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Evolution of Pumping and Piezometry of the Carboniferous Aquifers, Western Border of Air Massif: Case of the Tarat Aquifer in the Arlit Sector

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ABSTRACT

The Tarat aquifer provides drinking water for the population of the city of Arlit and also provides water to industries. The exploitation of this aquifer has considerably increased in recent years. The main objective of this study is to contribute to a better understanding of the functioning of the Tarat aquifer. Thus, a methodological approach focusing mainly on the piezometric study and the analysis of evolution and estimation of the volumes of water pumped, since its development from 1969 to 2012, which has resulted in highlighting not only a general decline in the level of the Tarat aquifer, but also the piezometer level (Arli_182), reacts strongly to the solicitations of the aquifer. On this same piezometer, the water table was lowered by 30 m from 1980 to 2006 (26 years), so a drawdown of 0.86 /year.

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1. Introduction

The western edge of the Air massif, known as the Tim Mersoï basin, constitute sedimentary deposits from Paleozoic to Cretaceous, which is a semi-arid region [1]. Despite the scarcity of surface water, the locality of Arlit has considerable groundwater resources and contains important uranium deposits [1]. This uranium potential has been exploited by two mining companies since the late 1970s. The exploitation of this uranium resource has been accompanied by excessive pumping of the Tarat aquifer to ensure the supply of drinking water for the population, but also for industrial use.

The increase in uranium production in recent years (from 2620 tons in 2010 to 3065 tons in 2012), followed by a strong demographic explosion in the city of Arlit and Akokan, has resulted in an increase in the demand for drinking water for the population and also for industrial use.

This strong pressure on the aquifer, firstly for the supply of drinking water to the population and then for mining activities, has led to a significant drop in the piezometry of the aquifer since it was first exploited [2, 3]. The Tarat aquifer is non-renewable, so its sustainability is directly dependent on the flow taken. Rational and sustainable exploitation of this resource is necessary and requires an understanding of the hydrodynamic functioning of this fossil aquifer. The main objective of this study is to analyze the evolution of the pumping and the piezometry of the Tarat aquifer.

2. Location of the Study Area

Located in the north-eastern part of the country of Niger, more precisely between longitudes 7°15' and 7°30' East and latitudes 18°30' and 19° North (Fig. 1).

The climate is of desert type, hot arid, characterized by a high temperature with an annual average of 28.7 °C [4]. Daytime temperatures are high with a thermal amplitude that can reach 30°C in exposed areas [5].

The winds associated with the high temperatures are responsible for high evaporation. In this region, the wind is the main source of transport of eroded material [6]. A study of local wind directions shows a strong predominance of northeast winds and to a lesser extent southeast and southwest winds [7].

2.1. Geological Context

The Tim Mersoï basin is the northeast extension of the lullemeden syncline [8-12]. It is limited to the east by the Air massif, to the north by the Hoggar massif, and to the west by the In Guezzam ridge. It extends into Algeria where it is called the Tin Serririne basin [12]. (Fig. 1). The oldest sedimentary series are of Cambro-Ordovician age (Jouliia, 1959) and part of the basin contains a sedimentary cover with ages ranging from Devonian (Teraghy sandstone) to Lower Cretaceous (Tegama group). Four major families of faults are recognized in the Tim Mersoï basin. These are the N0° fault system known as the Arlit fault, the N30° fault system of Madaouéla, the N70°- N80° Tin Adrar beam and the N130° N140° faults [14, 15].

The litho-stratigraphic column of the Tim Mersoï basin (Fig. 2) comprises two sequences: (i) a lower sequence represented by the carboniferous grey formations (Farazekat, Talak, Guézouman, Tchinezogue, Tarat, Madaouéla and Arlit) and (ii) a summit sequence corresponding to the red formations of Permian age (Izégouande, Tejja Tamamat, Moradi) to Jurassic (Téloua) [13, 17-19].

2.2. Hydrogeological Context

In the Arlit region, three permeable horizons are encountered, constituting an aquifer system comprising the following water tables from bottom to top [20, 21].

Guézouman Aquifer

The wall of the aquifer is constituted by the Talak formation composed of very thick clay (100 to 200 meters), and its roof is constituted by the Tchinezogue formation, (very fine sandstone to silty) also impermeable. We can

thus consider that the water table of Guézouman is independent of the sub and overlying water tables. The thickness of the Gezouman varies from 30 to 70 meters for an average value of 40 meters. [21].

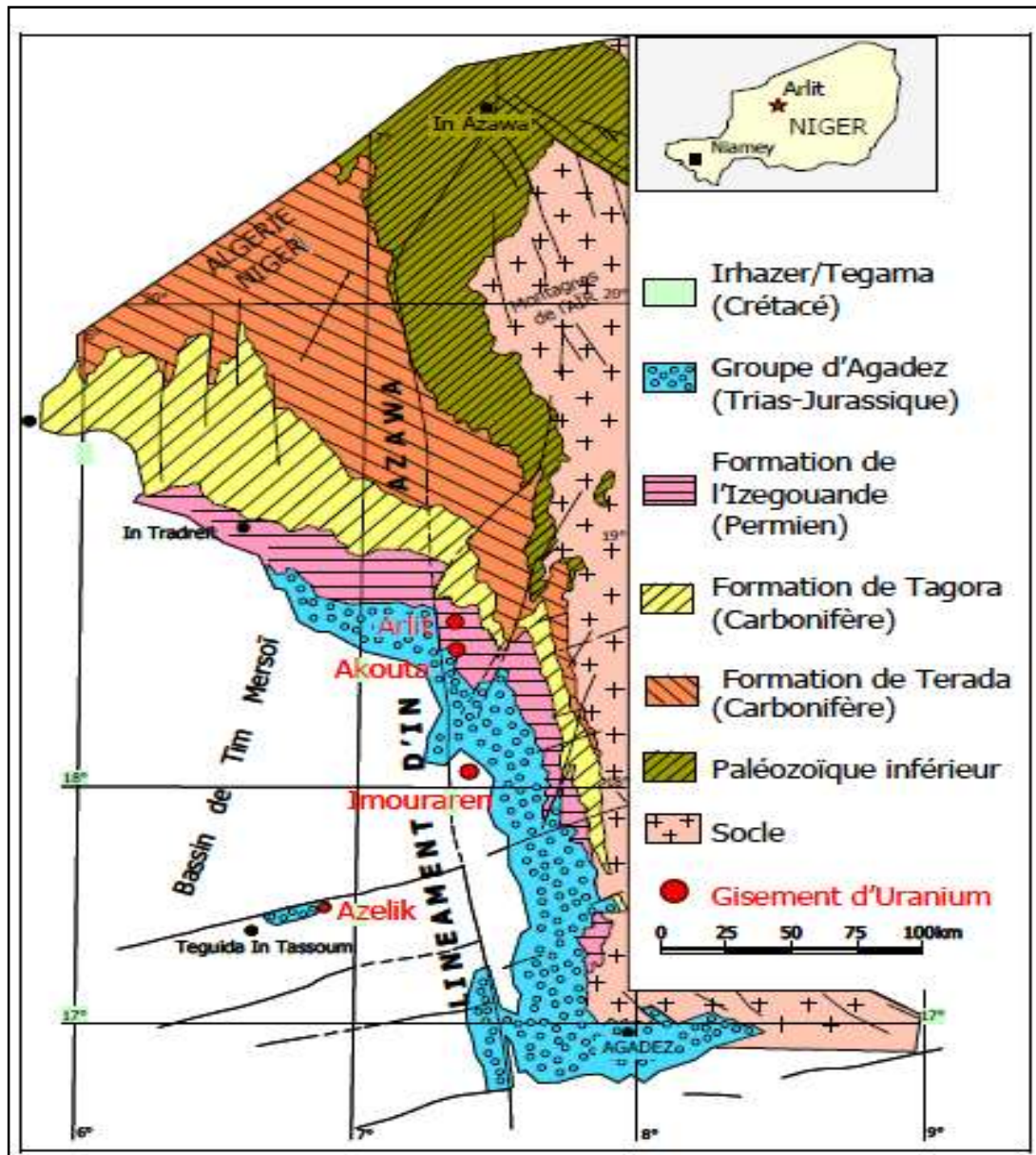


Figure 1: Geological map of the western edge of the Air [16].

Transmissivities are also low, ranging between $1.5 \cdot 10^{-6}$ and $1.8 \cdot 10^{-4}$ m²/s. The coefficients of storage are homogeneous values around $4.5 \cdot 10^{-5}$ [22].

Tarat Aquifer

The aquifer is formed by the entire basic sandstone series of the Tarat formation. The power of the aquifer is subject to very large variations due to both tectonic structures and the mode of sedimentation related to the energy of the depositional environment. The Tarat nappe is limited to the North and East by its extension limit and to the West by the Arlit fault. The permeabilities are between $7.8 \cdot 10^{-7}$ and $1.2 \cdot 10^{-4}$ m/s with a majority of values between $5.6 \cdot 10^{-6}$ and $1.1 \cdot 10^{-5}$ m/s. As for the transmissivities, they vary from $7.4 \cdot 10^{-5}$ to $1.1 \cdot 10^{-3}$ m²/s; and the storage coefficients are of the order of 10^{-5} [22].

ÈRES	PÉRIODES	ÉPOQUES	GROUPES	FORMATIONS OU UNITÉS ET ÉCHELLE		COLONNE LITHOLOGIQUE			DESCRIPTION SOMMAIRE DES FACIÉS	PRINCIPALES NAPPES
						Arg.	Grès Calc.	Ggr.		
PALÉOZOÏQUE SUPÉRIEUR	Jurassique	sup.	Grès. D'Agadez	F. Abrek	1000				Nappe de Tèloua	
		moy.		F. Tèloua 1						
		inf.		F. Tèloua 2						
		Trias		F. Tèloua 1	1400					
	Permien	Izégouandane		F. Moradi					Nappe d'Izégouande	
				F. Izégouande	1200					
		Tagora	sup.	U. Arlit						Nappe de Tarat
				Madoouéla						
				Tarat	1000					
			inf.	Blanchâtre						
				Guézouman						
				Unité d'Akokan						
		Viséen	sup.	F. Talak	800				Nappe de Farazekat	
			inf.	Farazekat						
		Toum.								Nappe de Guézouman
Dévo-nien	sup.	Térida inf.	Amesgueur	600				Nappe de Farazekat		
	moy.		Touaret							
	inf.		Ilekel							
PALÉOZOÏQUE INFÉRIEUR	Silurien	Schistes à Graptolites		400				Nappe de Farazekat		
	Cambro-Ordovicien	In-Azaoua	F. d'In-Azaoua					Nappe de Farazekat		
			Tindi	300						
			Timesgar					Nappe de Farazekat		
PRÉCAMBRIEN										

Figure 2: Litho-stratigraphic column of the Tim Mesroi Basin, a Western ridge of Air massif [7].

Izégouande Aquifer

The aquifer is constituted by the entire Izégouande formation. However, some tests carried out in the north of the Arlit area have shown that the water table is sometimes contained in the small lenses of arkosic sandstone, lenses that are especially abundant towards the base of the formation [23]. The water table then behaves like a loaded water table even when the formation is outcropping. The permeabilities K are low and range from 1.2×10^{-6} to 7.5×10^{-7} m/s. Transmissivities T are also low and range from 1.10^{-4} to 7.8×10^{-5} m²/s. [24].

3. Materials and Methods

3.1. Materials

In this study, pumping data from (12) boreholes (8 boreholes for drinking water, and 4 boreholes for industrial water) with monthly monitoring from 1969 to 2012 were used. In addition, data from (2) two piezometers (Arli_167 and Arli_182) with monthly piezometric levels from 1976 to 2012 were used. The computer tools for processing the data, mainly Microsoft Excel 2013, the working materials: A piezometric probe, a digital camera, a GPS In this study, pumping data from (12) boreholes (8 boreholes for drinking water, and 4 boreholes for industrial water) with monthly monitoring from 1969 to 2012 were used. Water volume are measured monthly and calculated per year in cubic meters.

In addition, data from (2) two piezometers (Arli_167 and Arli_182) with monthly piezometric levels from 1976 to 2012 were used. The piezometric levels are measured monthly and calculated per year in meters. The computer tools for data processing are, mainly Microsoft Excel 2013. As equipment, it was used a piezometer probe to measure the water level in an aquifer in each piezometer. A GPS was also used to record the coordinates of each piezometer and its altitude in m.

3.2. Method of Processing Pumping and Piezometric Data

The piezometric level represents the absolute altitude of the surface of the water table. It was determined by subtracting, for each water point, the static level from the altitude of the ground surface (casing sides). The elaboration of the graphs was done with Excel.

The volumes of drinking water and industrial water have been determined from the measurements of the electronic meters installed at the end of the wells, and these values are recorded automatically. The methodology also consisted in determining the maximum and minimum values as well as the average volumes of water pumped from 1969 to 2012.

The piezometric level represents the absolute altitude of the water table. It was determined by subtracting, for each water point, the static level from the altitude of the ground surface (casing sides). Then the maximum and minimum values, as well as the averages, were determined for the two piezometers. The elaboration of the graphs was done with Excel.

4. Results and Discussions

4.1. Pumping in the Tarat Aquifer

The Tarat aquifer is exploited mainly in the eastern compartment of the Arlit fault through drilling for drinking water (AEP) and industrial water (AEI), as well as for mining.

The annual evolution of drinking water withdrawals (AEP) (Fig. 3) shows that:

The Tarat aquifer is exploited mainly in the eastern compartment (located east of the Arlit fault flexure), through drilling for drinking water (PEA) and industrial water (IEA), as well as for mining. For drinking water, the values vary from 34400 m³ to 4095104 m³ and an average of 2329970.97 m³. For industrial water, the values of pumped water volumes are between 0 and 2999254 m³ and an average of 1465147.36 m³.

The annual evolution of drinking water withdrawals (PEA) (Fig. 3) shows that:

- ✓ The period from 1969 to 1974 the withdrawals are low because these years correspond to the beginning of the mining activities.
- ✓ From 1974 to 1989, withdrawals increased to reach a maximum in 1989 (7.476.870 m³), due to the strong attraction of the population to the mining areas, which led to the creation of the town of Arlit.
- ✓ From 1989 to 2012, withdrawals have a downward trend, with the minimum reached in 2010 (3.062.811 m³), due to the adoption of a sustainable development policy in 2002 by the mining companies (through awareness campaigns on water management, water cut-off from 11 p.m. to 4 a.m.), and also due to the exploitation of the Izéguande aquifer. The latter constitutes an alternative for the water needs of the population [23].
- ✓ The production of drinking water is currently provided by eight (8) wells, five (5) of which capture the Tarat aquifer and three (3) that of Izéguande (AMAN, 2012b). The wells have provided cumulative water of about 2.080.184 m³ (23.682 m³/h) for the year 2013, 46% of which comes from the Tarat.

With regard to industrial water withdrawals (EI) (Fig. 3), it is apparent that:

- ✓ From 1971 to 1977 the withdrawals are relatively low with a maximum of (1.082.408 m³). These years correspond to the beginning of mining activities.

From 1977 to 1989, industrial water withdrawals increase by a maximum of (2.689.091 m³) in 1983. These years coincide with the increase in uranium production.

- ✓ From 1990 to 2005, withdrawals fell as a result of the drop in production.
- ✓ Beginning in 2006, withdrawals increased to reach a maximum in 2012 (3.062.811 m³) with the increase in record production by SOMAÏR, which reached 3065 tons of uranium. This indicates that the amount of industrial water is closely linked to the production of ore.

In addition, the discrepancy between the quantity of water (EI and AEP) is explained by the fact that only the industrial water pumped from the wells was considered. The accumulation of water from mine drainage was not presented.

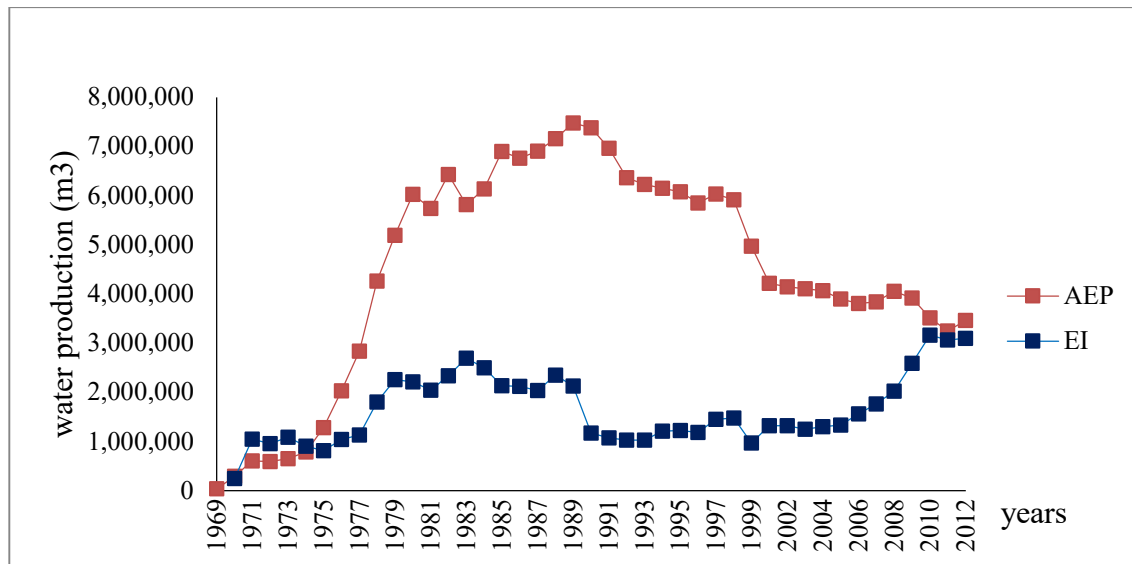


Figure 3: Evolution of annual water production for Arlit and AEI.

4.2. Evolution of the Piezometry

We have examined the temporal evolution of the piezometric level for a certain number of piezometers including among others: Arli_167, Arli_186, at the date of December 31 for the corresponding years on the different graphs. In the Arli_167 piezometer, the values of the piezometric level vary from 368.88 m to 388.43 m, and an average of 378.34 m. Thus, these are the values of piezometric levels recorded in December of the different years. The recorded reactions are illustrated in Figures (4 and 5) below.

On the graph (Fig. 4), the evolution of the piezometric level of Arli_167 located in the North of the mine of Ariège and Arlette shows a tendency to decrease. This decrease began in 1980, the year during which the Ariège mine was in operation, and persisted until 2009. However, in 2000, this downward trend was accentuated due to the transformation of the Ariège mine into a pit for the production of industrial water. Moreover, the most important decrease was observed in 2006 with a slight increase in 2008. This can be explained by the fact that 2006 corresponded to the surge in the price of uranium, resulting in an increase in industrial water withdrawals. The Arli_167 piezometer reflects the general trend of the water table in this sector.

The graph in Figure 5 shows the evolution of the piezometer Arli_182 located south of the Ariège mine. In the Arli_182 piezometer, the values of the piezometric level vary from 342.51 m to 374.95 m, and an average of 356.58 m. The graph shows a continuous and generalized fall of the water table. The decrease started in 1980 and continued until 2009. Thus, the level of Arli_182, reacts strongly to the solicitations of the water table. On this same piezometer, the water table has been lowered by 30 m from 1980 to 2006 (26 years), that is to say, a lowering of 1.15/year.

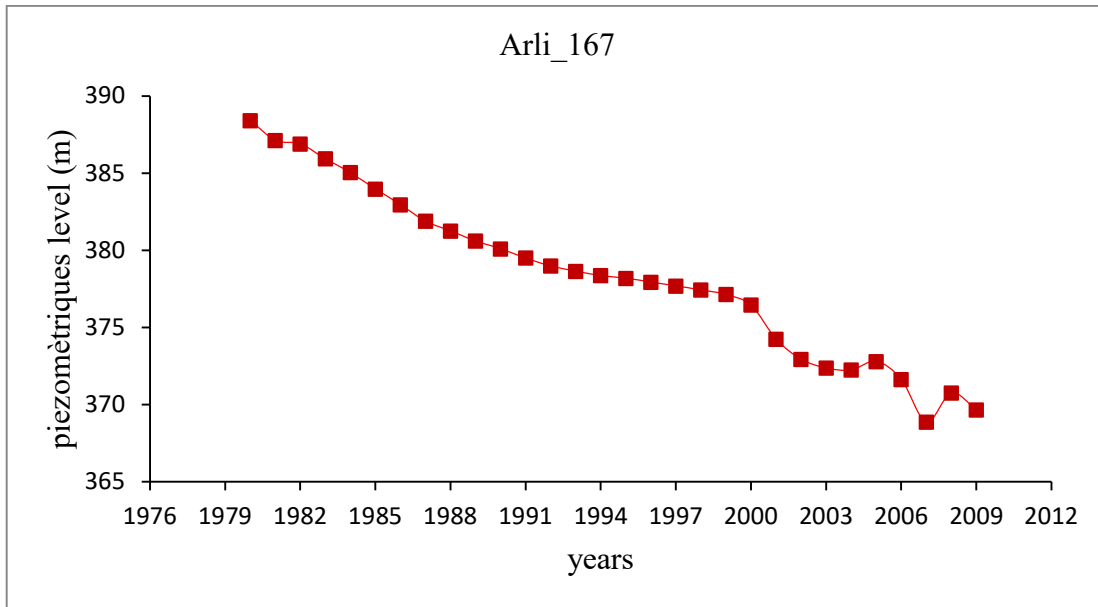


Figure 4: Evolution of the piezometric levels in the piezometer Arli_167.

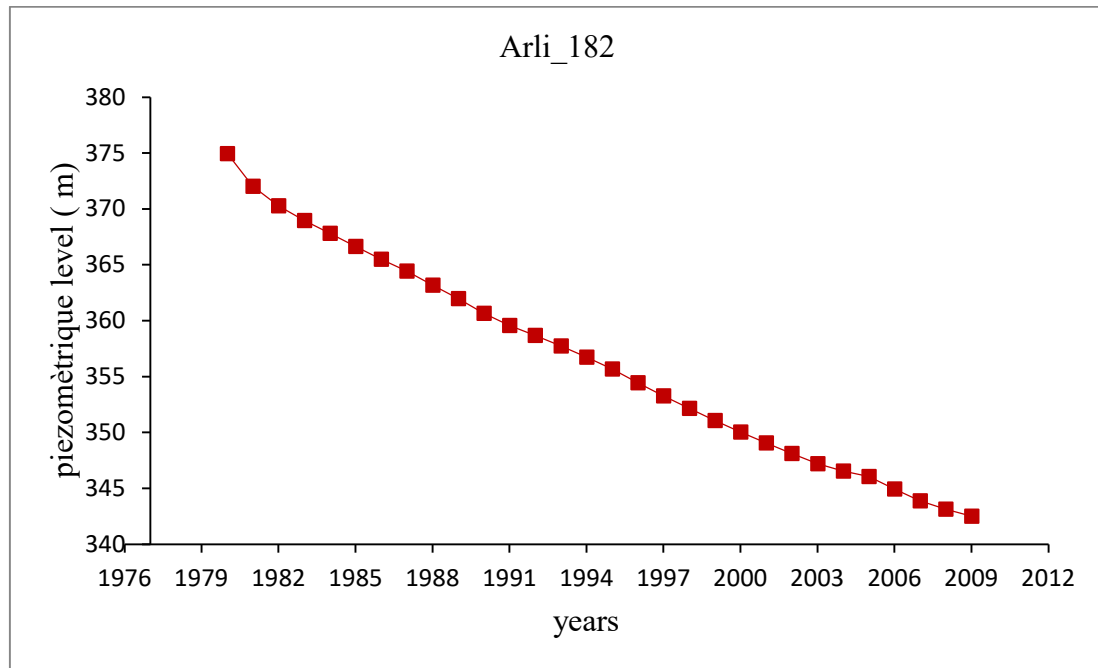


Figure 5: Evolution of piezometric levels in the Arli_182 piezometer.

Conclusion

At the end of this work, it appears that the Tarat water table has a general trend, and a continuous decrease according to the pumpings. This decline began in 1980 when the Ariège mine was in operation and persisted until 2009. However, in 2000, this downward trend was accentuated by an increase, and this increase is due to the transformation of the Ariège mine into a pit for the production of industrial water. The level of Arli_182, reacts strongly to the solicitations of the water table. On this same piezometer, the water table has been lowered by 30 m from 1980 to 2006 (26 years), that is to say, a lowering of (30/26), that is 1.15 /year.

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