocking of the bottom valves, and also on the request of the farmers of the city of Damous, to allow the supply of their wells for irrigation of crops, releases are carried out. For example, between November 2016 and December 2018, a volume of 152 million m^3 was released. These openings of the gates (Figure 4) of the dam allow artificial recharge of the water table.

Figure 4. *Releases from the Kef Eddir dam*

We followed the releases of March 2020 and May 2021 and tried to estimate their impacts on the piezometric level of the water table. Field trips were scheduled before the releases, during the flow caused by them, and after the releases, to measure the piezometry of the water table with a manual piezometric probe (Figures 5 and 6). The dates of the trips are in Table 1.

Figure 5. *Piezometry measurement*

Figure 6. *Manual piezometric probe*

Table 1. *Outings dates*

Year	1st output	2nd output	3rd output
2020	2 March	18 March	15 April
2021	27 April	28 May	3 June

In March 2020, a volume of 0.610 million m^3 was released on 5, 6, 9, 10, 11, 12, 13, 16, 17, 18, 19, 25, and 27, and the measurements concerned 13 wells, while in May 2021, the volume released on 3, 6, 11, 12, 17, 20, 24, and 28 was 0.484 million m^3, and the number of wells was 18. These are traditional wells that can be operated by several farmers. They are located along Damous wadi (Figure 7). Table 2 shows increasing distances of particular wells from the dam. It should be noted that seven wells are common for both years, which allows us to make a comparison of groundwater recharge between the two releases.

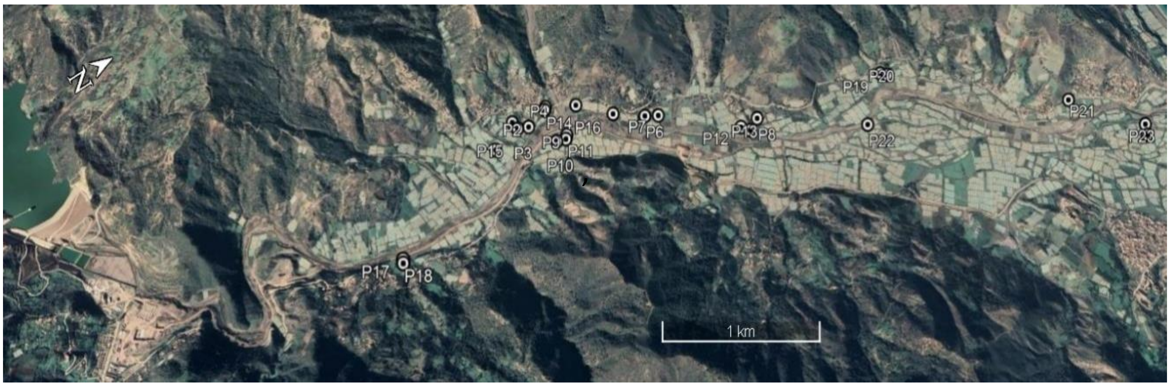

Figure 7. *Situation of the wells*

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Table 2. *Positions of wells relative to the dam*

Wells	**P17**	**P18**	**P15**	**P1**	**P2**	**P3**	**P4**	**P9**	**P14**	**P10**	**P11**	**P5**
d (km)	2.4	2.4	3.1	3.2	3.2	3.4	3.5	3.5	3.5	3.6	3.6	3.8
Wells	**P16**	**P6**	**P7**	**P13**	**P12**	**P8**	**P22**	**P19**	**P20**	**P21**	**P23**	**P24**
d (km)	3.9	4.2	4.3	4.9	5	5.1	5.8	6	6.1	7.3	7.8	7.9

In May and June 2022, although there were no releases during this period, we still measured the piezometry and pushed our investigations by taking water samples from six wells (wells no. 1, 2, 19, 21, 23, 24) to measure the conductivity and compare it to that of the dam water.

3 RESULTS AND DISCUSSION

As already mentioned, to monitor each release, three outings have been scheduled. The first outing allows us to diagnose of the state of play, the second during the flow obtained thanks to the releases, and the last one after the exhaustion of the flow. These outings made it possible to assess the effect of infiltration on the piezometric level of the wadi Damous aquifer and to see if the recharge maintains in time.

The measurements of the depth of water presence in the aquifer during the three outings are represented by histograms (Figures 8 and 9). Figure 10 shows the well loading for March 2020 and May 2021. On this last graph, the wells are positioned from the closest to the farthest one from the dam.

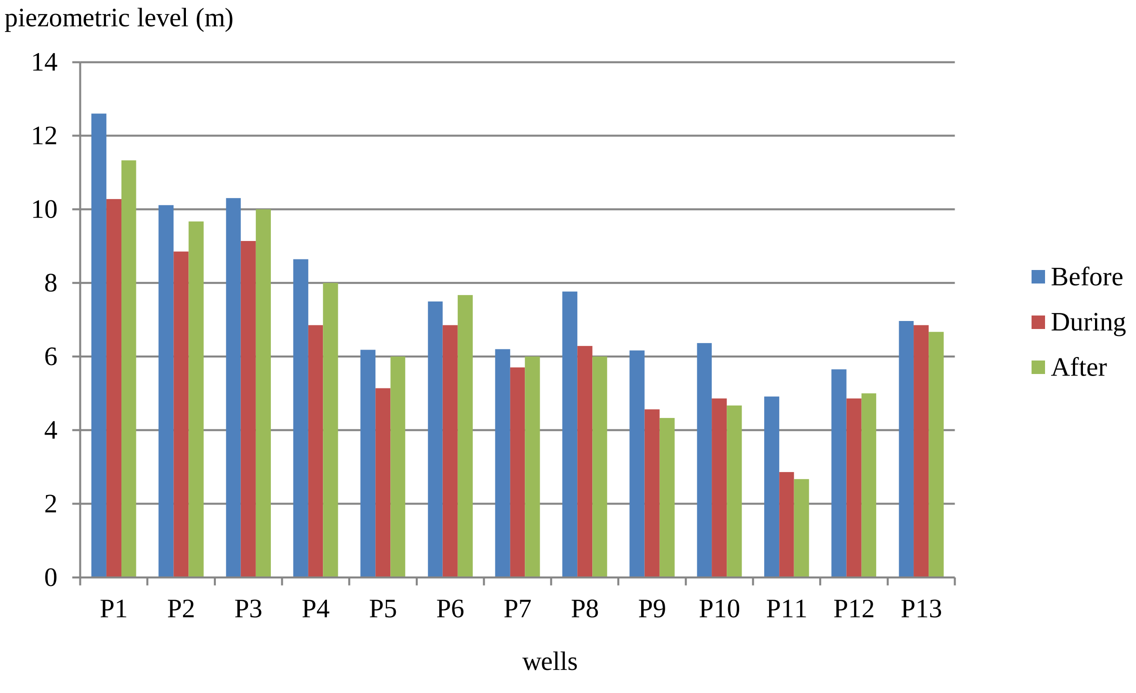

Figure 8. *Piezometric level of wells (before, during and after) for March 2020*

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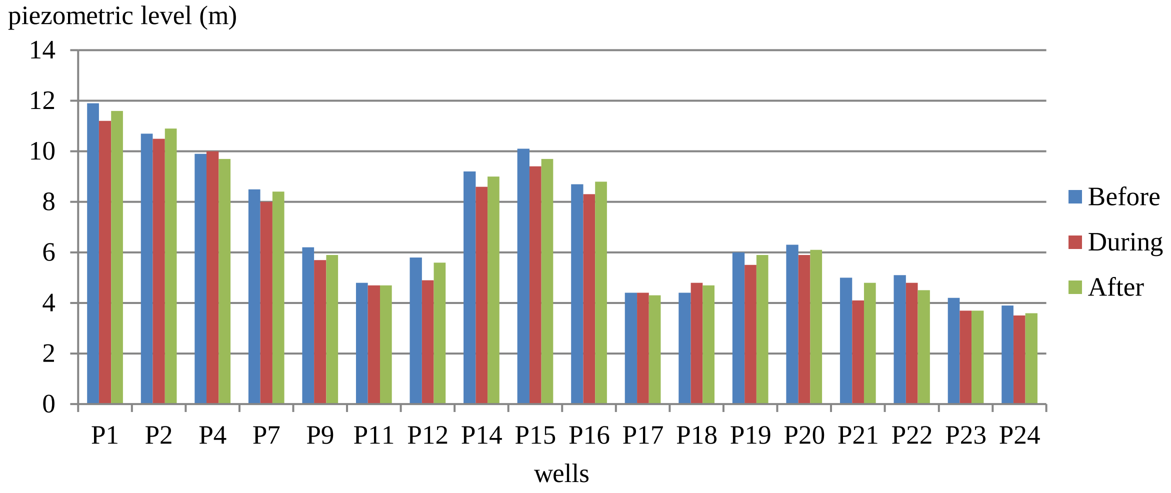

Figure 9. *Piezometric level of wells (before, during and after) for May 2021*

What is noted during the first outing and for the two years (2020 and 2021) is that the wadi bed is dry. The water level in the 13 wells of the year 2020 is more than 5 m, except for well 4 (4.92 m). For wells 1, 2, and 3, the water is at a depth that exceeds 10 m.

The same observation applies for the year 2021 for the 18 wells concerned, the depth of the water is between 3.9 m and 11.9 m, with three measurements (wells no. 1, 2, 15) that exceed the 10 m, and only 5 wells out of the 18 wells of this year 2021 are below 5 m.

After the releases, and therefore following the infiltrations, the measurements of the second outing naturally showed an improvement in the piezometric level of the water table. This improvement is the result of a recharge (Figure 10) that varies from about 10 cm to more than 2 m for the year 2020. This recharge is significantly better for the wells located near the dam. In May 2021, this recharge is slow, and this clearly appears for the seven common wells. The recharge in 2021 varies between 0 and 0.9 m. It should be noted that the volume released in 2021 is lower compared to that of 2020. The water from dam releases contains silt that, in the long term, can reduce the soil infiltration capacity. After this second outing, the water remains above 5 m for nine wells for the year 2020 and ten wells for 2021.

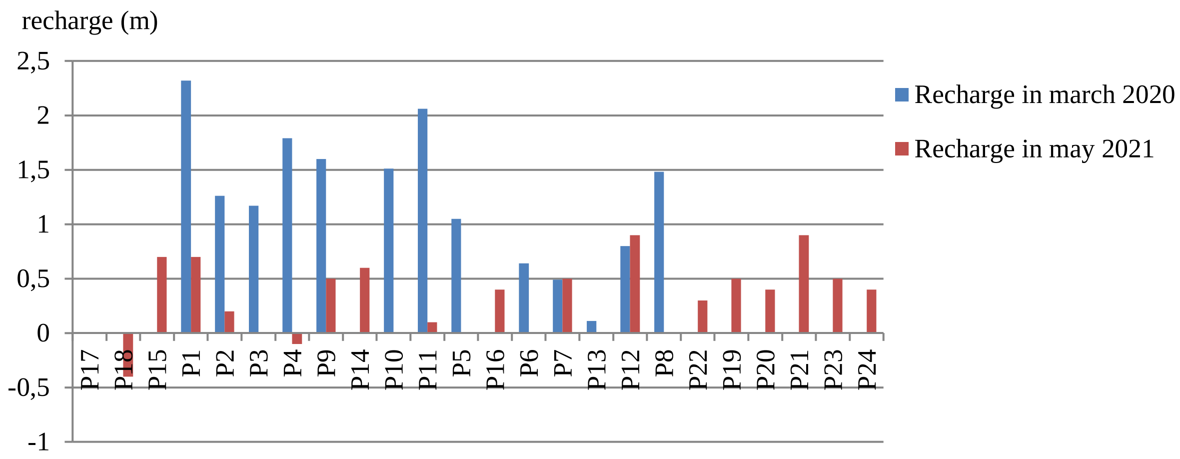

Figure 10. *Recharge of wells*

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The question we asked ourselves is: is this recharge, even if it is not very important, maintained knowing that the releases are a good opportunity for farmers to irrigate their crops thanks to the recharged wells?

After the releases and following the exploitation of the groundwater, the depth of the water presence drops again. Measurements of the third outing of 2020 show that improvement remains maintained for the majority of the wells, and the water is at a shallower depth than before the releases, but compared to the second outing (during), six wells out of the thirteen recorded a decrease of around 1 m. For 2021, this replenishment tends to cancel out and is only from 10 to 30 cm; the water level tends towards the initial level (before the releases).

The piezometry of the wells that were monitored during these three years, shown in Figure 11, shows a clear improvement for wells no. 1 and 2, but for the other wells (located near the sea), we note a stability or even a drop that can reach 2 m (well no. 7 between 2020 and 2021, and well no. 24 between 2021 and 2022).

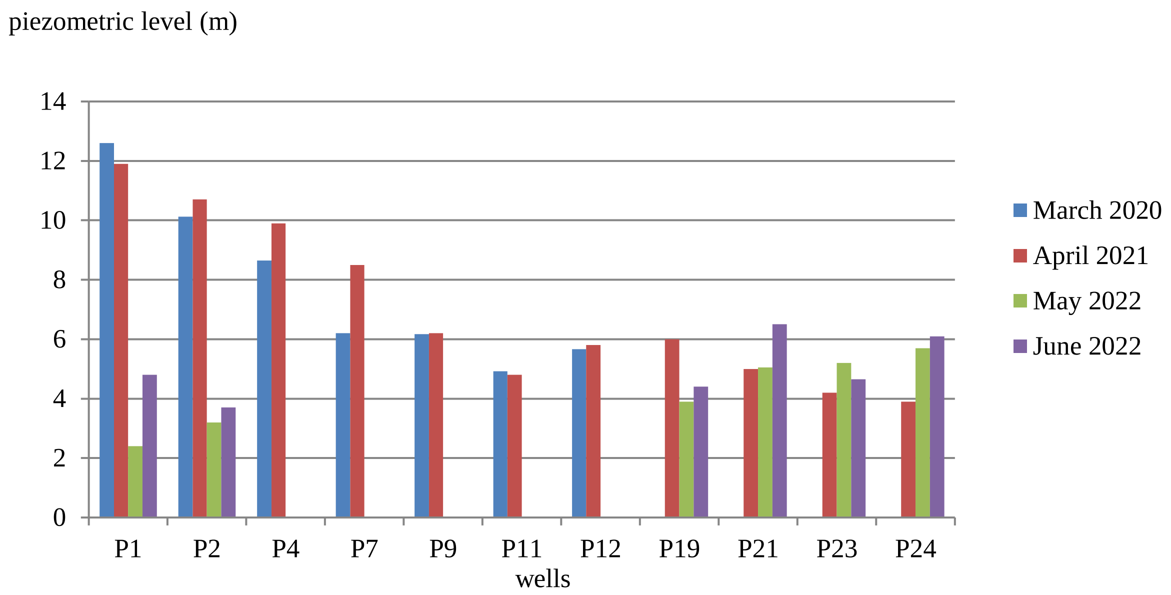

Figure 11. *Piezometric level for March 2020, April 2021, May 2022, and June 2022*

The very high conductivity of the water sampled from six wells in May and June 2022 compared to that of the dam (1000 µs/cm) indicates a salinity of the groundwater, particularly for the wells located near the sea (19, 21, 23, and 24) where it exceeds 2000 µs/cm (Table 3). This salinity is due to seawater intrusion following the drop in the level of the water table. It is noted that in the interval of one month, this conductivity continues to increase, hence the need for replenishment of the aquifer.

Table 3. *Conductivity of the water of wells and dam*

	P1	P2	P19	P21	P23	P24	Dam
Conductivity in the month of May 2022 (µs/cm)	1583	1608	2014	2422	2200.78	2300.42	1046
Conductivity in the month of June 2022 (µs/cm)	1622	1655	2058	2570	2399	2353	

4 CONCLUSION

Artificial recharge makes it possible, through the various techniques it offers (settling basins, injection wells, releases from dams, etc.), to optimize the infiltration of water into the ground where it is stored.

The Kef Eddir dam, located in the wilaya of Tipaza, schedules periodic releases to allow replenishment of the Damous wadi aquifer. To estimate the impact of these releases on the piezometric level of the wadi Damous aquifer, the releases of March 2020 (0.610 Mm^3) and May 2021 (0.484 Mm^3) were monitored. The depth at which the water was found was measured for 13 wells in 2020 and 18 wells in 2021. This operation was performed before, during, and after releases. In May and June 2022, the piezometry of six wells was also measured, and samples were taken to measure the conductivity of the water.

This short monitoring of three years of the wadi Damous aquifer has shown that releases from the Kef Eddir dam throughout the year make it possible to maintain the stable level of the aquifer, but at depths that can exceed 5 or even 10 m. These depths indicate excessive exploitation of the aquifer and have also led to its contamination by seawater.

The exploitation of the Damous wadi aquifer must be closely monitored. Releases from the Kef Eddir dam remain insufficient and must be supported by other replenishment techniques to maintain this water table at an acceptable level and to reverse the marine intrusion process that pollutes its water.

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