Origins of Recharge of the Grombalia Groundwater

Rym Mhamdi, Mohamed Mechergui

***Abstract:** The aquifer system of Grombalia is fed directly by the rainfall inputs and indirectly by the inputs of oued and adjacent aquifers. The ground water is submitted to intensive exploitation for irrigation purposes. This situation pushed for the use of hydraulic installations and the practice of artificial recharge (seven recharge sites).*

To see the origins of recharge of the Grombalia groundwater, trend curves must be drawn between the piezometric level and rainfall inputs. The interpretation of these curves allowed us to conclude that there are different zones:

-Areas where the main feed agent for the ground water is rainfall as such as the BeniKhalled area.
-Areas where there are two feed agents for the ground water which are the rainfall and the oued, such as the zones of Douar Ben Attia and Fondouk Jedi.

-Areas where other sources of supply of the ground water and much more powerful than the rainfall such as the zones of MenzelBouZelfa, Bouchrik, CharrayBou, BouArgoub. For the Bouchrik area, it is influenced by the contributions of ouedsidiToumi and the volumes injected into the Gobba1 recharge site. Regarding the Echrifet area, this is the effect of the coastline marked by the accumulation of water in this area. In the Boucharay area, ouedEllomaleh inputs are the main recharge factor for the groundwater. In fact, for the MenzelBouzelfa zone, the main factors of recharge of the ground water are the contributions

Of OuedSidiSaïd and the water injected into the El Amrine recharge site.

-Regarding the area of BouArgoub, OuedBouArgoub contributes strongly to the recharge of the ground water.

***Keywords:** Grombalia plain, groundwater, natural recharge, artificial recharge, correlation coefficient, piezometric fluctuations, and rainfall input.*

INTRODUCTION

The plain of Grombalia is a coastal plain, located in the North East of Tunisia. This plain contains a multi-layer aquiferous system, it consists of three water tables: a groundwater (363 km²) in area (Rekaya, 1993), a semi-deep-water table and a deep water table (Ennabli, 1980).Two types of groundwater supply are to be considered: the direct supply (which comes from the infiltration of rainwater through the permeable layers) and the indirect supply(including the contribution of the oued of the border SE and SW and the contribution of adjacent ground water (Scholler, 1939 and Castany, 1948).The groundwater of Grombalia, which is the subject of this work, is submitted to an intensive exploitation for the purposes of irrigation. This situation pushed for the use of hydraulic installationsstructures and the practice of artificial recharge.

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The purpose of this work is to see the origin of groundwater recharge, to specify the type of recharge in the entire field of study and to see the impact of implemented recharge on the piezometric evolution of the ground water.

This work consists of two parts. The first part will focus on the study of groundwater aquifer characteristics and a presentation of the study area and recharge structures located in the watershed, as well as a description of the methodology and working tools. The second part will cover the piezometric evolution at the level of the piezometers implanted in the aquifer.

PRESENTATION OF THE STUDY AREA:

The plain of Grombalia is about forty kilometers south-east of the city of Tunis. It constitutes the downstream zone of the Oued El Bey watershed. This plain is crossed mainly by OuedBey, it covers an area of 411 km² (El Heni, 2007).

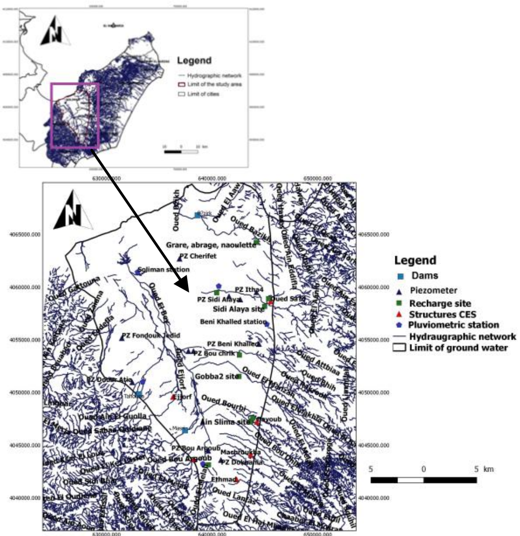

Figure 1: Study area

The Grombalia plain is an important collapse ditch filled by very thick quaternary deposits (500m) (Castany,1948). The Grombalia region belongs to the upper semi-arid level, at mild winter.The average annual rainfall is about 488 mm / year. The average temperature is about 18 ° C. The aquifer system of The Grombalia plain integrates the pre-Quaternary structures (Eocene and oligo-miocene from North East, South East and South West) as well as the Quaternary plain of Grombalia. We thus distinguish within this complex system: a ground water, a semi deep water table and a deep-water table.(Ennabli, 1980).

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➢ **Exploitation :**

Renewable resources were estimated at 214.106m3, of which 33.106m3 for deep water table (Annual book of exploitation of deep water table, 2017, DGRE) and 181.106m3 for groundwater. (Annual book of exploitation of groundwater, 2017, DGRE).The groundwater is exploited by the surface wells (8840 wells).The deep aquifer is captured by the drilling (610 drilling).

➢ **CES structures:** We find the Thres holds in gabions (BouArgoub, GrombaliaetMenzelBouzelfa) and the mechanical benches with main objectives as the protection against floods and the recharge of the ground water.

➢ **Artificial recharge sites of ground water :**The recharge of the GrombaliaGound water is ensured by:

- **basins of infiltration**:There are five sites :
  - ♣ Site Gobba1: This recharge site has an area of 12 ha. It consists of 28 basins. The recharging operation started on November 23, 1992.
  - ♣ Gobba2 site: This site is composed of 21 infiltration basins, covering an area of 4.7 ha. The first water recharge tests took place in 2007.
  - ♣ SidiAlaya site: This site is composed of 28 infiltration basins, built on an area of 1.5 ha. The recharge operation started in 1993
  - ♣ El Amrine site: This site is composed of 6 basins located on an area of 0.18 ha.
  - ♣ BouArgoub site: this site is composed of 19 infiltration basins located on an area of 4.3 ha.
- **Release of the dams :** we have two sites : Site Bayoub **and** Site AinSlima

MATERIALS AND METHODS:

In our work, we used QGIS software version 2.18.14 (Las Palmas).To see the origin and location of natural recharge areas and to study the impact of hydraulic structures on the piezometric level of the Grombalia ground water, one must:

-Draw diagrams for each piezometer representing average piezometric fluctuations and rainfall inputs as a function of time. Indeed, there are 11 piezometers (fig.6) that have been implanted in the groundwater of Grombalia. We will choose 8 piezometer in this study. We will use the values taken from the 4 closest rain stations to these piezometers: Grombalia station, MenzelBouZelfa station, Solimen station and BeniKhalled station (fig.6).For each piezometer, the difference between the piezometric level of the highest water, that is to say the month of May for each agricultural year, and the piezometric level of the lowest waters which is the month of September for the preceding agricultural year (difference between the piezometric level of the month of May of the year (n) and the piezometric level of the year (n-1)), (ΔNP)), and cumulative rainfall from September to May for each agricultural year.

-trace the trend curves for each piezometer.

RESULTS

1-Diagrams representing average of piezometric fluctuations and rainfall inputs as a function of time.

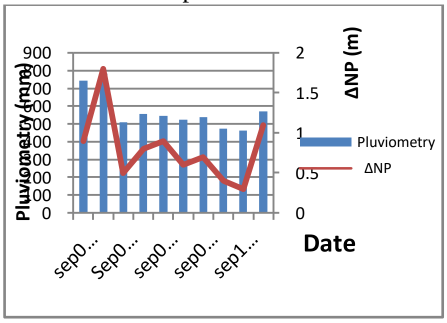

Fig.2:Piezometric fluctuations at the PzBeni khaled and rainfall inputs as a function of time(Benikhaled station)

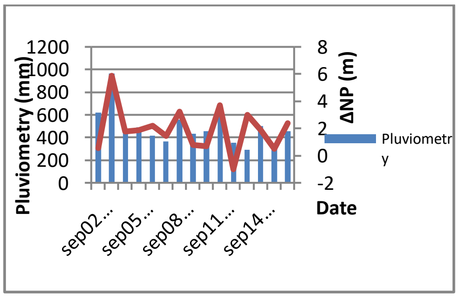

Fig.3:Piezometric fluctuations at DouarAttia and rainfall inputs as a function of time (Station Grombalia)

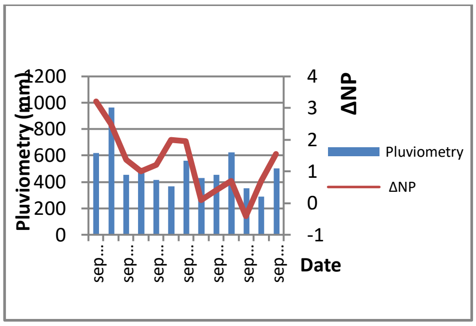

Fig.4:Piezometric fluctuations at the PzFondoukEjdid and rainfall inputs as a functionof time (Station Grombalia)

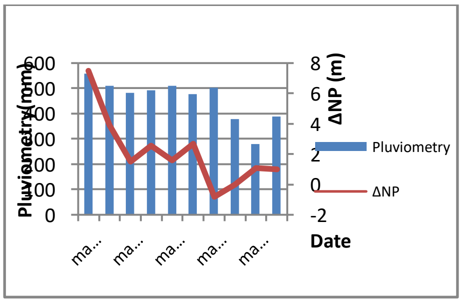

Fig.5:Piezometric fluctuations at the PzBouArgoub and rainfall inputs as a function of time (Station Bou Argoub)

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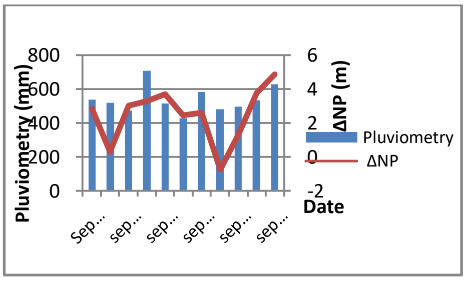

Fig.6:Piezometric fluctuations at the BouCharray and rainfall inputs as a function of time(MenzelBouZelfa Station)

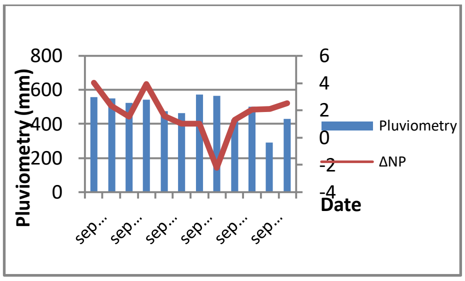

Fig.7:Piezometric fluctuations at the PzBouchrik and rainfall inputs as a function of time (Grombalia Station)

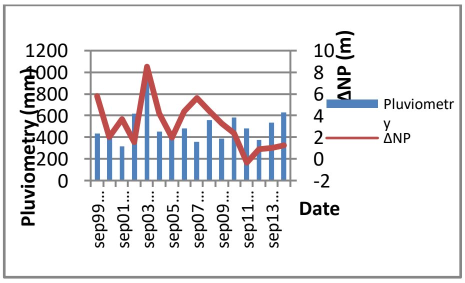

Fig.8:Piezometric fluctuations at the PzMenzelBouZelfa and rainfall inputs as a functionof time (Menzel Bou Zelfa Station)

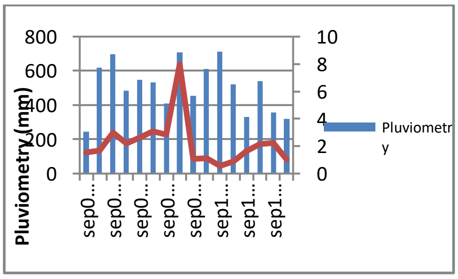

Fig.9:Piezometric fluctuations at the PzEchrifet and rainfall inputs as a function of time (Menzel Bou Zelfa Station)

2-CORRELATION BETWEEN PIEZOMETRIC LEVEL AND RAINFALL INPUTS

Piézomètre	R^2 %	a	b
Beni Khalled	0,719	0,003	-1,144
Douar BnAttia	0,472	0,006	-1,385
FondokJdid	0,424	-0,167	2.421
Bouargoub	0,274	0,014	-4,576
Boucharray	0,200	0,009	-2,59
Bouchrik	0,009	-0,001	2,67
Menzel bouBouzelfa	0,117	0,005	0,642
Echrifet	0,12	0,004	0,173

Tab.1: Table summarizing the correlations of the 10 piezometers.

DISCUSSION:

- **PZ BeniKhalled(n°IRH:12961):** This piezometer is implanted in the sandy quaternary, near ouedAttbiaa.(fig.2). The diagram (fig.2) above show an increase of the piezometric level of 2m in September 2003-May 2004 following an increase of therainfall of 50mm, then a drop of 1.5m following a decrease in rainfall of 280 mm in September 2004-May 2005, which confirms a good association between the piezometric level and the pluviometry. The diagram also shows that in 2006, there was an increase in the piezometric level; despite the rainfall contribution is constant compared to the previous year, which shows that this area is supplied by other sources besides the rain such as the return of the inputs of irrigation water as well as the contributions of ouedEttabiaa.

The trend curve has a correlation coefficient of 72%. (tab.1), this indicates that there is a high correlation between the rainfall inputs and the piezometric level, which is necessarily linked to the sandy geological formation of high permeability. So, we can say that rainfall is the main factor of recharge in the area of BeniKhalled.

- **PZ DouarAttia (12440):** this piezometer is implanted near ouedEttahouna, in theQuaternary of southwestern border of the plain of Grombalia,(fig.3) which is characterized by an alternation of gravel, sand and conglomerates that are favorable to the infiltration of water.The figure indicates conformity between the pluviometry and piezometric fluctuations at the level of this piezometer. The highest rainfall is recorded in Sep2003-May2004 (961mm). It is associated with an elevation of the piezometric level of 5.3m. This rise is followed by a fall in the two variables during the years 2005, 2006, 2007 and 2008. In 2009, there is an increase in the piezometric level of 1.8m following an increase in rainfall of 200 mm. In 2013, despite thedecrease in rainfall of 70mm, there was an increase in piezometry of 4m, this shows that we have other sources of supply of the water such as the contributions of ouedEttahouna and ouedEllouza.The high correlation coefficient of 48% shows thatin this zone the ground water is supplied essentiallyby rainfall, mainly due to Quaternary stratigraphyof the southwestern border of the plain of Grombalia, which is characterized by an alternation of gravel, sand and conglomerates that are favorable to the infiltration of water. This zone (Douar Ben Attia) is also influenced by the contributions of oued such as ouedEttahouna and ouedEllouza draining the hills of the ridge.
- **PZ FondoukEjdid (12405)**: This piezometer is implanted in a formation rich in sand and sandstone. (fig.4). The diagram above shows an increase in the piezometric

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level in 2004 following a rainfall increase of 350mm, then a drop of 1.5m following a decrease in rainfall of 500mm in September2005-May2006, which confirms a good association between piezometric level and rainfall. The diagram also shows two peaks of piezometric increase in 2007 and 2008, although rainfall is almost constant compared to 2006. In 2013, there is an increase in the piezometric level compared to 2012 despite the decrease in rainfall of 60mm. This shows that this area is supplied by other sources such as ouedEddefla. The trend curve shows a good correlation coefficient of 41.9%, (tab.1) since this piezometer is implanted in a formation rich in sand and sandstone. The remaining 60% is due through ouedEddefla and oued El Bey.

- **PZ BouArgoub (13474) :**The diagram (fig.5) shows a first piezometric level drop of 5m in 2007, then a second fall of 3m in 2011 despite the constant rainfall, then a peak in 2013 despite the decrease in rainfall of 130 mm compared to the previous year which confirms that the piezometric level is not dependent on the rainfall, rainfall is a secondary agent for feeding the ground water. The trend curve gives a correlation coefficient of 28% (tab.1) which is in line with the results of the previous diagram despite the high permeability of the sandy geological formation. This confirms that there are others of supply of the tablecloth such as ouedBouArgouband the BouArgoub recharge site. In this zone the pumping of the aquifer is intensive, resulting in an unrecognized rainfall effect.
- **PZ BouCharay (13329):**The diagram (fig.6) shows peaks of rise and falls of the piezometric level which are not dependent on rainfall inputs. For example, in 2012 despite the importance of rainfall, we note that there is a drop in the piezometric level of 3m.The correlation coefficient is low and amounts to 20%, (tab.1), this piezometer is implanted in the lagoon Quaternary represented by sandy clays and sand beds with calcareous intercalations.
- **PZ Bouchrik (13397):**This piezometer is located near the Gobba1 recharge site :This diagram (fig.7) shows that even though rainfall inputs are close, we have an increase of the piezometric level of 2m during the years 2005, 2006, 2007, 2008, and a fall of 4m during the years 2011, 2012, 2013. This proves that piezometry is independent of rainfall. The correlation coefficient is very low: 0.9%,(tab.1)yet the medium value is favorable for infiltration this piezometer is installed in a vast sandy formation distinctly after the recent Quaternary period. This shows that this area is fed by other sources such as OuedSidiToumi and the Gobba1 recharge site.
- **PZ MenzelBouZelfa (12134):**This piezometer is implanted in the sandy quaternary (Monatrien) near the El Amrine recharge site. In this diagram (fig.8), there is a decrease in the piezometric level of 3.8m during the year 2000 compared to the previous year even though the rainfall in 2000 is close to that of 1999.This is due to the important volume injected during the year 1999 (162000 m³), there is also an increase in thepiezometric level of 7m in 2003 compared to theyear 2002 due to an increase in rainfall (350mm).This diagram also shows us an increase of thepiezometric level of 3.5m in 2007 compared to2005. This can be explained by the effect of the artificial recharge at the El Amrine site during this period (167000 m³), rather than a fall until 2012 explained by the cessation of artificial recharge at this site.The trend curve gives a correlation coefficient of 11.7% (tab.1).This average correlation even though it is a sandy zone of high permeability.
- **PZ Echrifet (PZ 12406/2) :** This piezometer is located in the Echrifet zone, in front of the coastline.The diagram (fig.9) shows a peak of the piezometric level in September 2008 - May 2009 which is due to an increase in rainfall (300mm during this period of time compared to the previous year, rather than a fall of 7m between 2009 and 2010 in spite of the importance of the pluviometry contributions. The trend curve gives a correlation coefficient of 12% (tab.1) which is consistent with the results of the previous diagram. This piezometer is located on the fossil dunes of Soliman (Sand and sandstone often very coarse). The low correlation can be explained only by the intensive pumping in this zone, which results in an unrecognized rainfall effect. There is also another main source of recharge in this area which is the effect of the coastal cord located behind the piezometer and that generates a pool of water in this zone.

CONCLUSION:

The interpretation of the diagrams representing piezometric fluctuations at the level of piezometers and rainfall inputs as a function of time as well as the diagrams representing the correlation between the piezometric level of the piezometers and the rainfall inputs, allows us to conclude the following:

-At the BéniKhalled zone, the main recharge factor for the ground water is rainfall.

-At Douar Ben Attia and FondokJdid zones, therains contribute quite strongly to the feeding of thegroundwater We also have other sources of feed, for Douar Ben Attia :ouedEttahouna, while inFondoukJedid :ouedEddefla and El Bey

-At the MenzelBouZelfa, Bouchrik, BouCharray, BouArgoub, Echrifet and SidiAlaya zones, there are other more powerful factors in groundwater recharge (rainfall contributes little to groundwater recharge). For MenzelBouzelfa zone, the main factors of recharge of the aquifer are the contributions of OuedSidiSaïd and the waters injected into the El Amrine recharge site. The Bouchrik area is fed by other sources such as OuedSidiToumi and the Gobba1 recharge site. For the Echrifet zone,; it is the effect of the coastal cord located in front of the piezometer where there is water accumulation in this zone. In the Boucharay area, the contributions of the ouedEllomaleh constitute the main recharge factor for the aquifer. Regarding the area of BouArgoub, the contributions of ouedBouArgoub strongly contribute to the recharge of the ground water.

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