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Geochemical inverse modeling of chemical and isotopic data from groundwaters in Sahara (Ouargla basin, Algeria)

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Abstract

New samples were collected in the three major Saharan aquifers namely, the "Con tinental Intercalaire" (CI), the "Complexe Terminal" (CT) and the Phreatic aquifer (Phr) and completed with unpublished more ancient chemical and isotopic data. Instead of

- ⁵ classical Debye-Hückel extended law, Specific Interaction Theory (SIT) model, recently incorporated in Phreeqc 3.0 was used. Inverse modeling of hydro chemical data constrained by isotopic data was used here to quantitatively assess the influence of geochemical processes: at depth, the dissolution of salts from the geological formations during upward leakage without evaporation explains the tran sitions from CI to CT and
- to a first pole of Phr (pole I); near the surface, the dissolution of salts from sebkhas by rainwater explains another pole of Phr (pole II). In every case, secondary precipitation of calcite occurs during dissolution. All Phr waters result from the mixing of these two poles together with calcite precipitation and ion exchange processes. These processes are quantitatively assessed by Phreeqc model. Globally, gypsum dissolution and calcite
 precipitation were found to act as a carbon sink.
 - 1 Introduction

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A scientific study published in 2008 showed that 85% of the world population lives in the driest half of the Earth. More than 1 billion people residing in arid and semiarid areas of the world have only access to little or no renewable water resources

20 (OECD, 2008). In many arid regions such as Sahara, groundwater is the only source of water supply for domestic, agricultural or industrial purposes, causing most of the time overuse and/or degradation of water quality.

The groundwater resources of Ouargla basin (Lower-Sahara, Algerian; Fig. 1) are contained in three main reservoirs (UNESCO, 1972; Eckstein and Eckstein, 2003; OSS, 2003, 2008):



- at the top, the phreatic aquifer (Phr), located in sandy gypsum permeable formations of Quaternary, is almost unexploited (only north of Ouargla) due to its salinity (50 g L⁻¹);
- in the middle, the "Complexe Terminal" (CT) aquifer, (Cornet and Gouscov, 1952; UNESCO, 1972) which is the most exploited, and includes several aquifers in different geological formations. It circulates in one or two lithostratigraphic formations of the Eocene and Senonian carbonates or Mio-pliocene sands;

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 at the bottom, the "Continental Intercalaire" (CI) aquifer, where water is contained in the lower Cretaceous continental formations (Barremian and Albian), mainly composed of sandstones, sands and clays. It is only partially exploited because of its significant depth.

After use, waters are discharged in a closed system (endorheic basin) and constitute a potential hazard to the environment, to public health and may jeopardize the sustainability of agriculture (rising of the phreatic aquifer watertable, extension of soil salinization and so on; Hamdi-Aïssa et al., 2004; Slimani, 2006). Several previous studies (Guendouz, 1985; Fontes et al., 1986; Guendouz and Moulla, 1996; Edmunds et al., 2003; Guendouz et al., 2003; Hamdi-Aïssa et al., 2004; Foster et al., 2006; OSS, 2008; Al-Gamal, 2011) tried, starting from chemical and isotopic information (²H, ¹⁸O, ²³⁴U, ²³⁸U, ³⁶O) to be at the starting the multi-arity batteries between emified.

²³⁸U, ³⁶Cl) to best characterize the relationships between aquifers. They were more specifically tackling the issue of the Continental Intercalaire recharge. These investigations dealt particularly with water chemical facies, mapped isocontents of various parameters, and reported typical geochemical ratios ([SO₄²⁻]/[Cl⁻], [Mg²⁺]/[Ca²⁺]) as well as other correlations. Minerals/solutions equilibria were checked by computing saturation indices with respect to calcite, gypsum, anhydrite and halite, but processes
 were only qualitatively assessed.

In the present study, new data were collected in order to characterize the hydrochemical and the isotopic composition of the major aquifers in Ouargla' region. They also aimed at identifying the origin of the mineralization and water-rock interactions that



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occur along the flow. New possibilities offered by progress in geochemical simulations were used. More specifically, Specific Interaction Theory (SIT) recently incorporated in Phreeqc 3.0 (Parkhurst and Appelo, 2013) seems now to bridge the gap between the "extended" Debye-Hückel law that is valid only for dilute solutions and Pitzer's model,

⁵ which is mainly used for brines, and which appears now as over parameterized (Grenthe and Plyasunov, 1997). Inverse modeling with Phreeqc 3.0 was used to quantitatively assess the influence of the processes that explain the acquisition of solutes for the different aquifers: dissolution, precipitation, mixing and ion exchange. This results in constraints on mass balances as well as on the exchange of matter between aquifers.

10 2 Methodology

2.1 Presentation of the study area

The study area is located in the northeastern desert of Algeria "Lower-Sahara" (Le Houérou, 2009) near the city of Ouargla (Fig. 1), 31°54′ to 32°1′ N and 5°15′ to 5°27′ E, with a mean elevation of 134 (m a.s.l.). It is located in the quaternary fossil valley of Oued Mya basin. Present climate belongs to the arid Mediterranean-type (Dubief, 1963; Le Houérou, 2009; ONM, 1975/2013). This climate is characterized by a mean annual temperature of 22.5 °C, a yearly rainfall of 43.6 mm yr⁻¹ and a very high evaporation rate of 2138 mm yr⁻¹.

Geologically, Ouargla's region and the entire Lower Sahara consist of sedimentary formations (Fig. 2). The basin is carved into Mio-pliocene (MP) deposits, which alternate with red sands, clays and sometimes marls; gypsum is not abundant and dated from Pontian (MP; Cornet and Gouscov, 1952; Dubief, 1953; Ould Baba Sy and Besbes, 2006). The continental Pliocene consists of a local limestone crust with puddingstone or lacustrine limestone (Fig. 2), shaped by æolian erosion into flat areas (regs).

²⁵ The Quaternary formations are lithologically composed of alternating layers of permeable sand and relatively impermeable marl (Aumassip et al., 1972; Chellat et al., 2014).



The exploitation of Mio-pliocene aquifer is ancient and at the origin of the creation of the oasis (Lelièvre, 1969; Moulias, 1927). The piezometric level was higher (145 m a.s.l.) but overexploitation at the end of the XIXth century led to a catastrophic decrease of the resource, with presently more than 900 boreholes (ANRH, 2011).

- ⁵ The exploitation of Senonian aquifer dates back to 1953 at a depth 140 to 200 m depth, with a small initial rate ca. 540 L mn⁻¹; two boreholes have been exploited since 1965 and 1969, with a total flowrate ca. 2500 L mn⁻¹, for drinking water and irrigation. The exploitation of Albian aquifer dates back to 1956, with a piezometric level 405 m and a pressure 22 kg cm⁻². Presently, two boreholes are exploited:
 - El Hedeb I, 1335 m depth, with a flowrate 141 Ls^{-1} ;
 - El Hedeb II, 1400 m depth, with a flowrate $68 L s^{-1}$.

2.2 Sampling and analytical methods

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The sampling scheme complies with the flow directions of the two formations (Phr and CT aquifers); for the CI aquifer only five points are available, so it is impossible
to choose a transect (Fig. 3). Groundwater samples (*n* = 107) were collected during a field campaign in 2013, along the main flow line of Oued Mya, 67 piezometers tap the phreatic aquifer, 32 wells tap the CT aquifer and 8 boreholes tap the CI aquifer (Fig. 3). Analyses of Na⁺, K⁺, Ca²⁺, Mg²⁺, Cl⁻, SO₄²⁻ and HCO3⁻ were performed by ion chromatography at Algiers Nuclear Research Center (CRNA). Previous and yet unpublished data (Guendouz and Moulla, 1996) sampled in 1996 are used here too: 59 samples for Phr aquifer, 15 samples for CT aquifer and 3 samples for the CI aquifer for chemical analyses, data ¹⁸O and ³H (Guendouz and Moulla, 1996).

2.3 Geochemical method

Phreeqc (Parkhurst and Appelo, 2013) was used to check minerals/solution equilibria ²⁵ using the specific interaction theory (SIT), i.e. the extension of Debye-Hückel law by



Scatchard and Guggenheim incorporated recently in Phreeqc 3.0. Inverse modeling was used to calculate the number of minerals and gases' moles that must respectively dissolve or precipitate/degas to account for the difference in composition between initial and final water end members (Plummer and Back, 1980; Kenoyer and Bowser, 1992;

⁵ Deutsch, 1997; Plummer and Sprinckle, 2001; Guler and Thyne, 2004; Parkhurst and Appelo, 2013). This mass balance technique has been used to quantify reactions controlling water chemistry along flow paths (Thomas et al., 1989). It is also used to quantify the mixing proportions of end-member components in a flow system (Kuells et al., 2000; Belkhiri et al., 2010, 2012).

10 3 Results and discussion

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Tables 1 to 5 illustrate the results of the chemical and the isotopic analyses. Samples are ordered according to an increasing salt content that was estimated from their specific electric conductivity (EC). In both phreatic and CT aquifers, temperature is close to 25° C, while for CI aquifer, temperature is close to 50° C. The results presented in those tables are raw analytical data that were corrected for defects of charge balance before computing activities with Phreeqc. As analytical errors could not be ascribed to a specific analyte, the correction was made proportionally. The corrections do not affect the anions to anions mole ratios such as for [HCO3⁻]/([Cl⁻]+2[SO4²⁻]) or [SO4²⁻]/[Cl⁻], whereas they affect the cation to anion ratio such as for [Na⁺]/[Cl⁻].

20 3.1 Characterization of chemical facies of the groundwater

Piper diagrams drawn for the studied groundwaters (Fig. 4) broadly show a scatter plot dominated by a Chloride-Sodium facies. However, when going into small details, the widespread chemical facies of the Phr aquifer is closer to the NaCl pole than those of CI and CT aquifers. The facies of the Phreatic aquifer most concentrated samples are in the following order: Ca-sulfate < Na-sulfate = Mg-sulfate < Na-chloride. This se-



quential order of solutes is comparable to that of other groundwater occurring in North Africa, and especially in the neighboring area of the chotts (depressions where salts concentrate by evaporation) Merouane and Melrhir (Vallès et al., 1997; Hamdi-Aïssa et al., 2004).

5 3.2 Spatial distribution of the mineralization

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The salinity of the phreatic aquifer varies considerably depending on the location (near wells or drains) and time (influence of irrigation; Fig. 5a).

Its salinity is low around irrigated and fairly well-drained areas, such as the palm groves of Hassi Miloud, just north of Ouargla (Fig. 3) that benefit from freshwater and are drained to the sebkha Oum el Raneb. However, the three lowest salinity values are observed in the wells of Ouargla palm-grove itself, where the Phr aquifer watertable is deeper than 2 m.

Conversely, the highest salinity waters are found in wells drilled in the chotts and sebkhas (a sebkha is the central part of a chott where salinity is the largest) Safioune and Oum er Raneb where the aquifer is often shallower than 50 cm.

The salinity of the Complexe Terminal (Mio-pliocene) aquifer (Fig. 5b) is much lower than that of the Phr aquifer, and ranges from 1 to 2 g L^{-1} ; however, its hardness is larger and it contains more sulfate, chloride and sodium than the waters of the Senonian formations and those of the CI aquifer. The salinity of the Senonian aquifer ranges from 1.1 to 1.7 g L^{-1} , while the average salinity of the Continental Intercalaire is 0.7 g L^{-1} (Fig. 5c).

A likely contamination of the Mio-pliocene aquifer by phreatic groundwaters through casing leakage in an area where water is heavily loaded with salt and therefore particularly aggressive cannot be excluded.



3.3 Saturation Indices

The calculated saturation indices reveal that waters from CI at 50 °C are close to equilibrium with respect to calcite (Figs. 6 top and 7), except for 3 samples that are slightly oversaturated. They are however all undersaturated with respect to gypsum (Figs. 6 bottom and 8).

Moreover, they are oversaturated with respect to dolomite and undersaturated with respect to anhydrite (Fig. 8) and halite (Fig. 9).

Waters from CT and phreatic aquifers show the same pattern, but some of them are more largely oversaturated with respect to calcite, at 25 °C (Fig. 7).

- However, several phreatic waters (P031, P566, PLX4, PL18, P002, P023, P116, P066, P162 and P036) that are located in the sebkhas of Sefioune, Oum-er-Raneb, Bamendil and Ain el Beida's chott are saturated with gypsum and anhydrite. This is in accordance with high evaporative environments found elsewhere (UNESCO, 1972; Hamdi-Aïssa et al., 2004; Slimani, 2006).
- No significant saturation indices' evolution from the south to the north upstream and downstream of Oued Mya (Fig. 8) is observed. This suggests that the acquisition of mineralization is due to geochemical processes that have already reached equilibrium or steady state in the upstream areas of Ouargla.

3.4 Change of facies from the carbonated pole to the evaporites' pole

The facies shifts progressively from the carbonated (CI and CT aquifers) to the evaporites'one (Phr aquifer) with an increase in sulfates and chlorides at the expense of carbonates (SI of gypsum, anhydrite and halite). This is illustrated by a decrease of the following two ratios: [HCO3⁻]/([CI⁻]+2[SO₄²⁻]; Fig. 10) from 0.2 to 0 and of the ratio [SO₄²⁻]/[CI⁻] from 0.8 to values ranging from 0.3 and 0 (Fig. 11) while salinity increases. Carbonate concentrations tend towards very small values, while it is not the case for sulfates. This is due to both gypsum dissolution and calcite precipitation.



Chlorides in groundwater may come from three different sources: (i) ancient sea water entrapped in sediments; (ii) dissolution of halite and related minerals that are present in evaporite deposits and (iii) dissolution of dry fallout from the atmosphere, particularly in these arid regions (Matiatos et al., 2014; Hadj-Ammar et al., 2014).

For most of the sampled points the [Na⁺] / [Cl⁻] ratio remains close to 1, but significant ranges are observed: from 0.85 to 1.26 for Cl aquifer, from 0.40 to 1.02 for the CT aquifer and from 0.13 to 2.15 for the Phr aquifer. All the measured points from the three considered aquifers are more or less linearly scattered around the unity slope straight line that stands for halite dissolution (Fig. 12). The latter appears as the most dominant reaction occurring in the medium. However, at very high salinity, Na⁺ seems to swerve from the straight line, towards smaller values.

A further scrutiny of (Fig. 12) shows that CI waters are very close to the 1 : 1 line. CT waters are enriched in both Na⁺ and Cl⁻ but slightly lower than the 1 : 1 line while phreatic waters are largely enriched and much more scattered. CT waters are closer to the seawater mole ratio (0.858), but some lower values imply a contribution from another source of chloride than halite or from entrapped seawater. Conversely, a [Na⁺]/[Cl⁻] ratio larger than 1 is observed for phreatic waters, which implies the

contribution of another source of sodium, most likely sodium sulfate, that is present as mirabilite or thenardite in the chotts and the sebkhas areas.

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 $_{20}$ [Br⁻]/[Cl⁻] ratio ranges from 2 × 10⁻³ to 3 × 10⁻³. The value of this molar ratio for halite is around 2.5 × 10⁻³, which matches the aforementioned range and confirms that halite dissolution is the most dominant reaction taking place in the studied medium.

In these aquifers, calcium originates both from carbonate and sulfate (Figs. 13 and 14). Three samples from CI aquifer are close to the [Ca²⁺]/[HCO3⁻] 1:2 line, ²⁵ while calcium sulfate dissolution explains the excess of calcium. However, a small but significant number of samples (9) from phreatic aquifer are depleted in calcium, and plot under the [Ca²⁺]/[HCO3⁻] 1:2 line. This cannot be explained by precipitation of calcite, as some are undersaturated with respect to that mineral, while others are oversaturated.



In this case, a cation exchange process seems to occur leading to a preferential adsorption of divalent cations, with a release of Na^+ . This is confirmed by the inverse modeling that is developed below and which implies Mg^{2+} fixation and Na+ and K+ releases.

Larger sulfate values observed in the phreatic aquifer (Fig. 14) with [Ca²⁺]/[SO4²⁻]<1 can be attributed to a sodium-magnesium sulfate dissolution from a mineral bearing such elements. This is for instance the case of bloedite.

3.5 Isotope geochemistry

CT and CI aquifer exhibit depleted and homogeneous ¹⁸O contents, ranging from -8.32
 to -7.85‰. This was already previously reported by many authors (Edmunds et al., 2003; Guendouz et al., 2003; Moulla et al., 2012). On the other hand, ¹⁸O values for the phreatic aquifer are widely dispersed and vary between -8.84 to 3.42‰ (Table 6). Waters located north of the Hassi Miloud to Sebkhet Safioune axis are more enriched in heavy isotopes and therefore more evaporated. In that area, water table is
 close to the surface and mixing of both CI and CT groundwaters with phreatic ones through irrigation is nonexistent. Conversely, waters located south of Hassi Miloud up to Ouargla city show depleted values. This is the clear fingerprint of a contribution to the Phr waters from the underlying CI and CT aquifers (Gonfiantini et al., 1975; Guendouz, 1985; Fontes et al., 1986; Guendouz and Moulla, 1996).

- Phreatic waters result from a mixing of two end-members. An evidence for this is given by considering the ([CI⁻], ¹⁸O) relationship (Fig. 15). The two poles are: (i) a first pole of ¹⁸O depleted groundwater (Fig. 16), and (ii) another pole of ¹⁸O enriched groundwater with positive values and a high salinity. The latter is composed of phreatic waters occurring in the northern part of the study region.
- Pole I represents the waters from CI and CT whose isotopic composition is depleted in ¹⁸O (average value around -8.2%; Fig. 15). They correspond to an old water recharge (palæorecharge); whose age estimated by means of ¹⁴C, exceeds 15 000 years BP (Guendouz, 1985; Guendouz and Michelot, 2006). So, it is not a water



body that is recharged by recent precipitation. It consists of CI and CT groundwaters and partly of phreatic waters, and can be ascribed to an upward leakage favored by the extension of faults near Amguid El-Biod dorsal.

Pole II, observed in Sebkhet Safioune, can be ascribed to the direct dissolution of ⁵ surficial evaporitic deposits conveyed by evaporated rainwater.

Evaporation alone cannot explain the distribution of data that is observed (Fig. 15). An evidence for this is given in a semi-logarithmic plot (Fig. 16), as classically obtained according to the simple approximation of Rayleigh equation (cf. Appendix):

$$\delta^{18}O \approx 1000 \times (1 - \alpha)\log[\text{Cl}-] + \text{cte}, \tag{1}$$

 $\sim -\epsilon \log[CI-] + cte,$

where α is the fractionation factor during evaporation, and $\epsilon \equiv -1000 \times (1 - \alpha)$ is the enrichment factor, and cte is an abbreviation for constant (Ma et al., 2010; Chkir et al., 2009).

CI and CT waters are better separated in the semi-logarithmic plot because they are differentiated by their chloride content. According to Eq. (1), simple evaporation gives a straight line (solid line in Fig. 16). The value of ε used is the value at 25 °C, which is equal to -73.5. There is only one sample (P115) on the evaporation straight line, which could be considered as an outlier in Fig. 15 ([CI–] \simeq 0). All other samples fit on the logarithmic curve derived from the mixing line illustrated by Fig. 15.

The phreatic waters that are close to pole I (Fig. 15) correspond to groundwaters occurring in the edges of the basin (Hassi Miloud, piezometer P433; Fig. 16). They are low-mineralized and acquire their salinity via two processes namely: dissolution of evaporites along their underground transit up to Sebkhet Safioune and dilution through upward leakage by the less-mineralized waters of CI and CT aquifers (for example Hedeb L for CI and DZE4 for CT: Fig. 16; Guendouz, 1985; Guendouz, and Moulla.

Hedeb I for CI and D7F4 for CT; Fig. 16; Guendouz, 1985; Guendouz and Moulla, 1996).



(2)

The rates of the mixing that are due to upward leakage from CI to CT towards the phreatic aquifer can be calculated by means of a mass balance equation. It only requires knowing the δ values of each fraction that is involved in the mixing process. The δ value of the mixture is given by:

 $\delta_{\text{mix}} = f_1 \times \delta_1 + f_2 \times \delta_2$

where f_1 is the fraction of CI aquifer, f_2 the fraction of the CT and δ_1 , δ_2 are the respective isotope contents.

Average values of mixing fractions from each aquifer to the phreatic waters computed by means of Eq. (3) gave the rates of 65 % for CI aquifer and 35 % for CT aquifer.

¹⁰ A mixture of a phreatic water component that is close to pole I (i.e. P433) with another one which is rather close to pole II (i.e. P039; Figs. 15 and 16), for an intermediate water with a δ^{18} O signature ranging from –5 to –2‰ gives mixture fraction values of 52% for pole I and 48% for pole II. Isotope results will be used to independently cross-check the validity of the mixing fractions derived from an inverse modeling involving chemical data (cf. infra).

Turonian evaporites are found to lie in between CI deep aquifer, and the Senonian and Miocene formations bearing CT aquifer. CT waters can thus simply originate from ascending CI waters that dissolve Turonian evaporites, a process which does not involve any change in ¹⁸O content. Conversely, phreatic waters result to a minor degree from evaporation, and mostly from dissolution of sebkhas evaporites by ¹⁸O enriched rainwater and mixing with CI-CT waters.

3.5.1 Tritium content of water

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Tritium contents of Phr aquifer are relatively small (Table 6), they vary between 0 and 8TU. Piezometers PZ12, P036 and P068 show values close to 8TU, piezometers

P018, P019, P416, P034, P042 and P093 exhibit values ranging between 5 and 6 TU, and the rest of the samples' concentrations are lower than 2 TU. The comparison of



(3)

these results with that of precipitation which was 16 TU in 1992 suggests the existence of a mixture of water infiltrated before 1950 and a more recent one corresponding to the 1980s (Guendouz and Moulla, 1996; Edmunds et al., 2003; Guendouz et al., 2003; Moulla et al., 2012; ONM, 1975/2013). This is in agreement with the recorded hydrochemical and stable isotope data.

3.6 Inverse modeling

We assume that the relationship between ¹⁸O and CI– data obtained in 1996 is stable with time, which is a logical assumption as times of transfer from CI to both CT and Phr are very long. Considering both ¹⁸O and CI– data, thus CI, CT and Phr data populations can be categorized as follows:

- CI does not show appreciable ¹⁸O variations. Its data can be considered as a single population;
- the same holds for CT;

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- Phr samples consist however of different populations:
 - pole I, with δ^{18} O values close to -8, and small Cl⁻ concentrations, more specifically less than 35 mmol L⁻¹ (Fig. 17);
 - pole II, with δ^{18} O values larger than 3, and very large Cl⁻ concentrations, more specifically larger than 4000 mmol L⁻¹ (Fig. 17);
 - intermediate Phr samples resulting from mixing between poles I and II (mixing line in Fig. 15, mixing curve in Fig. 16);
 - intermediate samples resulting from evaporation of pole I (evaporation line in Fig. 16).

Statistical parameters for CI, CT, Phr pole I and Phr pole II are given in Table 7.



The mass-balance modeling has shown that relatively few phases are required to derive observed changes in water chemistry and to account for the hydrochemical evolution in Ouargla's region. The mineral phases' selection is based upon geological descriptions and analysis of rocks and sediments from the area (OSS, 2003; Hamdi-⁵ Aïssa et al., 2004).

The inverse model was constrained so that mineral phases from evaporites including gypsum, halite, mirabilite, glauberite, sylvite and bloedite were set to dissolve until they reach saturation, and calcite, dolomite were set to precipitate once they reached saturation. Cation exchange reactions of Ca^{2+} , Mg^{2+} , K^+ and Na^+ on exchange sites were included in the model to check which cations are adsorbed or desorbed during the process. Dissolution and desorption contribute as positive terms in the mass balance, as elements are released in solution. On the other hand, precipitation and adsorption contribute as negative terms, while elements removed from the solution. $CO_{2_{(g)}}$ dissolution is considered by Phreeqc as a dissolution of a mineral, whereas $CO_{2_{(g)}}$ degassing is dealt with as if it were a mineral precipitation.

Inverse modelling leads to a quantitative assessment of the different solutes' acquisition processes and a mass balance for the salts that are dissolved or precipitated from CI, CT and Phr groundwaters (Fig. 16, Table 8), as follows:

transition from CI to CT involves gypsum, halite and sylvite dissolution, and some ion exchange namely calcium and potassium fixation on exchange sites against magnesium release, with a very small and quite negligible amount of CO_{2(g)} degassing. The maximum elemental concentration fractional error equals 1 %. The model consists of a minimum number of phases (i.e. 6 solid phases and CO_{2(g)}); Another model implies as well dolomite precipitation with the same fractional error;

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 transition from CT to an average water component of pole I involves dissolution of halite, sylvite, and bloedite from Turonian evaporites, with a very tiny calcite precipitation. The maximum fractional error in elemental concentration is 4 %. An-



other model implies $CO_{2_{(g)}}$ escape from the solution, with the same fractional error. Large amounts of Mg²⁺ and SO₄²⁻ are released within the solution (Sharif et al., 2008; Li et al., 2010; Carucci et al., 2012);

- the formation of Phr pole II can be modeled as being a direct dissolution of salts from the sebkha by rainwater with positive δ^{18} O; the most concentrated water (P036 from Sebkhet Safioune) is taken here for pole II, and pure water as rainwater. In a decreasing order of amounts respectively involved in that process, halite, sylvite, gypsum and huntite dissolve, and little calcite precipitates while some Mg²⁺ are released vs. K+ fixation on exchange sites. The maximum elemental fractional error in the concentration is equal to 0.004 %. Another model implies dolomite precipitation with some more huntite dissolving, instead of calcite precipitation, but salt dissolution and ion exchange are the same. Huntite, dolomite and calcite stoichiometries are linearly related, so both models can fit field data, but calcite precipitation is preferred compared to dolomite precipitation at low temperature;

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- the origin of all phreatic waters can be explained by a mixing in variable proportions of pole I and pole II. For instance, waters from pole I and pole II can easily be separated by their $\delta^{18}O$ respectively close to -8 and +3.5% (Figs. 15 and 16). Mixing the two poles is of course not an inert reaction, but rather results in the dissolution and the precipitation of minerals. Inverse modeling is then used to compute both mixing rates and the extent of matter exchange between soil and solution. For example, a phreatic water (piezometer P068) with intermediate values ($\delta^{18}O = -3$ and [Cl⁻] $\simeq 2M$) is explained by the mixing of 58% water from pole I and 42% from pole II. In addition, calcite precipitates, Mg²⁺ fixes on exchange sites, against Na⁺ and K⁺, gypsum dissolves as well as a minor amount of huntite (Table 8). The maximum elemental concentration fractional error is 2.5% and the mixing fractions' weighted the $\delta^{18}O$ is -3.17%, which is is very close to the measured value (-3.04%). All the other models, making use



of a minimum number of phases, and not taking into consideration ion exchange reactions are not found compatible with isotope data. Mixing rates obtained with such models are for example 98% of pole I and 0.9% of pole II, which leads to a $\delta^{18}O = (-7.80\%)$ which is quite far for the real measured value (-3.04%).

⁵ The main types of groundwaters occurring in Ouargla basin are thus explained and could quantitatively be reconstructed. An exception is however sample P115, which is located exactly on the evaporation line of Phr pole I. Despite numerous attempts, it could not be quantitatively rebuilt. Its ³H value (6.8) indicates that it is derived from a more or less recent water component with very small salt content, most possibly affected by rainwater and some preferential flow within the piezometer. As this is the only sample on this evaporation line, there remains a doubt on its significance.

Globally, the summary of mass transfer reactions occurring in the studied system (Table 8) shows that gypsum dissolution results in calcite precipitation and $CO_{2_{(g)}}$ dissolution, thus acting as an inorganic carbon sink.

15 4 Conclusions

Groundwater hydrochemistry is a good record indicator for the water-rock interactions that occur along the groundwater flowpath. The mineral load reflects well the complex processes taking place while water circulates underground since its point of infiltration.

- The hydrochemical study of the aquifer system occurring in Ouargla's basin allowed us to identify the origin of its mineralization. Waters exhibit two different facies: sodium chloride and sodium sulfate for the phreatic aquifer (Phr), sodium sulfate for the Complexe Terminal (CT) aquifer and sodium chloride for the Continental Intercalaire (CI) aquifer. Calcium carbonate precipitation and evaporite dissolution explain the facies change from carbonate to sodium chloride or sodium sulfate. However reactions im-
- ²⁵ ply many minerals with common ions, deep reactions without evaporation as well as shallow processes affected by both evaporation and mixing. Those processes are sep-



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At depth, CI leaks upwardly and dissolves gypsum, halite and sylvite, with some ion exchange, to give waters of CT aquifer composition.

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from the sebkhas.

CT transformation into Phr pole I waters involves the dissolution of Turonian evaporites (halite, sylvite and bloedite) with minor calcite precipitation.

At the surface, direct dissolution by rainwater of salts from sebkhas (halite, sylvite, gypsum and some huntite) with precipitation of calcite and Mg²⁺/K⁺ ion exchange re-15 sults in pole II Phr composition.

All phreatic groundwaters result from a mixing of pole I and pole II water that is accompanied by calcite precipitation, fixation of Mg²⁺ on ion exchange sites against the release of K^+ and Na^+ .

Moreover, some $CO_{2_{(q)}}$ escapes from the solution at depth, but dissolves much more at the surface. The most complex phenomena occur during the dissolution of Turonian evaporites while CI leaks upwardly towards CT, and from Phr I to Phr II, while the transition from CT to Phr I implies a very limited number of phases. Globally, gypsum dissolution and calcite precipitation processes both act as an inorganic carbon sink.

by the upwardly mobile deep CT and CI groundwaters, fractions of the latter interacting

with evaporites from Turonian formations. Phreatic waters occurrence is explained as a mixing of two end-member components: pole I, which is very close to CI and CT, and

pole II, which is highly mineralized and results from the dissolution by rainwater of salts

Discussion Paper The main result is that Phr waters do not originate simply from infiltration of rainwater doi:10.5194/hess-2015-385 and dissolution of salts from the sebkhas. Conversely, Phr waters are largely influenced

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Appendix A

According to a simple Rayleigh equation, the evolution of the heavy isotope ratio in the remaining liquid R_{I} is given by:

 $R_{\rm I} \approx R_{\rm I,0} \times f_{\rm I}^{\alpha-1},$

⁵ where $f_{\rm I}$ is the fraction remaining liquid and α the fractionation factor.

The fraction remaining liquid is derived from chloride concentration, as chloride can be considered as conservative during evaporation: all phreatic waters are undersaturated with respect to halite, that precipitates only in the last stage. Hence, the following equation holds:

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$$f_{\rm I} \equiv \frac{n_{w,1}}{n_{w,0}} = \frac{[{\rm CI}^-]_0}{[{\rm CI}^-]_1}.$$

By taking natural logarithms, one obtains:

 $\ln R_{\rm I} \approx (1 - \alpha) \times \ln[{\rm CI}^{-}] + {\rm cte},$

As, by definition,

$$R_{\rm I} \equiv R_{\rm std.} \times (1 + \frac{\delta^{18}O}{1000}),$$

15 one has:

$$\begin{split} \ln R_{\rm I} &\equiv \ln R_{\rm std.} + \ln(1 + \frac{\delta^{18}O}{1000}), \\ &\approx \ln R_{\rm std.} + \frac{\delta^{18}O}{1000}, \end{split}$$



hence, with base 10 logarithms:

```
\delta^{18}O \approx 1000(1-\alpha)\log[\text{CI}^-] + \text{cte},
 \approx -\epsilon \log[Cl^{-}] + cte,
```

where as classically defined $\epsilon = 100(\alpha - 1)$ is the enrichment factor.

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Table 1. Field and analytical data for the Continental Intercalaire aquifer.

Locality	Lat.	Long.	Elev.	Date	EC	t	pН	Alk.	Cl⁻	SO ₄ ²⁻	Na⁺	K⁺	Mg²⁺	Ca⁺⁺	Br ⁻
		m			$\rm mS cm^{-1}$	°C					mm	$10 L^{-1}$			
Hedeb I	3534750	723986	134.8	09/11/2012	2.01	46.5	7.65	3.5	5.8	6.79	10.7	0.63	2.49	3.3	0.034
Hedeb I	3534750	723986	134.8	1996	1.9	49.3	7.35	0.42	5.81	1.07	5.71	0.18	0.77	0.48	
Hadeb II	3534310	724290	146.2	1996	2.02	47.4	7.64	0.58	6.19	1.22	5.06	0.2	1.28	0.82	
Aouinet Moussa	3548896	721076	132.6	1996	2.2	48.9	7.55	1.28	6.49	1.28	5.65	0.16	1.14	1.17	
Aouinet Moussa	3548896	721076	132.6	22/02/2013	2.2	48.9	7.55	3.19	9.8	3.89	6.3	0.69	5.71	1.27	
Hedeb I	3534750	723986	134.8	11/12/2010	2.19	49.3	7.35	1.91	12.4	4.58	10.7	0.7	3.77	2.35	
Hadeb II	3534310	724290	146.2	11/12/2010	2.26	47.4	7.64	2.11	13.1	5.46	13.9	0.53	4.53	1.41	
Hassi Khfif	3591659.8	721636.5	110	24/02/2013	2.43	50.5	6.83	2.98	14.3	5.24	10.8	0.84	3.44	4.63	0.033
Hedeb I	3534750	723986	134.8	27/02/2013	2.01	46.5	7.65	3.46	15.1	7.67	11.8	0.51	5.57	5.16	
Hassi Khfif	3591659.8	721636.5	110	09/11/2012	2	50.1	7.56	3.31	15.3	7.77	12.2	0.59	5.77	4.95	
El-Bour	3560264	720366	160	22/02/2013	2.96	54.5	7.34	2.58	18.6	6.21	20.6	0.66	4.79	1.38	

Table 2. Field and analytical data for the Complexe Terminal aquifer.

Locality	Site	Aquifer	Lat.	Long.	Elev.	Date	EC	t	pН	Alk.	CI-	SO_4^{2-}	Na ⁺	K ⁺	Mg ²⁺	Ca ²⁺	Br⁻
				m			mS cm ⁻¹	°C					mmo	$1 L^{-1}$			
Barnendil	D7F4	М	3560759.6	720586.2	296	20/01/2013	2.02	20.1	7.86	1.63	10.1	5.79	9.88	0.68	3.92	2.51	
Bamendil	D7F4	M	3560759.6	720586.2	296	1996	2	21.1	8.2	0.96	10.6	3.54	10.61	0.09	2.33	1.8	
lfri	D1F151	S	3538891.7	721060.5	204	1996	2.67	23.5	7	1.26	10.75	2.71	7.99	0.73	2.32	2.12	
Said Otba	D2F66	S	3540257.3	720085.4	216	1996	2.31	24	8	1.43	11.02	4.73	11.47	0.16	2.07	3.33	
Oglat Larbaå	D6F64	M	3566501.4	729369.3	177	1996	2.31	18	7.9	1.41	11.36	6.85	11.59	2.31	1.96	4.58	
El-Bour	D4F94	M	3536245.2	722641.7	100.6	27/01/2013	3.05	26.2	7.37	1.61	12.8	6.79	5.15	1.94	1.65	9.13	
Said Otba I	D2F71	S	3557412.4	718272.8	211.9	1996	2.27	24.2	8.2	1.54	13.53	5.72	14.99	0.33	3.28	2.57	
Debiche	D6F61	M	3547557.1	717067.1	173.5	26/01/2013	2.22	23.9	7.74	1.78	14.2	8.41	12.6	0.66	5.38	4.43	
Rouissat III	D3F10	S	3535068.1	722352.1	248	1996	3.1	26.1	7.27	2.39	14.27	6.89	13.05	0.4	3.36	5.42	
Said Otba I	D2F71	S	3557412.4	718272.8	211.9	26/01/2013	5.63	25.1	7.34	2.38	14.3	6.86	13.1	0.4	3.36	5.43	0.034
Rouissat III	D3F10	S	3535068.1	722352.1	248	20/01/2013	2.32	18.9	7.98	1.65	15.2	8.64	12.6	1.56	5.79	4.25	
lfri	D1F151	S	3538891.7	721060.5	204	27/01/2013	2.37	22.9	7.79	1.75	15.4	8.31	13.7	0.22	5.17	4.75	
Said Otba	D2F66	S	3540257.3	720085.4	216	31/01/2013	2.38	24.9	7.91	2.19	16.1	8.65	16.5	0.74	4.93	4.29	
Oglat Larbaå	D6F64	M	3566501.4	729369.3	177	31/01/2013	2.43	23.7	7.62	2.3	16.3	8.65	13.6	0.71	5.86	4.97	
SAR Mekhadma	D1F91	S	3536757.7	717822.3	221	03/02/2013	2.47	25.8	7.75	3.43	16.5	8.53	16.1	0.68	5.27	4.92	
Sidi Kouiled	D9F12	S	3540855.1	729055.4	329	24/01/2013	2.57	21.3	8.05	4.65	16.8	8.85	16.1	0.79	6.21	5.01	
Ain N'sara	D6F50	S	3559323.6	716868.4	255	25/01/2013	3.36	25.7	7.36	1.98	16.9	9.71	15.9	0.35	3.39	7.87	0.033
A.Louise	D4F73	S	3537523.4	721904.6	310	26/01/2013	2.57	24	7.49	1.98	17.4	9.04	13.9	1.99	5.78	5.05	
Ghazalet A.H	D6F79	M	3598750.2	720356.8	119	02/02/2013	2.84	22.5	7.55	3.47	17.4	9.35	16.6	0.62	6.24	4.96	
Ain moussa II	D9F30	S	3537814.1	719665.1	220.6	02/02/2013	7.52	23.9	7.52	2.37	17.5	8.24	17.3	0.39	3.1	6.46	0.033
Ain N'sara	D6F50	S	3559323.6	716868.4	255	02/02/2013	2.62	23.8	7.65	2.11	17.7	9.19	15.5	1.13	6.11	4.73	
H.Miloud	D1F135	M	3547557.1	717067.1	173	03/02/2013	2.76	21.6	7.55	3.32	17.9	9.22	16.5	1.01	6.17	4.91	
El Bour	D6F97	S	3540936.5	715816.0	169	25/01/2013	2.65	19.9	8.02	2.14	17.9	9.28	15.8	1.6	5.84	4.73	
H.Miloud	D1F135	M	3547557.1	717067.1	173	1996	2.07	22.7	8.1	2.8	18.08	5.73	16.61	0.51	3.65	4.26	
N'goussa El Hou	D6F51	S	3556256.7	718979.5	198	31/01/2013	2.97	22.9	7.52	2.03	18.4	9.63	17.1	0.45	6.17	4.99	
El Koum	D6F67	S	3573694.1	721639.7	143	21/01/2013	3.07	22.9	8.09	3.52	18.4	9.71	17.9	0.32	6.49	5.14	
El Koum	D6F67	S	3573694.1	721639.7	143	1996	2.5	25	7.6	1.5	18.79	7.17	10.18	3.43	4.97	5.81	
ITAS	D1F150	M	3536186.6	717046.1	93.1	21/01/2013	3.66	23.9	7.54	1.48	18.8	7.07	10.1	3.41	4.94	5.77	
Ain moussa V	D9F13	M	3538409.2	718680.2	210.2	08/02/2013	2.39	25.3	7.22	2.28	19.4	9.45	18.8	0.39	3.31	7.61	0.034
El-Bour	D4F94	M	3536245.2	722641.7	100.6	1996	2.3	21.2	7.9	1.58	20.05	7.21	12.09	2.62	5.76	5.17	
Rouissat I	D3F18	M	3535564.2	722498.9	80.4	26/01/2013	3.13	23	8.1	3.15	21.2	11.1	19.6	0.87	7.08	6.01	
Rouissat I	D3F18	M	3535564.2	722498.9	80.4	1996	2	20	7.84	1.86	21.66	8.46	17.72	1.19	5.05	6	
St. pompage chott	D5F80	S	3541656.9	723521.9	224.1	04/02/2013	3.28	24.5	8.23	3.91	22.1	11.9	19.9	2.13	7.64	6.28	
Chott Palmeraie	D5F77	S	3538219.3	725541.3	242.8	05/02/2013	3.37	24.6	7.53	3.26	22.3	12.1	20.9	1.15	8.25	5.78	
Bour El Haicha	D1F134	M	3545533.1	720391.7	86	05/02/2013	3.4	22.2	7.34	4.13	23.2	12.2	21.2	1.49	8.61	6.01	
Abazat	D2F69	M	3552504.9	712786.3	137.1	03/02/2013	3.54	24.6	7.61	2.24	24.7	12.7	21.1	1.65	8.45	6.47	
Garet Chemia	D1F113	S	3536174.1	716808.5	213.7	28/01/2013	4.05	28	7.3	2.21	25.9	9.47	25.4	0.57	3.64	7.17	0.037
Frane	D6F62	M	3570175.8	717133.8	167.5	27/01/2013	3.79	24.2	7.95	2.27	25.9	13.5	22.6	0.64	8.91	7.16	
Oum Raneb	D6 F69	M	3540451.1	721919.8	215.8	25/01/2013	4.2	24.1	7.03	2.61	27.9	8.67	22.9	0.62	4.42	7.96	0.035
N'goussa El Hou	D6F51	S	3556256.7	718979.5	198	1996	3.15	23.2	8	2.59	28.39	8.61	23.14	0.62	4.46	8.01	
H.Miloud Benyaza	D1F138	M	3551192.5	717042.1	88.9	28/01/2013	3.85	25.2	7.61	2.44	28.4	14.2	23.9	1.66	10.01	7.12	
Ain Laarab	D6F49	M	3558822.6	716799.1	156.5	28/01/2013	3.97	23.7	7.33	2.16	28.9	9.01	23.9	0.53	5	7.72	0.037
H.Miloud Benyaza	D1F138	M	3551192.5	717042.1	88.9	1996	2.9	22.8	7.5	2.16	28.92	9.03	23.87	0.52	4.99	7.7	
Rouissat	D3F8	М	3545470.7	732837.6	332.4	03/02/2013	4.38	25.4	7.51	1.71	29.8	8.33	22.8	1.23	6.23	6.08	
Rouissat	D3F8	М	3545470.7	732837.6	332.4	1996	6.16	25.3	7.22	1.71	29.81	8.33	22.86	1.23	6.23	6.08	
Ain El Arch	D3F26	М	3534843.9	723381.8	93.6	1996	5.11	25.1	7.45	1.56	34.68	8.94	23.98	0.87	8.38	6.5	
St. pompage chott	D5F80	S	3541656.9	723521.9	224.1	1996	3.69	25.4	7.67	2.28	42.22	13.53	36.77	1.12	7.43	9.73	

M = Mio-pliocene aquifer; S = Senonian aquifer.



Discussion Paper

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Table 3. Field and analytical data for the Phreatic aquifer.

/m mS cm ⁻¹ 'C mm L ⁻¹ Khezana P433 3597046 719626 118 2010/2013 2.0 2.7 9.18 1.65 1.20 7.8 1.3 0.99 4.34 2.8 Hass <milloud< td=""> P059 3597046 719626 118 1.90 2.2 2.18 1.86 1.46 1.87 1.85 0.61 1.55 0.01 1.55 0.61 7.5 1.86 1.87 7.85 0.61 7.5 0.01 1.57 0.93 5.75 5.0 0.01 1.57 0.93 5.75 0.03 1.75 0.93 7.57 7.52 2.90 1.41 1.48 1.99 4.16 0.90 5.75 5.20 2.31 0.41 1.43 8.107 1.83 7.71 2.48 7.83 7.80 7.83 7.83 7.87 2.27 2.88 7.94 1.41 2.99 2.41 1.40 3.53 7.63 2.99 2.42 2.48 4.31<!--</th--><th>Locality</th><th>Site</th><th>Lat.</th><th>Long.</th><th>Elev.</th><th>Date</th><th>EC</th><th>t</th><th>pН</th><th>Alk.</th><th>Cl⁻</th><th>SO_{4}^{2-}</th><th>Na⁺</th><th>K^{+}</th><th>Mg²⁺</th><th>Ca²⁺</th><th>Br⁻</th></milloud<>	Locality	Site	Lat.	Long.	Elev.	Date	EC	t	pН	Alk.	Cl⁻	SO_{4}^{2-}	Na ⁺	K^{+}	Mg ²⁺	Ca ²⁺	Br⁻
Khezana P433 359704 71926 118 2001/2013 2.0 2.2 2.8 1.6 1.6 1.2 7.3 1.15 0.90 3.4 2.8 Hass Minud P059 354716 71982 1.2 2701/2013 2.1 2.39 7.5 1.86 1.45 7.78 1.66 0.93 5.7 5 0.031 Hassi Maga PLX3 355786 717604.5 1.25 2001/2013 2.3 2.35 8.6 1.6 1.5 7.8 0.6 0.41 1.43 1.78 2.60 0.21 2.13 2.29 1.33 2.29 1.33 2.21 2.29 2.33 2.21 1.81 1.61 1.63 1.70 2.40 0.31 4.33 0.32 Hassi Mioud P005 3547216 71305.8 1.24 1.996 2.75 2.23 2.33 2.21 1.24 2.16 3.17 4.28 3.13 3.13 3.13 3.13 3.16				/m			$\rm mS cm^{-1}$	°C					mm	ol L ⁻¹			
Khezana P433 J597046 71826 118 1996 2 22.1 836 1.4 12 6.87 11.57 0.93 4.4 2.9 Hassi Mole PL06 718358 718367 718046 718046 71804 718046 71804 718046 718044 71804 71804 718044 71804 71804 718044 71804 71804 71804 718044 71804 71804 71804	Khezana	P433	3597046	719626	118	20/01/2013	2.09	22.7	9.18	1.56	12.02	7.3	13	0.99	4.34	2.8	
Hassi Mioud P059 3547216 7183 124 124 2.1 2.3 815 1.6 1.3 7.3 1.26 1.25 4.33 3.43 0.024 Hassi Naga PLX3 354761.4 717604.5 125 2001/2013 2.33 2.37 712 525 18.21 9.7 4.26 0.39 5.75 5 0.031 Maison de culture PL31 3537988 72114 124 1996 2.51 2.83 7.83 2.7 12.41 1.42 1.99 3.66 3.17 4.25 5.31 5.6 5.4 Hassi Miloud P059 3547216 7113721 124 2.14 2.18 1.86 8.25 6.31 7.7 Maison de culture PL31 3557988 72114 112 2001/2013 3.7 7.22 2.92 2.34 1.31 7.8 2.20 8.40 2.40 8.40 2.42 2.40 8.40 2.42 2.40 8.41	Khezana	P433	3597046	719626	118	1996	2	22.1	8.86	1.46	12	6.87	11.57	0.93	4.4	2.9	
Ain Kheir PL06 Function PL06 Function PL06 Function PL07 Function PL07 Function PL07 Function Function PL08 PL07 PL08 PL	Hassi Miloud	P059	3547216	718358	124	27/01/2013	2.1	23.9	8.15	1.86	13	7.3	12.6	1.25	4.43	3.43	0.024
Hassi Maga PLX3 3584761.4 717604.5 715 2001/2013 2.93 2.93 2.93 2.94 10.7 9.4 16.6 0.93 5.76 5 0.031 Maison de culture PL31 5537988 720114 124 1996 2.96 23.33 7.12 25.5 18.21 19.97 24.20 0.41 1.43 8.13 2.77 23.45 7.83 2.27 12.4 1.26 5.35 5.21 8.21 1.98 7.74 1.41 2.69 2.61 1.33 7.75 2.21 1.24 1.8 1.86 8.25 6.28 0.38 Cherbouz P115 5357962 71874 112 2001/2013 3.44 7.75 2.39 2.51 1.37 5.06 8.80 0.25 6.28 0.38 7.66 0.38 0.34 1.33 7.98 7.75 2.39 2.51 1.37 5.06 8.80 0.21 2.21 2.246 0.88 0.41 <td< td=""><td>Ain Kheir</td><td>PL06</td><td></td><td></td><td></td><td>1996</td><td>4.01</td><td>23.79</td><td>7.52</td><td>1.86</td><td>14.15</td><td>17.89</td><td>15.89</td><td>0.61</td><td>10.61</td><td>7.5</td><td></td></td<>	Ain Kheir	PL06				1996	4.01	23.79	7.52	1.86	14.15	17.89	15.89	0.61	10.61	7.5	
LTP 30LTP 30LTP 30LTP 30LTP 30LTP 30LTP 30LTP 30LABB37LABB37LABB37LABB37B38T201112419962.512.388.081.241.9887.141.451.500.622.335.31Hassi MiloudP059354721671835812419962.7723.457.832.2720.339.3663.174.251.350.36Oglet LarbaaP4303567287.5730058.813924/01/20133.72.228.234.222.268.68.42.214.013.17Frane El KounP4013572802718741122001/20133.72.292.341.341.381.868.256.280.032GherbouzPL15535796271874130119962.422.347.722.992.341.324.186.882.340.84Station d'épurationPL2235753397186751092001/20134.082.422.384.392.539.151.774.187.900.025Frane Alk DiemePL2235753397186751192001/20134.102.272.022.681.324.182.249.337.36Frane Alk DiemePL2235753397240631.172.992.217.161.322.174.182.990.550.033Frane Alk Dieme <t< td=""><td>Hassi Naga</td><td>PLX3</td><td>3584761.4</td><td>717604.5</td><td>125</td><td>20/01/2013</td><td>2.93</td><td>23</td><td>8.09</td><td>2.04</td><td>17.7</td><td>9.4</td><td>16.6</td><td>0.93</td><td>5.75</td><td>5</td><td>0.031</td></t<>	Hassi Naga	PLX3	3584761.4	717604.5	125	20/01/2013	2.93	23	8.09	2.04	17.7	9.4	16.6	0.93	5.75	5	0.031
Maison de culture PL31 3537980 720114 124 1996 2.51 2.58 8.08 1.6 1.6 1.7 2.8 2.65 0.62 2.13 2.99 Hassi Miloud P059 3547216 718358 124 1996 2.77 23.45 7.83 2.27 2.83 8.08 1.41 2.90 6.52 5.31 Qiget Larbaa P400 3557280.2 71971.4 112 2001/2013 3.44 2.27 2.28 2.23 1.24 1.80 6.26 6.20 0.032 Gherbour P131 3537980 720114 124 2001/2013 3.44 2.27 7.52 2.91 2.33 1.34 2.18 8.25 6.26 0.032 Gherbour P141 33573980 71875 109 2.001/2013 4.47 2.47 7.57 2.99 2.64 1.39 5.06 2.20 0.80 2.37 1.60 2.33 7.36 1.60 2.34 7.8 3.01 2.42 2.80 3.9 2.53 1.61 3.53 2.90 2.		LTP 30				1996	4.08	23.73	7.12	5.25	18.21	9.97	24.29	0.41	1.43	8.13	
El Bour P006 354727 719421 161 1996 2.97 234 7.88 1.27 18.98 7.74 12.41 2.69 5.35 1.35 0.86 Oglet Larbaa P430 3567287.5 730058.8 124 2010/12013 3.7 2.72 2.83 7.88 2.27 2.03 3.86 2.27 2.81 1.8 2.8 2.51 8.51 5.35 0.66 Oglet Larbaa P430 3557862 718744 112 2001/2013 3.74 2.27 2.33 1.34 1.8 6.8 2.21 4.18 1.86 2.25 0.82 0.32 Gherbouz P115 3537962 718744 112 1096 5.51 2.36 7.3 3.01 2.12 2.42 0.88 2.01 0.33 7.36 0.02 7.36 0.10 2.42 2.35 0.55 2.39 0.41 1.30 0.40 2.32 2.41 1.8 0.33 7.66 1.30 2.02 2.68 1.30 0.24 0.33 7.36 0.33 0.33	Maison de culture	PL31	3537988	720114	124	1996	2.51	23.83	8.08	1.46	18.91	7.8	26.05	0.62	2.13	2.99	
Hassi Mioud P059 3547216 718358 124 1969 2.77 2.84 7.83 2.27 2.0.83 9.366 34.17 4.25 1.35 0.86 Maison de culture PL31 3537988 720114 124 28/01/2013 3.47 22.2 8.23 4.22 2.26 8.6 2.84 2.21 4.14 1.86 8.25 6.28 0.32 Gherbouz PL15 3537986 719721.4 112 2001/2013 3.44 23.47 7.72 2.92 2.54 1.37 50.56 2.82 0.88 0.032 Gherbouz PL13 3537988 71993.06 110 1996 2.34 7.75 2.39 24.16 1.323 4.18 7.64 0.33 Station d'pumition PL42 357339 718875 100 2001/2013 4.6 7.83 4.13 2.77 1.6 1.03 1.48 0.44 3.67 4.6 3.33 7.36 1.22 2.62 9.86 1.48 0.49 3.63 7.36 0.025 1.48 1.48	El Bour	P006	3564272	719421	161	1996	2.96	23.43	7.88	1.27	18.98	7.74	12.41	2.69	5.32	5.31	
Oglet Larbaa P430 3567287.5 730058.8 139 24/01/2013 4.5 7.5 8.29 8.21 1.2.4 21.8 2.59 8.61 5.47 Maison de culture PL13 3577808 72014 112 20/01/2013 3.44 27.5 7.52 2.21 23.3 13.4 21.8 1.86 8.25 6.28 0.302 Gherbouz PL15 3537962 716744 134 1996 2.47 7.72 2.99 2.54 13.9 5.66 2.82 0.68 2.34 0.84 Station d'épuration PL30 35638398 721404 130 1996 5.1 2.80 7.39 2.12 2.426 0.88 2.49 0.33 7.36 Frane Ank Direle PLX2 3537323 724063.3 127 1996 4.7 2.26 2.26 8.61 5.23 7.77 1.41 7.5 0.30 8.21 1.44 1.48 7.76 1.30 2.62 3.68	Hassi Miloud	P059	3547216	718358	124	1996	2.77	23.45	7.83	2.27	20.83	9.366	34.17	4.25	1.35	0.86	
Maison de culture PL31 3537888 720114 124 28/01/2013 3.7 22.2 8.28 4.22 2.26 8.6 6.86 2.81 4.01 3.7 Frane El Koum PL15 3537962 718744 134 1996 2.47 23.47 7.72 2.99 23.54 13.97 50.56 2.82 0.98 0.25 Bour El Haicha P408 354499.3 719930.6 110 1996 2.43 23.46 7.75 2.39 24.16 13.23 41.98 6.08 2.16 2.23 Station d'épuration PL22 3575339 718744 100 20/01/2013 4.08 2.42 2.88 4.39 25.3 1.57 2.37 1.77 4.18 7.93 0.025 Route Ain Bida PLX4 357794.8 714428.5 111 20/01/2013 4.1 2.52 7.61 3.03 2.62 9.8 2.03 1.48 5.8 Route Ain Mousa P057 3544943 717353 133 1996 2.32 7.61 7.50 7.65 0	Oglet Larbaa	P430	3567287.5	730058.8	139	24/01/2013	4.5	27.5	8.29	3.29	22.1	12.4	21.8	2.59	8.61	5.47	
Frame El Kourn P401 3572820.2 719721.4 112 20/01/2013 3.44 27.5 7.52 2.21 23.3 13.4 21.8 1.86 8.25 6.26 0.032 Gherbouz PL15 3537962 718744 134 1996 2.47 23.47 7.72 2.99 23.4 13.97 50.56 2.82 0.88 0.25 Bour El Haicha P408 3544999.3 719930.6 110 1996 2.43 23.47 7.72 2.99 23.4 18.16 18.22 4.16 1.0 1.0 1.0 1996 2.42 2.83 4.0 2.53 9.5 2.31 1.77 4.18 7.17 4.18 7.18 7.17 4.18 7.18 7.41 0.025 Route Ain Mousa P057 3548943 717850.7 129 27/01/2013 3.66 2.46 8.11 2.29 2.84 8.77 1.6 19 2.29 9.8 5.2 0.03 3.33 7.36 1.03 1.53 1.52 1.6 1.8 2.24 1.8 8.04	Maison de culture	PL31	3537988	720114	124	28/01/2013	3.7	22.2	8.23	4.22	22.6	8.6	28.4	2.21	4.01	3.17	
Gherbouz PL15 3537962 718744 134 1996 2.42 23.47 7.72 2.99 23.54 13.37 13.26 0.88 0.08 0.25 Bour El Haicha P408 5543993 71930.6 110 1996 2.43 23.40 7.75 2.99 23.16 12.33 13.23 18.8 6.08 2.23 4.40 2.32 21.02 24.60 0.88 2.016 2.23 7.77 4.18 7.91 0.025 Frane Ank Djemel P422 3575339 721406.3 127 1996 4.7 23.61 7.22 25.8 9.5 2.37 1.77 4.18 7.41 0.025 Route Ain Mousa P056 3547329.7 716520.7 129 27/01/2013 3.66 2.46 8.1 3 2.77 1.65 2.82 9.8 2.43 8.49 2.03 1.48 5.03 1.43 1.44 1.45 2.03 1.48 5.03 1.43 1.44 1.04 1.03 1.025 1.033 1.04 1.01/2013 3.66 2.44 <t< td=""><td>Frane El Koum</td><td>P401</td><td>3572820.2</td><td>719721.4</td><td>112</td><td>20/01/2013</td><td>3.44</td><td>27.5</td><td>7.52</td><td>2.21</td><td>23.3</td><td>13.4</td><td>21.8</td><td>1.86</td><td>8.25</td><td>6.28</td><td>0.032</td></t<>	Frane El Koum	P401	3572820.2	719721.4	112	20/01/2013	3.44	27.5	7.52	2.21	23.3	13.4	21.8	1.86	8.25	6.28	0.032
Bour EI Haicha P408 \$544999.3 71930.6 110 1996 2.51 2.34 7.75 2.39 24.16 13.29 41.89 6.08 2.34 0.84 Station d'épuration PL30 3538398 721404 130 1996 5.51 23.80 7.39 21.22 24.26 0.88 2.01 2.23 Route Ain Bida PLX2 3537323.9 718875 109 20/01/2013 4.10 2.22 2.22 2.56 10.36 14.83 0.24 9.33 7.36 Hochegga PLX4 3577944.8 714428.5 111 20/01/2013 3.66 24.6 8.1 3 27.7 10.6 19 2.29 9.09 6.55 0.033 Hochegia Pl35 353586 71060 14.1 1996 2.22 7.68 1.76 13.5 16.6 2.49 0.97 15.69 4.49 Polyclinique Belabés PLX4 353770 71119 119 31/01/2013	Gherbouz	PL15	3537962	718744	134	1996	2.47	23.47	7.72	2.99	23.54	13.97	50.56	2.82	0.98	0.25	
Station d'épuration PL30 3588398 721404 130 1996 5.5 23.80 7.39 3.01 24.32 21.22 24.66 0.88 20.16 2.23 Frane Ank Djemel P422 3573339 714875 109 20/01/2013 4.08 24.2 8.38 4.39 25.3 9.5 23.7 1.77 4.18 7.91 0.025 H Chegga PLX4 357734.8 71428.5 111 20/01/2013 3.66 2.46 8.11 3.7.6 7.46 0.033 Route Ain Moussa P057 3548943 717353 133 1996 2.52 2.68 7.64 1.34 2.27 7.86 0.33 2.42 1.48 1.58 0.03 0.83 0.73 Mekmahad PL05 3537109.4 714419.1 117 1996 2.26 7.68 7.76 1.66 2.49 0.97 15.69 4.49 Polyclinique Belabéa PL18 3537207 712119 119	Bour El Haicha	P408	3544999.3	719930.6	110	1996	2.43	23.46	7.75	2.39	24.16	13.23	41.89	6.08	2.34	0.84	
Franc Ank Djemel P422 3575339 718875 109 20/01/2013 4.08 2.42 8.38 4.39 2.5.3 9.5.3 2.3.7 1.7.7 4.18 7.91 0.025 Route Ain Bida PLX4 3577394.8 714428.5 111 20/01/2013 4.1 25.2 7.61 0.36 14.83 0.24 9.33 7.36 Massi Miloud P058 3547329.7 716520.7 129 27/01/2013 3.61 2.2 7.61 1.8 17.8 2.03 2.82 9.8 2.4 2.32 9.90 6.55 0.033 Route Ain Moussa P057 3548943 711353 133 1996 5.23 2.84 7.65 2.847 14.85 2.03 1.86 2.04 0.97 1.569 4.49 Polyclinique Belabés PL18 353720 721119 119 31/01/2013 4.67 2.23 7.8 1.5 31.9 1.08 2.23 0.8 1.66 2.49 0.97	Station d'épuration	PL30	3538398	721404	130	1996	5.51	23.80	7.39	3.01	24.32	21.22	24.26	0.88	20.16	2.23	
Route Ain Bida PLX2 3537323.9 724063.3 127 1996 4.7 23.61 7.22 2.02 25.68 10.36 14.83 0.24 9.33 7.36 H Chegga PLX4 3577944.8 714428.5 111 20/01/2013 3.66 24.6 8.1 3 2.7.7 10.6 19 2.29 9.09 6.55 0.033 Route Ain Moussa P057 3548943 717353 133 1996 2.52 2.64 8.67 14.82 8.14 0.03 0.83 0.33 Mekmahad PL05 35371094 714419.1 137 1996 2.62 7.68 1.75 30.87 16.66 24.9 0.97 15.69 4.49 Polyclinique Belabés PL18 3537707 721119 119 91/01/2013 4.67 22.7 7.89 1.78 31.2 16.4 21.3 3.61 1.17 8.37 H Chegga PL14 3537794.8 714425.5 111 <t< td=""><td>Frane Ank Djemel</td><td>P422</td><td>3575339</td><td>718875</td><td>109</td><td>20/01/2013</td><td>4.08</td><td>24.2</td><td>8.38</td><td>4.39</td><td>25.3</td><td>9.5</td><td>23.7</td><td>1.77</td><td>4.18</td><td>7.91</td><td>0.025</td></t<>	Frane Ank Djemel	P422	3575339	718875	109	20/01/2013	4.08	24.2	8.38	4.39	25.3	9.5	23.7	1.77	4.18	7.91	0.025
H Chegga PLX4 3577944.8 714428.5 111 20/01/2013 3.66 24.6 8.1 3.03 26.2 9.8 24 2.32 4.96 7.46 0.033 Hassi Miloud P058 3547329.7 716520.7 129 27/01/2013 3.66 24.6 8.1 3 27.7 10.6 19 2.29 9.0 6.55 0.033 Route Ain Moussa P057 3548943 717353 133 1996 5.3 23.44 7.66 1.34 28.27 14.68 17.68 2.003 18.48 0.73 Mekmahad PL05 5537070 721119 117 1996 2.32 7.68 1.78 31.2 16.66 24.9 0.97 15.68 4.49 2.005 5.87 7.53 6.5 1.48 17.48 17.42 1.17 1996 2.369 7.62 1.78 1.18 17.12 1.94 2.42 1.83 1.12 1.01.8 1.01.8 1.12 1.03 1.05 1.81 1.96 1.12 1.01 1.01 1.01 1.11 <td>Route Ain Bida</td> <td>PLX2</td> <td>3537323.9</td> <td>724063.3</td> <td>127</td> <td>1996</td> <td>4.7</td> <td>23.61</td> <td>7.22</td> <td>2.02</td> <td>25.68</td> <td>10.36</td> <td>14.83</td> <td>0.24</td> <td>9.33</td> <td>7.36</td> <td></td>	Route Ain Bida	PLX2	3537323.9	724063.3	127	1996	4.7	23.61	7.22	2.02	25.68	10.36	14.83	0.24	9.33	7.36	
Hassi Mioud P058 5547329.7 716520.7 129 27/01/2013 3.66 2.46 8.1 3 2.77 10.6 19 2.29 9.09 6.55 0.033 Route El Goléa P115 3553866 714060 141.6 1996 2.62 2.34 7.6 1.3 28.4 1.14 8 1.7.58 2.03 1.48 5.8 Mekmahad PL05 353709.7 71419.1 137 1996 2.32 7.76 1.75 30.87 16.66 2.49 0.97 15.69 4.49 Polyclinique Blabés PLX 3577944.8 71428.5 111 1996 4.49 2.367 7.58 1.5 31.52 10.08 2.05 5.87 7.53 6.5 Route El Goléa P116 3537962 718744 134 21/01/2013 4.65 2.30 8.16 1.8 3.24 1.68 3.24 1.68 3.24 1.67 1.83 2.2.3 0.8 1.65 7.89 Route El Goléa P117 3531435 713298 111 1996	H Chegga	PLX4	3577944.8	714428.5	111	20/01/2013	4.1	25.2	7.61	3.03	26.2	9.8	24	2.32	4.96	7.46	0.033
Route Ain Moussa P057 3548943 717353 133 1996 2.62 2.64 1.76 1.44 17.58 2.03 1.148 5.8 Route El Goléa P115 3533566 71400 141.6 1996 2.62 23.68 7.65 2.84 28.77 14.52 58.74 0.03 0.83 0.73 Mekmahad PL05 3537109.4 718419.1 137 1996 2.36 7.76 1.75 3.87 14.66 24.9 0.97 15.69 4.49 Polyclinique Belabés PL18 3537207 721119 119 310/12013 4.76 22.67 7.85 1.5 1.52 1.81 1.83 7.75 6.5 Route El Goléa P116 3532463 71375 117 1996 5.62 2.36 7.65 1.81 1.28 3.18 0.86 6.76 1.08 Route El Goléa P117 3531435 713298 111 1996 5.72 7.70 7	Hassi Miloud	P058	3547329.7	716520.7	129	27/01/2013	3.66	24.6	8.1	3	27.7	10.6	19	2.29	9.09	6.55	0.033
Route El Goléa P115 3533586 714060 141.6 1996 2.2 2.8.6 7.6 2.8.4 2.8.7 14.5.6 5.8.7 0.03 0.83 0.73 Mekmahad PL05 5337109 714149.1 137 1996 2.3.87 7.76 1.78 31.2 16.66 24.9 0.97 15.69 4.49 Polyclinique Belabés PL18 353720 721119 119 31/01/2013 4.67 22.2 7.89 1.78 31.2 16.66 24.9 0.97 15.69 4.49 Route El Goléa P116 3532463 71175 1117 1996 5.62 2.3.6 7.68 1.5 31.2 10.48 2.0.8 6.67 10.83 Gherbouz P115 353762 71874 134 210/12013 5.7 2.70 7.75 3.88 11.9 2.7.7 5.93 5.98 7.75 Route El Goléa P117 3531455 7173298 111 1902/2013	Route Ain Moussa	P057	3548943	717353	133	1996	5.3	23.44	7.69	1.34	28.21	11.48	17.58	2.03	11.48	5.8	
Mekmahad PL05 3537109.4 718419.1 137 1996 23.87 7.76 1.75 30.87 16.66 24.9 0.97 15.69 4.49 Polyclinique Belabès PL18 3537270 721119 119 31/01/2013 4.67 22.2 7.89 1.78 31.2 15.4 21.3 3.87 7.53 6.5 Route El Goléa P116 3532463 713715 117 1996 4.49 23.67 7.58 1.5 31.52 10.08 20.05 5.87 7.53 6.5 Route El Goléa P116 3537962 718744 134 21/01/2013 4.66 23.8 16.18 12.4 16.6 10.83 Route El Goléa P117 3531435 713298 111 1996 4.77 23.70 7.61 1.53 31.21 14.6 22.2 3.08 1.61 12.1 29.2 3.53 6.36 8.17 Boute El Goléa P117 3531435 713298	Route El Goléa	P115	3533586	714060	141.6	1996	2.62	23.68	7.65	2.84	28.77	14.52	58.74	0.03	0.83	0.73	
Polyclinique Belabès PL18 3537270 721119 119 31/01/2013 4.67 22.2 7.89 1.78 31.2 15.4 21.3 3.87 11.17 8.37 H Chegga PLX 357794.8 714428.5 111 1996 4.49 23.67 7.58 1.5 31.2 10.88 20.05 5.87 7.53 6.5 Gherbouz P116 3532463 713715 117 1996 5.62 23.69 7.62 1.58 31.2 14.6 27.8 0.8 6.5 Route El Goléa P117 3537455 718744 134 21/01/2013 5.72 7.70 7.70 1.55 3.81 1.18 0.96 1.92 7.53 5.74 Route El Goléa P117 3531435 713298 111 1996 6.08 2.71 7.60 3.63 12.1 2.92 3.35 5.98 5.74 Boate El Goléa P110 3537055 719746 114 1996	Mekmahad	PL05	3537109.4	718419.1	137	1996		23.87	7.76	1.75	30.87	16.66	24.9	0.97	15.69	4.49	
H Chegga PLX4 3577944.8 714428.5 111 1996 4.9 23.67 7.58 1.5 31.52 10.08 20.05 5.87 7.53 6.5 Route El Goléa P116 3532463 713715 117 1996 5.62 23.69 7.62 1.5 31.52 10.08 20.25 5.87 7.53 6.5 Gherbouz P115 3537952 718744 134 21/01/2013 4.65 23.69 7.62 1.76 32.41 4.6 27.8 0.8 0.67 10.83 Route El Goléa P117 3531435 713298 111 1996 4.77 2.70 7.61 5.3 3.51 11.9 2.7 5.93 5.86 7.57 Ecole paramédicale PL12 353455 719746 114 1996 6.08 2.71 7.68 3.50 12.1 2.92 3.35 6.19 2.7.7 5.93 5.86 7.57 5.83 5.72 2.5 7.54 1.88 71.83 4.45 5.68 Route El Goléa P110	Polyclinique Belabès	PL18	3537270	721119	119	31/01/2013	4.67	22.2	7.89	1.78	31.2	15.4	21.3	3.87	11.17	8.37	
Route El Goléa P116 3532463 713715 117 1996 5.62 23.69 7.62 1.45 31.94 12.83 22.23 0.8 10.55 7.89 Gherbouz PL15 3537962 718744 134 21/01/2013 4.65 23.3 8.16 1.78 32.4 14.6 27.8 0.8 0.67 10.83 Route El Goléa P117 3531435 713298 111 1996 4.77 23.70 7.70 1.55 32.81 12.6 30.18 0.96 9.19 5.74 Ecole paramédicale PL23 3538478 72170 133 2401/2013 5.72 22.9 8.21 1.96 3.6 1.12 29.2 3.35 11.9 2.7.7 5.33 5.98 7.57 DSA PL10 3537055 719746 114 1996 6.08 2.3.71 7.69 1.32 35.01 1.6 2.8 3.21 6.36 3.16 2.8 3.21 <td>H Chegga</td> <td>PLX4</td> <td>3577944.8</td> <td>714428.5</td> <td>111</td> <td>1996</td> <td>4.49</td> <td>23.67</td> <td>7.58</td> <td>1.5</td> <td>31.52</td> <td>10.08</td> <td>20.05</td> <td>5.87</td> <td>7.53</td> <td>6.5</td> <td></td>	H Chegga	PLX4	3577944.8	714428.5	111	1996	4.49	23.67	7.58	1.5	31.52	10.08	20.05	5.87	7.53	6.5	
Gherbouz PL15 3537962 718744 134 21/01/2013 4.65 23.3 8.16 1.78 32.4 14.6 27.8 0.8 6.76 10.83 Route El Goléa P117 3531435 713298 111 1996 4.77 23.70 7.65 32.81 12.85 30.18 0.96 9.19 5.74 Boute Ain Moussa P057 3548943 717353 133 26/01/2013 5.7 2.76 2.48 33.5 1.19 2.7 5.93 5.89 7.57 Ecole paramédicale PL32 3538478 720170 131 21/01/2013 5.5 2.5 7.64 1.32 3.50 1.32 9.01 1.3.52 8.6 1.92 9.37 7.23 Boute El Goléa P116 3532463 713715 117 03/02/2013 5.5 2.5 7.72 3.83 11.6 2.85 3.21 6.75 8.37 Station d'épuration P116 3532463 71375	Route El Goléa	P116	3532463	713715	117	1996	5.62	23.69	7.62	1.45	31.94	12.83	22.23	0.8	10.55	7.89	
Route El Goléa P117 3531435 713298 111 1996 4.7 2.3.0 7.70 1.5.5 3.2.81 12.85 30.18 0.96 9.19 5.74 Route Ain Moussa P057 3548943 717353 133 26/01/2013 5.72 26.2 7.64 2.48 33.5 11.9 27.7 5.93 5.98 7.57 Ecole paramédicale PL32 3538478 720170 131 21/01/2013 5.72 2.2 8.21 1.86 30.61 12.1 29.2 3.35 6.38 8.17 DSA PL10 3537055 719746 114 1996 6.82 2.77 7.69 1.32 3.01 13.8 13.8 7.1 3.04 8.45 5.68 Route El Goléa P116 3532463 713715 117 03/02/2013 5.8 2.5 7.74 4.1 3.84 14.6 2.85 3.21 6.75 8.37 Station d'épuration P1.30 35	Gherbouz	PL15	3537962	718744	134	21/01/2013	4.65	23.3	8.16	1.78	32.4	14.6	27.8	0.8	6.76	10.83	
Route I Goléa P117 3584943 717353 133 26/01/2013 5.7 26.2 7.64 2.48 33.5 11.9 27.7 5.93 5.88 7.57 Ecole paramédicale PL32 3538478 720170 131 21/01/2013 5.72 22.9 8.21 1.96 3.66 1.21 29.2 3.35 6.10 21.93 5.686 1.92 19.37 7.23 Route I Goléa P117 3531435 713298 111 03/02/2013 5.8 25.8 7.7 2.58 3.4 13.8 3.11.6 28.5 3.24 1.66 38.3 11.6 28.5 3.21 1.75 8.37 Route I Goléa P116 3532463 711375 117 03/02/2013 5.8 22.5 8.04 1.66 38.3 11.6 28.5 3.21 1.75 8.37 Station d'épuration P1.30 3538398 721404 130 21/01/2013 5.5 2.37 7.86 0.35	Route El Goléa	P117	3531435	713298	111	1996	4.77	23.70	7.70	1.55	32.81	12.85	30.18	0.96	9.19	5.74	
Ecole paramédicale PL32 3538478 720170 131 21/01/2013 5.7 22.9 8.21 1.96 33.6 1.21 29.2 3.35 6.36 8.17 DSA PL10 3537055 719746 114 1996 6.08 23.71 7.69 1.32 35.01 13.52 8.6 1.92 9.37 7.23 Route El Goléa P117 3531435 713795 111 03/02/2013 5.5 2.7 2.72 3.63 1.18 3.71 3.04 8.45 5.68 Route El Goléa P116 3532463 713715 117 03/02/2013 5.5 2.5 7.72 3.84 14.6 28.5 4.45 1.62 8.14 Hassi Debich P416 3581097 730922 106 24/01/2013 5.5 2.7.8 8.6 0.55 8.6 1.8 1.8 3.6 1.8 3.16 9.03 9.1.2 DSA P110 3537055 719746 <td< td=""><td>Route Ain Moussa</td><td>P057</td><td>3548943</td><td>717353</td><td>133</td><td>26/01/2013</td><td>5.7</td><td>26.2</td><td>7.64</td><td>2.48</td><td>33.5</td><td>11.9</td><td>27.7</td><td>5.93</td><td>5.98</td><td>7.57</td><td></td></td<>	Route Ain Moussa	P057	3548943	717353	133	26/01/2013	5.7	26.2	7.64	2.48	33.5	11.9	27.7	5.93	5.98	7.57	
DSA PL10 3537055 719746 114 1996 6.08 23.71 7.69 1.32 35.01 13.52 8.6 1.92 19.37 7.23 Route El Goléa P117 3531435 713298 111 03/02/2013 5.5 25 7.72 3.25 35.4 13.8 37.1 3.04 8.45 5.68 Route El Goléa P116 3552463 713715 117 03/02/2013 5.8 22.5 8.04 1.6 38.5 3.21 6.75 8.37 Station d'épuration PL30 3538398 721404 130 31/01/2013 5.5 25.7 7.84 4.1 38.4 14.6 28.5 3.44 1.82 0.89 4.8 21.26 DSA PL10 3537055 719746 114 28/01/2013 5.51 2.4.6 8.44 2.37 38.8 16.9 36.9 1.9.3 9.03 9.21 Hasiz Debich PL10 3537055 719746	Ecole paramédicale	PL32	3538478	720170	131	21/01/2013	5.72	22.9	8.21	1.96	33.6	12.1	29.2	3.35	6.36	8.17	
Route El Goléa P117 3531435 713298 111 03/02/2013 5.5 2.5 7.72 3.25 3.5.4 1.8.8 37.1 3.0.4 8.45 5.68 Route El Goléa P116 3532463 713715 117 03/02/2013 5.5 2.5 8.04 1.66 36.3 11.6 28.5 3.21 6.75 8.37 Station d'épuration P140 358098 721404 130 31/01/2013 5.29 25.1 7.84 1.46 28.5 4.45 11.62 8.14 Hassi Debich P416 3581097 730922 106 24/01/2013 5.5 23.7 8.86 0.35 38.6 18 22.3 0.89 4.8 21.26 DSA P110 3537055 719746 114 28/01/2013 6.09 25.4 7.78 1.62 39.7 1.7 36 8.43 5.11 5.97 PARC SONACOM PL28 3536077 719558 134 21/01	DSA	PL10	3537055	719746	114	1996	6.08	23.71	7.69	1.32	35.01	13.52	8.6	1.92	19.37	7.23	
Route El Goléa P116 3532463 713715 117 03/02/2013 5.8 22.5 8.04 1.66 8.33 11.6 28.5 3.21 6.75 8.37 Station d'épuration PL30 353898 721404 130 31/01/2013 5.29 25.1 7.84 4.1 38.4 14.6 28.5 4.45 14.2 8.14 Hassi Debich P416 3581097 730922 106 24/01/2013 5.5 2.8 8.60 3.68 14.6 28.5 4.8 2.126 DSA P110 3537055 719746 114 28/01/2013 5.5 2.4 8.44 2.37 8.8 16.9 9.9 9.03 9.12 Hôpital LTPSN2 3536077 719558 134 21/01/2013 6.09 2.4 7.8 8.10 1.8 30.6 5.2 7.14 8.4 Bour El Haicha P408 3540933 719558 110 21/01/2013 6.02 2.36	Route El Goléa	P117	3531435	713298	111	03/02/2013	5.5	25	7.72	3.25	35.4	13.8	37.1	3.04	8.45	5.68	
Station d'épuration PL30 3588398 721404 130 31/01/2013 5.5 25.1 7.84 4.1 38.4 14.6 28.5 4.45 11.62 8.14 Hassi Debich P416 3581097 730922 106 24/01/2013 5.5 23.7 8.86 0.35 38.6 18 22.3 0.89 4.8 21.26 DSA PL10 3537055 719746 114 28/01/2013 5.51 2.46 8.44 1.82 9.89 1.93 9.03 9.21 Höptal LTPSN2 3538292.9 720442.9 132 27/01/2013 6.08 2.45 8.13 1.82 3.98 11.8 30.6 5.2 7.14 8.46 PARC SONACOM PL8 3554097 719558 134 21/01/2013 6.08 2.45 8.13 1.82 3.98 11.8 30.6 5.2 7.14 8.46 Bour El Haicha P408 5549933 71990.6 110 27/01/	Route El Goléa	P116	3532463	713715	117	03/02/2013	5.8	22.5	8.04	1.66	36.3	11.6	28.5	3.21	6.75	8.37	
Hassi Debich P416 3581097 730922 106 24/01/2013 5.5 23.7 8.6 0.35 38.6 18 22.3 0.89 4.8 21.26 DSA PL10 3537055 719746 114 28/01/2013 5.51 24.6 8.44 2.37 38.6 16.9 36.9 4.8 21.26 DSA PL10 3537055 719746 114 28/01/2013 5.51 24.6 8.44 2.37 38.6 16.9 36.9 4.8 5.11 5.97 PARC SONACOM PL28 3536077 719558 134 21/01/2013 6.08 24.5 8.13 1.82 39.8 11.8 30.6 5.2 7.14 8.46 Bour El Haicha P408 3544993.3 717022 128 1909 7.62 23.65 7.93 0.56 42.14 10.72 13.24 13.39 8.12 Route Ain Moussa P056 354933 717022 128 5001/2013	Station d'épuration	PL30	3538398	721404	130	31/01/2013	5.29	25.1	7.84	4.1	38.4	14.6	28.5	4.45	11.62	8.14	
DSA PL10 3537055 719746 114 28/01/2013 5.51 24.6 8.44 2.37 38.8 16.9 36.9 1.93 9.03 9.21 Hôpital LTPSN2 353802.9 72044.9 132 27/01/2013 6.09 25.4 7.8 1.62 39.7 11.7 36 8.43 5.1 5.97 PARC SONACOM PL28 3536077 719558 134 21/01/2013 6.08 25.4 7.8 1.82 39.7 11.7 36 8.46 5.2 7.14 8.46 Bour El Haicha P408 3540937 719558 110 27/01/2013 6.08 2.2 3.8 1.8 30.6 5.2 7.14 8.46 Bour El Haicha P408 3540933 719020 110 27/01/2013 6.08 2.36 7.82 3.6 12.4 10.72 18.37 1.39 8.12 Route Ain Moussa P056 3549933 717022 128 20/01/2013 <td>Hassi Debich</td> <td>P416</td> <td>3581097</td> <td>730922</td> <td>106</td> <td>24/01/2013</td> <td>5.5</td> <td>23.7</td> <td>8.86</td> <td>0.35</td> <td>38.6</td> <td>18</td> <td>22.3</td> <td>0.89</td> <td>4.8</td> <td>21.26</td> <td></td>	Hassi Debich	P416	3581097	730922	106	24/01/2013	5.5	23.7	8.86	0.35	38.6	18	22.3	0.89	4.8	21.26	
Hôpital LTPSN2 3538292.9 720442.9 132 27/01/2013 6.09 25.4 7.78 1.62 39.7 11.7 36 8.43 5.11 5.97 PARC SONACOM PL28 3536077 719558 134 21/01/2013 6.08 24.5 8.13 1.82 39.7 11.7 36 8.43 5.11 5.97 Bour El Haicha P408 3544999.3 719930.6 110 27/01/2013 6.22 23.1 8.07 18.2 19.1 27.5 13.29 8.12 Route Ain Moussa P056 3549933 717022 128 1996 7.62 23.6 7.93 2.16 42.5 17.9 32.1 8.03 12.49 Route Ain Moussa P056 3549933 717022 128 1996 7.62 2.66 7.63 2.16 42.5 17.9 32.1 8.03 12.49 8.07	DSA	PL10	3537055	719746	114	28/01/2013	5.51	24.6	8.44	2.37	38.8	16.9	36.9	1.93	9.03	9.21	
PARC SONACOM PL28 3536077 719558 134 21/01/2013 6.08 24.5 8.13 1.82 39.8 11.8 30.6 5.2 7.14 8.46 Bour El Haicha P408 3544999.3 719930.6 110 27/01/2013 6.22 23.1 8.07 1.82 42 19.1 27.5 13.39 8.12 Route Ain Moussa P056 3549933 717022 128 1996 7.62 23.65 7.93 0.56 42.14 10.72 18.67 1.86 3.62 3.21 8.01 Route Ain Moussa P056 3549933 717022 128 29.01/2013 5.98 2.46 7.63 2.16 42.5 17.9 32.1 8.03 12.63 3.32 Route Ain Moussa P056 354933 717022 128 26/01/2013 5.98 2.46 7.63 2.16 42.5 17.9 32.1 8.03 12.49 8.07	Hôpital	LTPSN2	3538292.9	720442.9	132	27/01/2013	6.09	25.4	7.78	1.62	39.7	11.7	36	8.43	5.11	5.97	
Bour El Haicha P408 \$5544999.3 719930.6 110 27/01/2013 6.22 23.1 8.07 1.82 42 19.1 27.5 13.21 13.39 8.12 Route Ain Moussa P056 3549933 717022 128 1996 7.62 23.65 7.93 0.56 42.14 10.72 18.87 1.86 12.63 9.32 Route Ain Moussa P056 3549933 717022 128 26/01/2013 5.98 24.6 7.63 16.42.5 17.9 32.1 8.03 12.49 8.07	PARC SONACOM	PL28	3536077	719558	134	21/01/2013	6.08	24.5	8.13	1.82	39.8	11.8	30.6	5.2	7.14	8.46	
Route Ain Moussa P056 3549933 717022 128 1996 7.62 23.65 7.93 0.56 42.14 10.72 18.87 1.86 12.63 9.32 Route Ain Moussa P056 3549933 717022 128 26/01/2013 5.98 24.6 7.63 2.16 42.5 17.9 32.1 8.03 12.49 8.07	Bour El Haicha	P408	3544999.3	719930.6	110	27/01/2013	6.22	23.1	8.07	1.82	42	19.1	27.5	13.21	13.39	8.12	
Route Ain Moussa P05 3549933 717022 128 26/01/2013 5.98 24.6 7.63 2.16 42.5 17.9 32.1 8.03 12.49 8.07	Route Ain Moussa	P056	3549933	717022	128	1996	7.62	23.65	7.93	0.56	42.14	10.72	18.87	1.86	12.63	9.32	
	Route Ain Moussa	P056	3549933	717022	128	26/01/2013	5.98	24.6	7.63	2.16	42.5	17.9	32.1	8.03	12.49	8.07	
Ecole Okba B. Nafaa PL41 3538660 719831 127 31/01/2013 6.26 24.1 7.68 2.11 44.9 13.2 36.2 11.8 6.32 6.68	Ecole Okba B. Nafaa	PL41	3538660	719831	127	31/01/2013	6.26	24.1	7.68	2.11	44.9	13.2	36.2	11.8	6.32	6.68	



Table 4. Field and analytical data for the Phreatic aquifer (continued).

m mScm ⁻¹ °C mmolL ⁻¹ PARC HYDRAULIQUE P419 3539494 725605 132 31/01/2013 7.03 26.4 7.84 2.05 45.1 14.4 41.4 10.78 5.95 6.91 Parc hydraulique PL13 35365250 720200 122 21/01/2013 7.64 27.1 7.94 1.78 44.4 10.55 6.59 6.91 Mekhadma PL25 3536230 718708 129 21/01/2013 7.64 27.1 7.94 1.78 48 14.5 44.4 10.55 6.56 7.4 7.61 Said Otba P506 3535528.1 725075.1 126 04/02/2013 8.32 24.3 8.12 1.71 52.6 14.6 42.8 10.97 7.51 7.83 Said Otba P506 3535528.1 725075.1 126 1996 6.7 23.28 7.46 1.8 54.39 17.58 33.32 4.11 22.16 5.17 <
PARC HYDRAULIQUE P419 3539494 725605 132 31/01/2013 7.03 26.4 7.84 2.05 45.1 14.4 41.4 10.78 5.95 6.91 Parc hydraulique PL13 3536550 720200 123 21/01/2013 7.03 26.4 7.84 2.05 45.1 14.4 41.4 10.78 5.95 6.91 Mekhadma PL25 3536230 720200 123 21/01/2013 7.64 27.1 7.94 47.8 14.5 44.4 10.55 6.35 6.59 Said Otba P506 3535528.1 725075.1 126 04/02/2013 8.32 24.3 8.12 1.71 52.6 14.6 42.8 10.97 7.51 7.83 Said Otba P506 3535528.1 725075.1 126 1996 6.7 23.28 7.46 1.8 54.39 17.58 33.2 4.11 22.16 5.17 7.83 Said Otba P506 3535528.1 726075.1
Parc hydraulique PL13 3536550 720200 123 21/01/2013 7.22 24.5 7.51 3.24 47.8 14.5 44.4 10.55 6.35 6.59 Mekhadma PL25 3536230 718708 129 21/01/2013 7.64 27.1 7.94 1.78 48 14.5 42.9 6.56 7.4 7.61 Said Otba P506 3535528.1 725075.1 126 04/02/2013 8.32 24.3 8.12 1.71 52.6 14.6 42.8 10.97 7.51 7.83 Said Otba P506 3535528.1 725075.1 126 1996 6.7 23.28 7.46 1.8 54.39 17.58 33.2 4.11 22.16 5.17 Said Otba P566 354528.1 725075.1 126 1996 6.7 23.28 7.46 1.8 54.39 17.58 33.2 4.11 22.16 5.17 Mekhadma P566 35404331 719613
Mekhadma PL25 3536230 718708 129 21/01/2013 7.64 27.1 7.94 1.78 48 14.5 42.9 6.56 7.4 7.61 Said Otba P506 3535528.1 725075.1 126 04/02/2013 8.32 24.3 8.12 1.71 52.6 14.6 42.8 10.97 7.51 7.83 Said Otba P506 3535528.1 725075.1 126 1996 6.7 23.28 7.46 1.8 54.39 17.58 33.32 4.11 22.16 5.17 Mekhadma P566 35404331 7/19613 115 27/10/2013 9 24.6 7.64 1.72 62.5 15.2 7.16 3.03 4.61 6.06
Said Otba P506 3535528.1 725075.1 126 04/02/2013 8.32 24.3 8.12 1.71 52.6 14.6 42.8 10.97 7.51 7.83 Said Otba P506 3535528.1 725075.1 126 1996 6.7 23.28 7.46 1.8 54.39 17.58 33.22 4.11 22.16 5.17 Makhadma P566 35404331 7/196613 15 7/10/13 9 2.46 7.64 1.72 6.7 5.15 7.16 3.03 4.61 6.06
Said Otba P506 3535528.1 725075.1 126 1996 6.7 23.28 7.46 1.8 54.39 17.58 33.32 4.11 22.16 5.17 Mekhadma P566 3540433.1 719661.3 115 27/01/2013 9 24.6 7.64 1.72 62.5 15.2 71.6 3.03 4.61 6.06
Mekhadma P566 35404331 7196613 115 27/01/2013 9 24 6 7 64 1 72 62 5 15 2 71 6 3 03 4 61 6 06
Mekhadma PL17 3536908 718511 130 21/01/2013 9.4 24.5 8.06 3.39 63.2 15.6 77.2 2.51 4.08 5.11
Palm. Gara Krima P413 3530116.2 722775.1 130 04/02/2013 10.09 30.2 7.91 1.63 63.6 21.5 88.3 4.08 4.21 4.65
Mekhadma PL25 3536230 718708 129 1996 9.5 23.72 7.96 0.63 75.57 10.62 10.22 2.64 32.94 9.54
Said Otba (Bab sbaa) P066 3542636.5 718957.4 126 1996 7.75 23.48 7.62 1.51 80.23 12.45 45.87 2.46 23.59 5.91
CEM Malek B. Nabi PL03 3540010.9 725738.1 130 1996 7.34 23.86 7.60 3.04 84.14 30.58 108.55 2.23 10.17 8.99
ENTV PL21 3536074 721268 128 1996 9.73 23.82 7.25 4.46 84.26 23.68 61.62 3.75 33.53 1.88
Hôtel Transat PL23 3538419 720950 126 28/01/2013 15 24.2 8.2 4.53 86.6 16.7 79.9 3.21 14.54 6.85
ENTV PL21 3536074 721268 128 28/01/2013 16.41 25.7 7.45 1.97 99.9 17.4 85.5 5.7 15.66 7.6
Mekmahad PL05 3537109.4 718419.1 137 21/01/2013 16.8 24.8 7.64 2.02 101.3 17.7 85.9 5.85 16.69 7.59
Beni Thour PL44 3536039.3 721673.9 134 1996 4.68 23.85 7.19 2.74 109.75 67.21 134.67 5.71 42.02 8.77
Tazegrart PLSN1 3537675 719416 125 22/01/2013 17.08 24.9 8 3.41 114.2 18.1 92.9 12.8 16.85 7.81
CEM Malek B. Nabi PL03 3540010.9 725738.1 130 27/01/2013 10.84 23.1 7.54 3.29 117.3 14.7 116.4 2.06 8.99 7.24
El Bour P006 3564272 719421 161 03/02/2013 18.31 23.6 7.76 6.26 131.9 18.1 96.3 8.61 27.11 7.99
Ain Moussa P015 3551711 720591 103 1996 12.42 23.62 7.71 2.38 134.68 28.2 72.98 3.1 52.44 6.25
Station de pompage PL04 3541410.1 723501.1 138 27/01/2013 19.01 26.4 7.85 4.03 138 16.7 108.8 13.06 19.51 8.72
Drain Chott Ouargla D.Ch 1996 23.88 7.67 2.68 142.22 24.5 96.31 3.16 44.22 3.02
Beni Thour PL44 3536039.3 721673.9 134 28/01/2013 20.18 25.8 7.8 4.96 153 17.7 125.9 6.29 22.83 8.08
CNMC PL27 3535474 718407 126 21/01/2013 21.23 24.8 8.11 1.7 169.4 18.4 130.3 4.89 27.81 8.63
Bamendil P076 3540137 716721 118 26/01/2013 22.31 27.2 7.57 4.33 171.5 17.1 130.8 6.32 28.01 8.83
N'Goussa P041 3559563 716543 135 26/01/2013 25.94 24.5 8.18 7.95 208.6 13.4 198.9 3.61 11.81 8.75
N'Goussa P009 3559388 717707 123 26/01/2013 27.51 28.4 8.39 11.45 208.8 15.8 195.1 2.65 18.7 9.01
LTP16 1996 11.53 23.78 7.48 3.84 213.35 48.63 147.9 7.46 75.31 4.25
P100 1996 17.18 23.64 7.59 3.37 235.01 46.44 264.84 4.74 25.57 5.56
Chott Adjadja Aven PLX1 3540758.8 726115.6 132 28/01/2013 32.93 23.4 7.95 4.44 245.6 20.9 141.4 26.88 44.56 17.66
Route Frane P003 3569043 721496 134 02/02/2013 31.03 23.5 8.01 6.91 252.7 17.9 208.2 9.41 29.99 10.03
El Bour-N'gouca P007 3562236 718651 129 26/01/2013 30.07 28.4 7.76 5.42 254.7 15.5 209.2 10.43 28.82 7.51
Route Ain Bida PLX2 3537323.9 724063.3 127 21/01/2013 43.25 25.7 8.07 5.15 262.2 93 270.4 15.5 62.77 21.46
Ain Moussa P015 3551711 720591 103 25/01/2013 32.02 22.7 8.03 2.95 263 15.4 206.9 6.56 32.12 9.95
Ain Moussa P402 3549503 721514 138 25/01/2013 60 28.7 8.6 7.69 313.2 93.9 442.8 23.26 12.56 10.17
Route Frane P001 3572148 722366 127 1996 23.63 8.37 4 323.62 58.13 331.43 5.01 49.77 3.97
Ain Moussa P014 3551466 719339 131 1996 23.40 7.31 3.98 336.96 64.29 328.67 5.53 62.37 5.45
N'Goussa P019 3562960 717719 113 02/02/2013 60.58 27.8 7.65 6.02 356.2 96 432.5 29.77 21.02 26.23
N'Goussa P018 3562122 716590 110 26/01/2013 61.06 26.2 8.42 6.46 372.4 82.3 347.1 22.64 60.71 26.63
An Moussa P014 3551466 719339 131 25/01/2013 49.04 25.2 7.89 1.8 399.7 21.1 389.3 2.41 18.97 7.39
House sedrata P113 3535586 714576 105 03/02/2013 62.24 24.8 8.2 5.96 414.8 83.8 362.7 33.34 70.23 26.51
N GOUSSA PUUY 3559388 /1//0/ 123 1996 23.2/ /.84 2.4 426.85 57.81 393.83 9.13 59.13 12.02



Table 5. Field and analytical data for the Phreatic aquifer (continued).

m mScm ⁻¹ "C mmull-" Route Frane P001 3572148 722366 127 02/02/2013 66.16 28.3 7.24 6.32 481.8 43.35 396.8 12.61 35.31 Sebkhet Safloune P031 3577604 720172 120 02/02/2013 7.59 27.9 8.06 5.62 481.9 43.53 35.77 45.34 52.97 12.0 35.77 12.34 53.77 12.34 53.77 12.34 52.77 12.44 52.77 12.44 52.77 12.44 52.77 12.44 52.77 12.44 52.77 12.44 52.77 12.44 52.95 61.11 19.77 17.75 53.33 20.9 5.55 11.27 14.75 12.83 32.01 52.55 11.27 14.4 12.65 33.1 16.71 34.45 53.61 14.72 12.85 7.71 53.3 16.71 34.24 7.02 13.71 37.6 66.03 7.66 65.05 <td< th=""><th>Locality</th><th>Site</th><th>Lat.</th><th>Long.</th><th>Elev.</th><th>Date</th><th>EC</th><th>t</th><th>pН</th><th>Alk.</th><th>CI-</th><th>SO42-</th><th>Na⁺</th><th>K*</th><th>Mg²⁺</th><th>Ca²⁺</th></td<>	Locality	Site	Lat.	Long.	Elev.	Date	EC	t	pН	Alk.	CI-	SO42-	Na ⁺	K*	Mg ²⁺	Ca ²⁺
Ender Frane P001 3572144 722366 127 0202/2013 66.16 28.3 7.41 6.32 48.17 10.15 350.82 25.96 116.21 35.71 Sebkhet Safloune P031 3577804 720172 120 0202/2013 7.58 27.9 8.06 5.55 503.3 110.3 470.5 28.67 7.91 4.3 25.77 14.3 25.77 14.3 25.97 12.34 53.78 9.77 10.43 25.96 61.1 19.73 4.73 20.97 52.34 20.96 61.1 19.73 4.73 20.97 53.46 61.9 63.5 10.13 47.95 55.5 112.77 9.42 55.95 11.27 9.42 55.95 112.71 9.42 55.95 112.71 9.42 55.97 11.28 10.20 23.57 7.46 13.72 5.46 41.10 7.29 15.87 10.23 11.41 59.78 5.26 5.11.17 11.60 12.57 7.42				m			$\rm mS cm^{-1}$	°C					mmol L ⁻¹			
Seekket Safioune P031 3577804 720172 120 1996 23.75 7.31 63.2 481.83 34.36 326.82 12.61 94.15 23.54 Bouls Frane P002 3577623 722028 106 1996 23.81 7.76 6.29 52.39 182.95 653.78 9.97 10.47 10.98 Oum Raneb P012 3554089 718612 114 2501/2013 64.05 30.3 7.83 20.9 52.96 6.41 19.73 4.73 Oum Raneb P012 3554089 7181812 114 2010/12/013 90.8 23.5 7.48 10.6 63.65 10.3 495.5 83.31 12.58 32.8 12.86 56.00 7.11 15.86 56.00 7.16 14.6 76.55 12.77 5.44 67.93 11.41 159.8 12.94 15.9 14.1 159.8 12.9 14.9 15.5 14.27 77.7 72.27 2.20 7.11 1	Route Frane	P001	3572148	722366	127	02/02/2013	66.16	28.3	7.24	6.49	468.7	101.5	350.3	25.96	116.21	35.31
Sebkhet Safioune P031 377804 72017 12 02/20213 75.66 27.9 8.06 50.35 50.37 110.3 470.5 28.67 71.2 54.77 10.39 Sebkhet Safioune P030 3577253 721396 130 1996 23.82 7.72 53.43 20.9 52.94 63.74 53.74 15.9 16.21 10.4 Oum Raneb P012 355.4069 71812 11.4 2501/2013 64.05 30.7 53.43 20.9 52.96 60.64 413.55 55.5 11.23 445.5 35.1 12.57 41.64 75.8 32.1 75.41 60.5 10.13 445.5 35.5 11.41 597.6 41.64 50.5 10.71 12.56 5.6 10.71 12.56 62.6 23.7 74.2 2.37 71.83 11.11 597.8 11.01 597.4 2.37 71.1 5.1 10.71 12.56 10.71 12.56 10.71 12.56 10	Sebkhet Safioune	P031	3577804	720172	120	1996		23.75	7.31	6.32	481.83	43.35	326.82	12.61	94.15	23.56
Boute Franc P002 3570523 722028 108 1996 23.61 7.76 529 522.39 182.95 653.77 13.78 10.7 10.87 Oum Raneh P012 3554089 71812 114 2501/2013 64.05 30.3 7.83 20.9 529.6 6.41 19.73 4.73 ANK Djemel P423 3540089 718112 114 2501/2013 60.8 2.35 7.71 539.3 60.64 13.55 58.31 15.55 112.77 9.42 ANK Djemel P423 3540081 7.7118 10 30.02/2013 64.66 23.1 7.83 9.61.07 7.84.4 650.5 8.50 12.68 12.86 Sald Otbs-Charme 90.0 3577253 72139.4 72301.1 13.8 1996 23.57 7.42 2.47 701.67 15.43 60.66 63.6 63.6 63.6 63.6 63.6 63.6 63.6 63.6 63.6 63.6 63.6	Sebkhet Safioune	P031	3577804	720172	120	02/02/2013	75.96	27.9	8.06	5.85	500.3	110.3	470.5	28.67	79.12	35.47
Sebknet Safiourne P030 3577253 71233 130 1996 23.52 77.2 4.33 52.77 12.34 533.79 11.59 105.21 10.6 10.7 4.33 52.77 12.34 533.79 11.57 54.3 533.79 11.57 54.3 533.79 11.57 54.3 533.79 11.57 54.3 533.79 11.57 54.3 533.79 11.57 54.3 533.75 54.3 12.57 44.8 62.35 64.6 2.7 12.35 64.6 2.7 13.89 635.65 10.13 495.5 55.57 11.4 71.2 2.5 74.8 337.1 671.8 90.3 74.29 15.97 41.46 7.5 12.57 44.3 60.77 15.4 60.56 85.5 12.77 42.3 11.1 15.57 11.4 55.7 11.4 55.7 11.4 11.4 55.7 11.4 11.4 11.4 11.4 11.4 11.4 11.4 11.1 11.1 11.1	Boute Frane	P002	3570523	722028	108	1996		23.81	7 76	6.29	522.39	182 95	653 78	9.97	104.7	10.99
Ourr Raneb P012 355/4089 716512 114 250/12013 64.05 30.3 7.28 32.0 520.6 6.41 19.73 4.73 Ourr Raneb P012 355/408 718612 114 1996 23.41 7.46 27.2 539.35 60.64 413.55 5.55 112.7 9.42 Said Obba-Chott P096 3540265 7.247.29 111 1996 23.57 7.48 6.19 636.5 101.3 495.5 38.31 125.61 30.32 Said Obba-Chott P096 3547265 7.1571 110 0.30/02/2013 64.66 5.57 14.67 7.07 154.45 605.66 65.15 11.72 7.72 2.47 7.07 53.1 615.9 2.57 7.48 5.60.07 7.04 9.58 11.44 7.55 560.07 7.04 9.58 11.44 7.55 560.07 7.45 2.34 7.57 560.07 7.45 2.34 57.41 560.07 7.45	Sebkhet Safioune	P030	3577253	721936	130	1996		23.52	7 72	4 43	527.7	123.48	533 79	11.59	106 21	10.65
Oum Raneb P012 3554069 718612 114 Control of the	Oum Baneb	P012	3554089	718612	114	25/01/2013	64 05	30.3	7.83	7 77	534.3	20.9	529.6	6.41	19 73	4 73
NK Djemel P423 354/0881 723176 102 31/01/2013 90.8 23.5 7.4 6.19 636.5 101.3 495.5 38.31 125.81 30.32 Said Otta-Choth P090 3577253 72193 130 03/02/2013 64.66 23.17 7.83 3.71 671.8 90.3 742.9 15.97 41.46 7.65 NGoussa P017 3360226 715781 130 03/02/2013 64.66 23.1 7.83 3.71 671.8 90.3 742.9 15.07 41.46 7.65 NKD piemel P021 357494 72028 100 02/02/201 62.82 2.57 7.42 2.37 77.16.27 34.79 56.007 7.04 99.58 11.04 Said Otta-Chott P096 354/0265 71719 113 1996 23.30 7.22 779.1 7.11 4.93 14.46 19.95 37.63 18.06 Said Otta-Chott P096 354/0265 <td< td=""><td>Oum Baneb</td><td>P012</td><td>3554089</td><td>718612</td><td>114</td><td>1996</td><td>01.00</td><td>23 41</td><td>7 46</td><td>2 72</td><td>539.35</td><td>60.64</td><td>413 55</td><td>5.55</td><td>112 77</td><td>9.42</td></td<>	Oum Baneb	P012	3554089	718612	114	1996	01.00	23 41	7 46	2 72	539.35	60.64	413 55	5.55	112 77	9.42
Said Otha-Chott PO96 354/0265 724729 111 0.001203 64.66 23.56 77.71 3.60 645.07 78.46 35728 5.89 208.4 12.86 Sebkhet Safioune P030 3577253 721936 130 03/02/2013 64.66 23.1 7.83 3.71 671.8 90.3 742.9 15.97 41.46 7.65 NGoussa P017 3567263 722028 108 20/02/2013 66.82 26.9 7.43 4.24 700.77 154.45 66.56 651.5 1.4.2 77.72 2.29 Said Otba-Chott P060 354/0265 7247.91 111 30/02/2013 66.82 26.9 7.77 1.8.6 661.5 1.4.2 77.72 2.29 79.11 73.1 71.1.6 74.72 1.6.7 7.4.2 77.1 1.5.6 661.5 1.4.27 77.72 2.2.9 7.91 7.3.3 71.1.6.8 7.4.2 2.5.8 80.4 9.4 8.42 1.9.9	ANK Diemel	P423	3540881	723178	102	31/01/2013	90.8	23.5	7 48	6 19	636.5	101.3	495.5	38.31	125.81	30.32
Sebkhet Safioune P030 3577253 721936 130 03/02/2013 64.66 23.1 7.83 3.71 671.8 90.3 742.9 15.97 41.46 7.65 NGoussa P017 3560256 715781 130 26/01/2013 100.1 31 7.13 3.78 679.3 114.1 597.8 10.20 15.53844 72316 160.58 53.6 163.08 14.24 Station de pompage PL04 3541410.1 723501.1 138 1996 23.57 7.42 2.37 77.15 7.45 560.07 7.04 95.58 11.0 NGoussa P019 3562260 717719 113 1996 23.30 7.72 2.27 77.11 7.13 7.11 14.1 53.1 615.9 3.77.2 3.53 63.0 59.9 12.05 53.0 610.3 7.71 7.43 7.33 7.14 4.23 9.95.2 3.33 3.47 7.74 Sold babaa P066 <	Said Otha-Chott	P096	3540265	724729	111	1996	00.0	23.59	7 71	3.69	645.07	78 46	357 28	5.89	208.4	12.86
N'Goussa P017 3560256 71578 103 2607/2013 100.1 31 7.13 3.78 679.3 114.1 597.8 10.71 125.8 22.29 ANK Djemel P021 3573943 723161 105 1996 23.57 7.43 4.24 700.77 154.45 605.80 7.40 99.58 11.04 Route Frane P002 3570523 722028 108 02/02/2013 62.82 26.9 8.7 7.45 16.5 15.9 24.6 69.64 50.39 Said Ota-Chott P006 354/266.5 71789 112 03/02/2013 150.6 26.2 7.18 12.4 77.1 53.1 61.9 23.46 69.64 50.3 33.47 77.7 2.42 77.13 71.16 51.9 25.69 8.7 10.05 24.01/2013 86.28 29.6 7.64 1.24 77.1 73.13 71.18 71.13 71.13 71.13 71.14 71.43 3.34 <td< td=""><td>Sebkbet Safioune</td><td>P030</td><td>3577253</td><td>721936</td><td>130</td><td>03/02/2013</td><td>64.66</td><td>23.1</td><td>7.83</td><td>3 71</td><td>671.8</td><td>90.3</td><td>742.9</td><td>15.97</td><td>41.46</td><td>7.65</td></td<>	Sebkbet Safioune	P030	3577253	721936	130	03/02/2013	64.66	23.1	7.83	3 71	671.8	90.3	742.9	15.97	41.46	7.65
ANK Djemel P021 3573943 723161 105 1096 23.55 7.43 4.24 700.77 154.45 605.68 53.6 153.0 14.24 Station de pompage PL04 3541410.1 72.3501.1 138 1996 23.57 7.42 2.37 716.27 34.75 560.07 7.04 99.58 11.04 Route Frame P002 3570253 722.02 110 03/02/2013 66.81 25.9 8.7 1.24 771 53.1 615.9 23.46 69.64 50.39 NGoussa P019 3562906 717.71 113 03/02/2013 150.6 22.8 2.7 18 12.9 799.1 28.124.7 18.95 25.5 3.5 39.0 42.35 800.4 94.4 824.1 10.99 53.5 39.5 2.5.9 17.0 17.13 17.13 17.14 80.4 824.9 12.42.1 49.54 13.3 33.47 17.7 2.41 818.67 81.6	N'Goussa	P017	3560256	715781	130	26/01/2013	100 1	31	7 13	3.78	679.3	114 1	597.8	10.71	125.85	26.29
Antiopland Pacta Distance Distance <thdistance< th=""> <</thdistance<>		P021	3573943	723161	105	1996	100.1	23 55	7.43	4 24	700 77	154 45	605.68	53.6	163.08	14 24
Bautie France POO2 3570523 722228 108 O2/02/2013 68.28 2.6.7 1.6.7 748.5 62.6 651.5 1.4.7 77.72 27.22 Said Otba-Chott P096 3562060 71771 111 0300/2013 66.31 52.9 8.7 1.24 771.1 511.4 62.8 69.64 50.39 Said Otba-Chott P096 3542636.5 718957.4 126 0300/2013 150.6 62.2 7.18 12.4 771.3 711.4 9.23 37.63 18.06 Said Otba-Ghoman P018 3562122 71650 110 1996 23.29 7.46 1.24 818.67 81 244.21 49.54 13.3 33.47 17.74 Qum Raneb P162 3546733 725129 98 2501/2013 110.4 23.66 7.75 1.85 900.1 15.5 930.8 7.53 2.3.3 34.47 Oum Raneb P212 3547988 72576 99 <t< td=""><td>Station de nomnade</td><td>PI 04</td><td>3541410 1</td><td>723501 1</td><td>138</td><td>1996</td><td></td><td>23.57</td><td>7 42</td><td>2 37</td><td>716.27</td><td>34 75</td><td>560.07</td><td>7 04</td><td>99.58</td><td>11 04</td></t<>	Station de nomnade	PI 04	3541410 1	723501 1	138	1996		23.57	7 42	2 37	716.27	34 75	560.07	7 04	99.58	11 04
Nach Halle Flob Stronge Table Flob	Boute Frane	P002	3570523	722028	108	02/02/2013	62.82	26.9	7.57	1.65	748 5	62.6	651 5	14 72	77 72	27 29
Sand Outer-Circla Figs Sand Science Science <td>Said Otha-Chott</td> <td>P006</td> <td>3540265</td> <td>724720</td> <td>111</td> <td>02/02/2013</td> <td>68.31</td> <td>25.0</td> <td>87</td> <td>1.00</td> <td>771</td> <td>53.1</td> <td>615.0</td> <td>23.46</td> <td>69.64</td> <td>50.30</td>	Said Otha-Chott	P006	3540265	724720	111	02/02/2013	68.31	25.0	87	1.00	771	53.1	615.0	23.46	69.64	50.30
Notossa P066 3542636.5 718957.4 126 03/02/2013 150.6 26.2 7.81 12.47 18.45 37.63 18.06 ANK Djemel P021 3573943 723161 105 24/01/2013 82.28 27.66 1.24 818.67 81 24/4.12 49.54 319.35 24.76 Ourn Raneb P162 3547234 722519 98 25/01/2013 160 30.7 7.15 2.43 842.8 289.9 1309.9 13.3 33.47 17.74 Route Sedrata P113 3535646 714576 105 1996 23.36 7.70 2.81 954.89 124.85 997.52 13.3 86.99 11.5 930.8 7.53 2.9.9 13.03 34.42 49.64 11.5 930.8 7.53 2.9.9 13.03 34.42 40.69 11.5 930.8 7.53 2.9.9 13.03 34.49 707.81 12.44 49.56 11.72 13.3 34.42 14.55 13.3 8.42.8 10.15 14.85 13.7 54.47 12.8 14.5	N'Goussa	P010	3562060	717710	113	1006	00.01	23 30	7 72	2 / 2	770 13	77 13	711.46	0.23	05.04	12.05
Calib Midligue Schröbing Flock F Floc F Flock F Flock F	Said Otha(Bah shaa)	P066	3542636.5	7189574	126	03/02/2013	150.6	26.2	7 18	12 20	700.13	283	1249 7	18.95	37.63	18.06
Nikoussa P018 356312 2101 103 24,012013 004,2 21,3 70,4 11,4 01,4 10,3 24,4 10,3 24,4 10,3 24,4 10,3 24,4 10,3 24,4 10,3 24,4 10,3 24,4 10,3 24,4 10,3 24,4 10,3 24,4 10,3 24,4 10,3 24,4 10,3 24,4 10,3 24,4 10,3 34,4 17,7 2,43 842,8 289,9 10,99,9 13,3 33,4 17,7 2,43 842,8 12,85 97,8 13,3 36,69 11,67 13,3 36,69 11,57 23,3 36,69 13,3 36,69 11,57 23,3 14,41 10,71 10,71 19,4 23,3 14,41 10,81 14,7 105,51 13,34 14,35 14,39 14,41 10,51 13,33 14,41 14,41 10,51 14,34 34,34 14,41 14,41 14,41 14,41 14,41	ANK Diemel	P021	3573043	723161	105	24/01/2013	82.28	20.2	7.64	2.25	800.4	94.4	824	10.00	53.35	25.30
Notossa P162 S502122 P163 P162 S502123 P163 P124 P164 P165 P164 P164 </td <td>N'Goussa</td> <td>D018</td> <td>3562122</td> <td>716500</td> <td>110</td> <td>1006</td> <td>02.20</td> <td>23.0</td> <td>7.04</td> <td>1.24</td> <td>818.67</td> <td>94.4</td> <td>244 21</td> <td>10.55</td> <td>310.35</td> <td>24.76</td>	N'Goussa	D018	3562122	716500	110	1006	02.20	23.0	7.04	1.24	818.67	94.4	244 21	10.55	310.35	24.76
Guin Indian Front Society 13 Schol 12 of 12 o	Oum Baneb	P162	35/6133	725120	08	25/01/2013	160	20.20	7.40	2 / 3	842.8	280.0	1300.0	12.34	33.47	17 74
House Sediata Harro Subscience Harro Subscience Harro Harro <t< td=""><td>Boute Sedrata</td><td>D112</td><td>3535586</td><td>714576</td><td>105</td><td>1006</td><td>100</td><td>23.66</td><td>7.13</td><td>2.40</td><td>042.0</td><td>124.95</td><td>007.52</td><td>13.3</td><td>86.60</td><td>11.67</td></t<>	Boute Sedrata	D112	3535586	714576	105	1006	100	23.66	7.13	2.40	042.0	124.95	007.52	13.3	86.60	11.67
Outminate P12 3538419 722931 110 GU022013 111,3 21,4 7,4 2.03 1103,31 94,49 707,81 19,14 270,91 13,3 Sebkhet Safioune P023 3577198 725726 99 1996 23,32 7,42 2.25 1176,99 91,14 1058,21 11.72 13,34 12,4 7,47 13,8 14,49 707,81 19,14 270,91 13,3 Sebkhet Safioune P023 3577198 725726 99 05/02/2013 117,9 29,4 8.09 1.85 1209,3 14,61 1458,1 14,71 155,1 18,27 7,47 13,0 13,9,61 125,4 47,98 4,34 Sebkhet Safioune P063 354568,8 72567,4 99 1996 23,50 7,66 134,01 1458,73 5,24 47,98 4,34 Bamendil P076 3540137 716721 118 1996 23,57 7,67 1,41 186,05 <td< td=""><td>Oum Baneb</td><td>D712</td><td>3547234</td><td>722031</td><td>110</td><td>05/02/2013</td><td>11/ 0</td><td>23.00</td><td>7.44</td><td>2.01</td><td>080 1</td><td>15.5</td><td>030.8</td><td>7 53</td><td>23.0</td><td>1/ 2/</td></td<>	Oum Baneb	D712	3547234	722031	110	05/02/2013	11/ 0	23.00	7.44	2.01	080 1	15.5	030.8	7 53	23.0	1/ 2/
Individual FL23 3336419 720930 120 1990 23.32 7.42 2.25 1176.99 91.14 105.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 103.31 94.49 707.31 123.47 76.37 76.4 7	Ulili Halleb	FZ12	2520/10	722931	106	1006	114.9	27.4	7.44	2.00	1102 21	04.40	707.01	10.14	23.9	19.24
Seekhet Safioune P023 357/196 725/20 99 1990 23.32 7.42 22.5 110.59 91.14 1036.21 11.12 13.7 12.7 13.7 12.7 13.7 12.7 13.7 12.7 13.7 12.7 13.7 12.7 13.7 12.7 13.7 <t< td=""><td>Solkhot Sofioupo</td><td>FL23</td><td>2577109</td><td>720930</td><td>120</td><td>1990</td><td></td><td>23.49</td><td>7.37</td><td>2.05</td><td>1176.00</td><td>94.49</td><td>1059.01</td><td>11 70</td><td>100.01</td><td>10.0</td></t<>	Solkhot Sofioupo	FL23	2577109	720930	120	1990		23.49	7.37	2.05	1176.00	94.49	1059.01	11 70	100.01	10.0
Seekhet Safioune P034 3079086 725033 97 0502213 117.9 29.4 8.19 1.85 112.1	Sepkhet Salioune	F023	2570609	725720	99	05/02/2012	120	23.32	0.00	1 76	1100.1	147	1050.21	10.07	EC 07	17.90
Secking Satural PO23 S37/196 725/20 99 050/22/013 P1.9 1.63 P129.4 6.19 1.63 1129.4 6.36 42.63 10.10 1129.4 6.36 42.63 10.10 1129.4 6.36 42.63 10.10 1129.4 6.36 42.63 10.10 1129.4 6.36 42.63 10.10 1129.4 6.36 42.64 10.10 1129.4 6.36 42.64 10.10 1129.4 6.36 42.64 10.10 1129.4 6.36 42.62 10.03 1129.4 6.36 42.62 10.03 1129.4 6.36 42.64 10.10 129.4 4.34 Sebkhet Safioune P063 3545586.8 725667.4 99 05/02/2013 178.9 26.7 7.67 1.41 180.53 91.55 143.73 26.2 278.77 1.25 Sebkhet Safioune P063 3545586.8 725667.4 99 05/02/2013 178.9 26.75 1.41 180.53 91.52 176.53<	Sepknet Salloune	P034	35/9090	725033	97	05/02/2013	117.0	34.9	0.00	1.70	1200.2	14.7	1120.4	0.27	10.37	10.15
Chold Algebla FLAT 3540/78.6 726 113.6 132 1996 23.60 6.02 139.61 125.74 18.6 18.26 10.61 13.2 1996 23.50 6.02 139.61 127.42 18.61 182.61	Chett Adiadia		3577190	725720	100	1000	117.9	29.4	0.19	0.00	1209.3	104.01	1450 70	0.00	42.00	10.15
Seekhet Safioune P063 3545360.8 725067.4 95 1996 23.7 7.64 7.84 16.9 16.5 16.2 16.5 16.2 16.0 16.3 16	Choll Aujauja Sobkhot Sofiouno	PLAI	3540756.6	726115.0	132	1996		23.00	7.46	3.02	1290.00	134.01	1456.73	10.6	47.90	4.34
Barnendil PO76 3540137 716721 118 1996 23.57 7.16 7.72 174.36 193.37 15.34 El Bour-N'gouca P007 3562236 718651 12.9 1996 23.53 7.71 5.72 174.35 191.37 26.2 278.77 1.78 Sebkhet Safioune P007 3562236 72667.4 99 05/02/2013 178.9 26.7 7.67 1.43 1887.9 92.9 145.8 26.6 22.83 1.43 1887.9 92.9 145.8 26.6 282.88 13.44 P044 1996 23.43 7.67 1.43 1887.9 92.9 145.8 26.6 282.88 13.44 P044 1996 23.42 7.59 1.1 230.85 12.20 195.73 29.49 271.8 10.41 P042 1996 23.41 7.59 2.21 2405.55 109.92 216.55 26.23 199.35 12.50 NGousa P041<	Sepkriet Sallourie	LTDOC	3343360.0	725007.4	99	1990		23.50	7.40	7.04	1079.00	710.00	1207.42	10.0	102.20	10.03
Balmendin PU/6 3540137 716/21 118 1996 23.53 7.16 1.72 143.56 143.56 143.56 143.73 26.65 331.81 12.26 Sebkhet Safioune P063 3545586.8 72567.4 99 05/02/2013 178.9 26.77 1.41 1860.53 216.67 331.38 12.26 Sebkhet Safioune P063 3545586.8 72567.4 99 05/02/2013 178.9 26.7 7.67 1.41 1860.53 216.67 182.7 1765.47 27.33 171.23 6.64 P044 P042 1996 23.56 7.69 1.41 2198.58 182.07 176.57 2.14 10.42 19.45 143.36 192.19 24.81 10.44 P042 1996 23.51 7.79 4.53 233.67 22.10 182.7 176.37 2.14 143.36 192.19 24.81 1.14 1.44 P041 3545963 722931 110 1996 <td< td=""><td>Demonstration of the</td><td>LIPUO</td><td>0540407</td><td>740704</td><td>440</td><td>1996</td><td></td><td>23.77</td><td>7.04</td><td>7.64</td><td>1030.00</td><td>/12.09</td><td>2021.01</td><td>41.55</td><td>190.51</td><td>13.34</td></td<>	Demonstration of the	LIPUO	0540407	740704	440	1996		23.77	7.04	7.64	1030.00	/12.09	2021.01	41.55	190.51	13.34
El BOLI-Ng Guida P007 3562236 71651 129 1996 23.20 7.67 1.41 160033 91.53 1434.73 26.2 27.67 1.43 Sebkhet Safioune P043 3545586.8 725667.4 99 05/02/2013 178.9 26.7 7.67 1.43 188.79 92.9 145.8 26.6 27.33 171.23 6.54 P044 P044 1996 23.39 7.79 4.53 2160.07 18.27 1765.47 27.33 171.23 6.54 P042 1996 23.42 7.59 1.1 230.85 101.22 1963.71 52.19 248.1 11.2 P048 P042 1996 23.51 7.59 1.1 230.85 101.22 1963.71 52.19 248.1 11.2 Oum Raneb P212 5547234 722931 110 1996 23.31 7.59 2.12 2405.55 109.22 12.65 25.23 199.35 12.65 25.61 <	El Deurs N'resues	P0/0	3540137	710/21	100	1996		23.53	7.71	5.72	1743.55	143.30	1404 70	20.00	070 77	12.20
Sebkriet Satiourie P063 3545366.8 725067.4 99 05/02/2013 176.9 2.6.7 7.79 4.5.3 206.67 20.62 20.64 17.123 65.4 174.3 168.71 176.74 27.38 171.23 65.4 174.3 168.71 176.74 27.33 171.23 65.4 P093 1996 23.36 7.49 1.49 2198.58 104.20 16.27 176.73 45.31 20.60 28.42 112.2 168.71 52.19 24.81 11.44 P042 1996 23.42 7.59 1.12 230.85 109.29 2178.55 25.23 199.33 12.65 Mum Raneb P212 3547234 722931 110 1996 23.31 7.54 3.35 2433.76 22.18 20.82 25.23 199.33 12.65 Mussi Debich P16 3581097 730922 106 1996 23.38 7.84 2.13 259.97.4 324.58 287.89 44.57 <td< td=""><td>El Dour-N gouca</td><td>P007</td><td>3562236</td><td>710001</td><td>129</td><td>1990</td><td>170.0</td><td>23.20</td><td>7.07</td><td>1.41</td><td>1000.00</td><td>91.55</td><td>1434.73</td><td>20.2</td><td>2/0.//</td><td>10.44</td></td<>	El Dour-N gouca	P007	3562236	710001	129	1990	170.0	23.20	7.07	1.41	1000.00	91.55	1434.73	20.2	2/0.//	10.44
P044 1996 23.58 7.49 4.53 2106.07 16.54.7 27.33 71.23 6.78 P093 1996 23.58 7.49 1.49 2198.58 182.08 195.53 29.49 27.38 17.13 10.34 P042 1996 23.51 7.54 3.35 230.65 122.08 105.21 248.1 11.24 P068 1996 23.51 7.59 2.21 2405.55 10.92 2178.55 25.23 199.3 12.65 Hassi Debich P416 3581097 730922 106 1996 23.38 7.94 2.13 249.94 240.55 25.23 199.35 12.65 NGoussa P041 3559563 716543 135 1996 23.38 7.94 2.13 245.98 245.99 44.57 152.83 10.07 9.2 NGoussa P041 3559563 716543 135 1996 23.38 7.94 2.13 241.44 240.67 9.2 NGoussa P034 3579698 72563 97 1996 23.37 6.87 1.99 241.44 240.78 152.83 10.07 Sebkhet Safioune P037 1996	Sepkriet Sallourie	P003	3040000.0	/2500/.4	99	05/02/2013	176.9	20.7	7.07	1.43	1007.9	92.9	1400.0	20.00	171.00	13.44
P093 P094 P094 P094 P095 P042 P068 P068 P042 P068 P041 P068 P041 P041 <th< td=""><td></td><td>P044</td><td></td><td></td><td></td><td>1996</td><td></td><td>23.39</td><td>7.79</td><td>4.53</td><td>2100.07</td><td>100.00</td><td>1/05.4/</td><td>27.33</td><td>070.10</td><td>10.04</td></th<>		P044				1996		23.39	7.79	4.53	2100.07	100.00	1/05.4/	27.33	070.10	10.04
P042 1996 23.42 7.59 1.1 22.30.8 101.22 190.71 52.19 24.81 11.2 Oum Raneb P212 3547234 722931 110 1996 23.51 7.54 3.32 232.67 222.08 230.22 26.84 219.9 7.19 Oum Raneb P212 3547234 722931 110 1996 23.31 7.59 2.21 240.55 109.92 2178.55 25.23 199.35 12.69 7.9 NGoussa P041 3559663 716543 135 1996 23.38 7.84 4.33 243.73 178.87 236.10 24.34 10.49 196.07 9.22 198.64 219.9 14.14 196.07 9.28 10.97 22.18 10.97 9.24 198.07 136.47 128.28 10.07 9.23 16.44 19.64 19.64 14.94 10.48 19.69 23.37 7.85 1.95 2752 134.14 261.67 24.42 180		P093				1996		23.58	7.49	1.49	2198.56	102.00	1957.53	29.49	2/0.10	10.44
Oum Raneb P212 3547234 722931 110 1996 23.31 7.59 2.21 2405.55 25.23 2178.55 25.24 199.35 12.65 Hassi Debich P416 3561097 730922 106 1996 23.33 7.84 4.33 2539.74 22405.55 25.23 199.35 12.65 MGoussa P041 3559563 716543 135 1996 23.34 7.94 2.13 2599.74 324.58 287.89 44.57 152.83 10.07 9.2 N'Goussa P034 3579698 725633 97 1996 23.34 7.85 1.95 2752 134.14 2616.77 24.42 180.14 10.48 Sebkhet Safioune P037 72563 97 1996 23.37 6.87 1.94 4189.51 201.44 404.262 17.9 257.4 32.9 34.75 7.86 Sebkhet Safioune P037 1996 23.36 6.92 1.52 4953.48 </td <td></td> <td>P042</td> <td></td> <td></td> <td></td> <td>1996</td> <td></td> <td>23.42</td> <td>7.59</td> <td>1.1</td> <td>2330.65</td> <td>101.22</td> <td>1963.71</td> <td>52.19</td> <td>240.1</td> <td>7.10</td>		P042				1996		23.42	7.59	1.1	2330.65	101.22	1963.71	52.19	240.1	7.10
Oum Haneb P212 364/234 722931 110 1996 23.31 7.59 2.21 240.55 109.92 217.855 22.63 199.30 12.55 Hassi Debich P416 3581097 730922 106 1996 23.33 7.84 4.33 2433.73 178.87 2361.09 24.34 196.07 9.2 N'Goussa P041 3559563 716543 135 1996 23.38 7.84 4.33 2433.73 178.87 2361.09 24.44 180.14 10.48 Sebkhet Safioune P034 3579698 72563 97 1996 23.37 6.87 1.94 4189.51 201.44 261.67 24.42 180.14 10.48 Sebkhet Safioune P03 1996 23.36 6.47 4.17 436.64 180.48 275.93 57.6 9.27.63 9.27.63 9.27.63 9.27.63 9.23.64 6.92 1.52 495.34 180.54 180.54 180.54 180.54 180.44 <td>O D</td> <td>P000</td> <td>05 4700 4</td> <td>700004</td> <td>440</td> <td>1996</td> <td></td> <td>23.51</td> <td>7.54</td> <td>3.35</td> <td>2335.67</td> <td>222.00</td> <td>2302.25</td> <td>20.04</td> <td>219.9</td> <td>7.19</td>	O D	P000	05 4700 4	700004	440	1996		23.51	7.54	3.35	2335.67	222.00	2302.25	20.04	219.9	7.19
Hass Debicition P416 3581097 730922 106 1996 23.33 7.84 4.33 2433.3 178.4 2361.09 24.34 196.07 92.4 N'Goussa P041 35559563 716543 135 1996 23.34 7.85 1.95 2572 134.14 2616.77 24.42 180.14 10.48 P039 P039 725633 97 1996 23.34 7.85 1.95 2752 134.14 2616.77 24.42 180.14 10.48 P039 P039 1996 23.35 6.87 1.94 4189.51 201.44 4042.62 17.9 257.81 9.23 Sebkhet Safioune P037 1996 23.36 6.87 1.52 4953.84 180.88 275.99 57.4 930.06 22.63 Sebkhet Safioune P037 1996 23.35 7.54 1.4 4972.75 108.12 4692.23 36.84 221.13 9.63 Sebkhet Safioune P036	Oum Raneb	PZ12	3547234	722931	110	1996		23.31	7.59	2.21	2405.55	109.92	21/8.55	25.23	199.35	12.65
N Golussa P041 3559503 71543 135 1996 23.36 7.94 21.3 2599.74 324.58 267.89 44.57 152.83 10.94 Sebkhet Safioune P034 3579698 72563 97 1996 23.34 7.85 1.95 2752 134.14 261.67 24.42 180.14 10.48 P039 P039 1996 23.37 6.87 1.94 4199.51 201.44 4042.62 17.9 25.74 19.23 Sebkhet Safioune P074 1996 23.36 6.92 1.52 453.84 180.88 275.9.9 57.4 9.30.06 22.63 Sebkhet Safioune P037 1996 23.36 6.92 1.52 495.34 180.45 461.06 2.9 347.57 7.86 Sebkhet Safioune P036 1996 23.35 7.54 1.4 4972.75 108.12 4692.23 36.84 221.13 9.63	Hassi Debich	P416	3581097	730922	106	1996		23.33	7.84	4.33	2433.73	1/8.8/	2361.09	24.34	196.07	9.2
Sebkret Satioune P034 3573636 725633 97 1996 23.34 7.65 1.95 2.752 134.14 2616.77 24.42 180.14 10.44	N GOUSSa	P041	3559563	716543	135	1996		23.38	7.94	2.13	2599.74	324.58	28/8.99	44.57	152.83	10.97
P039 1996 23.37 6.87 1.94 4189.51 201.44 4042.62 17.9 257.81 9.23 Sebkhet Safioune P074 1996 23.56 6.47 4.17 4356.48 180.88 275.99 57.4 930.06 22.65 Sebkhet Safioune P036 1996 23.36 6.92 1.52 4953.84 184.54 4611.06 2.9 347.57 7.86 Sebkhet Safioune P036 1996 23.35 7.54 1.4 4972.75 108.12 4692.23 36.84 221.13 9.63	Sepknet Satioune	P034	3579698	725633	97	1996		23.34	7.85	1.95	2/52	134.14	2010.77	24.42	180.14	10.48
Seeknet Satioune P0/4 1996 23.54 6.47 4.17 4356.48 180.88 2759.9 57.4 930.06 22.85 Sebkhet Safioune P037 1996 23.36 6.92 1.52 4953.84 180.54 180.54 181.54 4611.06 2.9 36.84 21.13 9.63 Sebkhet Safioune P036 1996 23.35 7.54 1.4 4972.75 108.12 4692.23 36.84 221.13 9.63	0-1-1-1	P039				1996		23.37	6.87	1.94	4189.51	201.44	4042.62	17.9	257.81	9.23
Sebknet Safioune PU37 1996 23.36 6.92 1.52 4953.84 184.54 4611.06 2.9 347.57 7.86 Sebkhet Safioune P036 1996 23.35 7.54 1.4 4972.75 108.12 4692.23 36.84 221.13 9.63	Sepkhet Satioune	P0/4				1996		23.54	6.47	4.17	4356.48	180.88	2759.9	57.4	930.06	22.63
Sebknet Satioune P036 1996 23.35 7.54 1.4 49/2.75 108.12 4692.23 36.84 221.13 9.63	Sepknet Satioune	P037				1996		23.36	6.92	1.52	4953.84	184.54	4011.06	2.9	347.57	7.86
	Seuknet Satioune	P036				1996		23.35	7.54	1.4	49/2./5	108.12	4692.23	36.84	221.13	9.63

Table 6. Isotopic data ¹⁸O and ³H and chloride concentration in Continental Intercalaire, Complexe Terminal and Phreatic aquifers.

Phreatic aquifer											
Piezometer	Cl⁻	δ ¹⁸ Ο	³Н	Piezometer	Cl⁻	δ ¹⁸ Ο	³ Н	Piezometer	Cl⁻	δ ¹⁸ Ο	³Н
	${\rm mmol}{\rm L}^{-1}$	‰	UT		$mmol L^{-1}$	‰	UT		$mmol L^{-1}$	‰	UT
P007	1860.5	-2.49	0	PL15	23.54	-7.85	0.6(1)	P074	4356.4	3.42	6.8(8)
P009	426.85	-6.6	1.2(3)	P066	80.23	-8.14	0.8(1)	PL06	14.15	-8.13	1.0(2)
P506	54.39	-6.83	1.6(3)	PL23	1103.32	-6.1	0	PL30	24.32	-7.48	2.4(4)
P018	818.67	-2.95	6.2(11)	P063	1379.3	-3.4	8.7(15)	P002	522.39	-5.71	0.6(1)
P019	779.13	-4.67	5.6(9)	P068	2335.6	-3.04	8.8(14)	PL21	84.26	-7.65	1.2(2)
PZ12	2405.5	-2.31	8.1(13)	P030	527.7	-6.57	2.4(4)	PL31	18.91	-7.38	1.6(3)
P023	1176.9	-2.62	0.2(1)	P076	1743.5	-5.56	2.8(5)	P433	12	-8.84	0
P416	2433.7	-7.88	5.9(9)	P021	700.7	-5.16	2.6(4)	PL03	84.14	-7.35	1.7(3)
P034	2752	-1.77	5.7(9)	PL04	716.27	-2.89		PL44	109.75	-8.82	1.0(2)
P036	4972.7	3.33	2.1(4)	P093	2198.5	-2.64	5.1(8)	PL05	30.87	-7.44	1.9(3)
P037	4953.8	3.12	1.8(3)	P096	645.07	-6.13	4.8(8)	P408	24.16	-7.92	0
P039	4189.5	0.97	2.2(4)	PLX1	1296.6	-5.6	1.1(2)	P116	31.94	-7.18	1.1(2)
P041	2599.7	-0.58	7.3(13)	PLX2	25.68	-7.6	1.3(2)	LTP 16	213.35	-7.48	1.6(3)
P044	2106.1	-4.46	2.7(5)	P015	134.68	-6.77	3.0(5)	P117	32.81	-6.92	0.1
P014	336.96	-6.9	2.8(5)	P001	323.62	-4.66	2.5(4)	PL10	35.01	-7.31	0.2(1)
P012	539.3	-6.41	2.2(4)	P100	235.01	-5.81	0	PL25	75.57	-7.41	0.9(2)
P042	2330.8	2.05	6.0(10)	P056	42.14	-7.03	2.9(5)	LTP30	18.21	-7.5	1.1(2)
P006	18.98	-6.64	0.5(1)	P113	954.89	-4.75	0.8(2)	LTP06	1638.6	-1.97	2.8(5)
P057	28.21	-7.33	1.1(2)	PLX4	31.52	-7.1	0.3(1)	P031	481.83	-6.06	3.0(5)
P059	20.83	-7.81	0	P115	28.77	-2.54	6.8(12)				
				Co	mplexe Term	ninal aqu	ifer				
Borehole	Cl⁻	$\delta^{18}O$	³ Н	Borehole	Cl⁻	$\delta^{18}O$	³ Н	Borehole	Cl⁻	$\delta^{18}O$	³Н
	mmol L^{-1}	‰	UT		mmol L^{-1}	‰	UT		mmol L^{-1}	‰	UT
D5F80	42.22	-7.85		D1F138	28.92	-8.13	0.7(1)	D2F71	13.53	-8.23	0.6(1)
D3F8	29.81	-8.14	1.4(2)	D3F18	21.66	-8.23	0.2(1)	D7F4	10.6	-8.27	0.1(1)
D3F26	34.68	-7.97	0.8(1)	D3F10	14.27	-7.88	1.5(2)	D2F66	11.02	-8.3	
D4F94	20.05	-8.18	0.6(1)	D6F51	28.39	-7.9	0.7(1)	D1F151	10.75	-8.32	0.4(1)
D6F67	18.79	-8.23	3.7(6)	D1F135	18.08	-7.97	1.1(2)	D6F64	11.36	-8.28	4.3(7)
				Conti	inental Interd	alaire ad	quifer				
Borehole	CI-	δ ¹⁸ Ο	³н	Borehole	CI_	δ ¹⁸ Ο	³н	Borehole	CI_	δ ¹⁸ Ο	³Н
	mmol L ⁻¹	%	UT		mmol L ⁻¹	%	UT		mmol L ⁻¹	%	UT
Hadeb I	5.8	-8.02	0	Hadeb II	6.19	-7.93	0.1(1)	Aouinet Moussa	6.49	-7.88	1.1(2)



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Aauifer	Size	Parameter	EC	t	Hα	Alk.	Cl⁻	SO ₄ ²⁻	Na ⁺	K ⁺	Ma ²⁺	Ca ²⁺
1			$mS cm^{-1}$	1-	$mmol L^{-1}$							
CI	11	Average	2.2	49.	7.5	2.3	11.	4.7	10.3	0.51	3.6	2.4
CI	11	Stdd. dev.	0.3	2.	0.2	1.	4.6	2.5	4.6	0.23	2.	1.8
СТ	50	Average	3.2	23.	7.8	2.3	20.	8.9	17.	1.0	5.5	5.6
СТ	50	Stdd. dev.	1.1	2.4	0.4	0.8	7.	2.6	6.	0.8	2.2	1.7
Phr pole I	30	Average	3.9	24.	7.9	2.3	24.7	11.8	24.2	2.1	7.2	5.3
Phr pole I	30	Stdd. dev.	1.3	1.3	0.4	1.	6.9	3.4	11.0	1.7	5.	2.7
Phr pole II	3	Average		23.4	7.	2.4	4761.	158.	4021.	32.4	500.	13.
Phr pole II	3	Stdd. dev.		0.1	0.5	1.6	350.	43.	1093.	28.	378.	8.



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Table 8. Summary of mass transfer for geochemical inverse modeling. Phases and thermodynamic database are from Phreeqc 3.0 (Parkhurst and Appelo, 2013).

Phases	Stoichiometry	CI/CT	CT/Phr I	Rainwater/P036	Phrl/Phrll 60 %/40 %
Calcite	CaCO ₃	_	-6.62E-06	-1.88E-01	-2.26E-01
$CO_2(g)$	CO ₂	-6.88E-05	-	8.42E-04	5.77E-04
Gypsum	CaSO₄.2H₂O	4.33E-03	_	1.55E-01	1.67E-01
Halite	NaCl	7.05E-03	3.76E-03	6.72E+00	1.28E+00
Sylvite	KCI	2.18E-03	1.08E-03	4.02E-01	-
Bloedite	Na ₂ Mg(SO ₄)2.4H ₂ O	-	1.44E-03	-	-
Huntite	CaMg ₃ (CO ₃)4	-	-	4.74E-02	5.65E-02
Ca ion exchange	CaX ₂	-1.11E-03	-	-	-
Mg ion exchange	MgX ₂	1.96E-03	-	1.75E-01	-2.02E-01
Na ion exchange	NaX	-	-	-	3.92E-01
K ion exchange	КХ	-1.69E-03	-	-3.49E-01	1.20E-02

Values are in mol kg⁻¹ H₂O. Positive (mass entering solution) and negative (mass leaving solution) phase mole transfers indicate dissolution and precipitation, respectively; – indicates no mass transfer.



Figure 1. Localisation and schematic relations of aquifers in Ouargla. Blue lines represent limits between aquifers, and the names of aquifers are given in bold letters; as the limit between Senonian and Miopliocene aquifers is not well defined, a dashed blue line is used. Names of villages and cities are given in roman (Bamendil, Ouargla, Sidi Khouiled), while geological/geomorphological features are in italic (Glacis, Sebkha, Chott, Dunes). Depths are relative to the ground surface. Letters a and b refer to the cross section (Fig. 2) and to the localisation map (Fig. 3).





Figure 2. Geologic cross section in the region of Ouargla. The blue pattern used for Chott and Sebkha correspond to the limit of the saturated zone.





Figure 3. Localisation map of sampling points.







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Figure 5. Contour maps of the salinity (expressed as global mineralization) in the aquifer system, **(a)** Phreatic aquifer; **(b)** and **(c)** Complexe Terminal [**(b)** Mio-pliocene and **(c)** Senonian]; figures are isovalues of global mineralization (values in gL^{-1}).



Figure 6. Equilibrium diagrams of calcite (top) and gypsum (bottom) for Continental Intercalaire (filled squares), Complexe Terminal (open circles) and Phreatic aquifer (open triangles). Equilibrium lines are defined as: $\log{Ca^{2+}} + \log{CO_3^{2-}} = \log K_{sp}$ for calcite, and $\log{Ca^{2+}} + 2\log{H_2O} + \log{SO_4^{2-}} = \log K_{sp}$ for gypsum.























Figure 10. Change from carbonate facies to evaporite from Continental Intercalaire (filled squares), Complexe Terminal (open circles) and Phreatic aquifer (open triangles).

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Figure 11. Change from sulfate facies to chloride from Continental Intercalaire (filled squares), Complexe Terminal (open circles) and Phreatic aquifer (open triangles).

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Figure 12. Correlation between Na⁺ and Cl⁻ concentrations in Continental Intercalaire (filled squares), Complexe Terminal (open circles) and Phreatic aquifer (open triangles). Seawater composition (star) is $[Na^+] = 459.3 \text{ mmol L}^{-1}$ and $[Cl^-] = 535.3 \text{ mmol L}^{-1}$ (Stumm and Morgan, 1999, p.899).





Figure 13. Calcium vs. HCO_3^- diagram in Continental Intercalaire (filled squares), Complexe Terminal (open circles), Phreatic aquifer (open triangles) and Seawater composition (star) is $[Ca^{2+}] = 10.2 \text{ mmol L}^{-1}$ and $[HCO_3^-] = 2.38 \text{ mmol L}^{-1}$ (Stumm and Morgan, 1999, p.899).





Figure 14. Calcium vs. SO_4^{2-} diagram in Continental Intercalaire (filled squares), Complexe Terminal (open circles), Phreatic aquifer (open triangles) and Seawater composition (star) is $[Ca^{2+}] = 10.2 \text{ mmol L}^{-1}$ and $[SO4^{2-}] = 28.2 \text{ mmol L}^{-1}$ (Stumm and Morgan, 1999, p.899).





Figure 15. Chloride concentration vs. δ^{18} O in Continental Intercalaire (filled squares), Complexe Terminal (open circles) and Phreatic aquifer (open triangles) from Ouargla.





plexe Terminal (open circles) and Phreatic aquifer (open triangles) from Ouargla.

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