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Assessment of groundwater volumes and quality suitability for different uses

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Abstract— **Groundwater resources have a great potential to satisfy human needs. In each case of study, volumes and water quality are essential aspects to be evaluated. The objective of this work is to assess the hydrogeological and geochemical aspects of the unconfined aquifer of the Campus of the National University of Rio Cuarto and its surroundings to determine groundwater reserves and the groundwater quality for irrigation, cattle and human consumption. The results show that there is an important geochemical homogeneity in the studied area and all the water samples are fresh (<600 uS/cm), most of calcium bicarbonate type. All the analyzed chemical variables show low values and do not surpass the established guidelines for human consumption, irrigation and cattle uses. There is an encouraging scenario with regard to the available groundwater volume. Considering that the aquifer is made up by coarse fluvial sediments and has high hydraulic conductivity and specific porosity, the estimated Regular and Total Reserves are plentiful. Only the regular reserves are enough to supply water to the different activities in the Campus (personnel, garden irrigation and experimental tasks). Also the unconfined aquifer shows an important rate of water annual replenishment from precipitations (20-28%), a very promising situation to the maintenance of groundwater reserves.**

Index Terms— **Groundwater volume, quality, human consumption, irrigation, cattle.**

I. Introduction

Groundwater is an invisible fraction of the hydrosphere and represents a hidden part of the water cycle. Groundwater is in some cases a renewable resource, which implies that it can be developed sustainably. Only a small part of the huge groundwater volumes or 'reserves' is dynamic, that is, more or less is regularly replenished by recharge and is sufficiently mobile to play the role of a natural regulator [1]. In a generic sense, groundwater is a natural resource. This does not mean, however, that all groundwater on Earth has the real potential to satisfy human needs or desires. Some groundwater is useless because its quality does not reach the water quality standards for different uses, even after conventional treatment. Moreover, the exploitation of some aquifers may be technically or economically unfeasible. Finally, the exploitation of groundwater may be subject to significant environmental constraints resulting from aspirations to conserve surface water, protect ecosystems or maintain the stability of the land surface. Therefore, and as was stated by [1], only part of the 'theoretical' groundwater resources, represented by total flows and stocks, can be considered as 'exploitable' groundwater resources. Groundwater uses vary appreciably by country, and partly depend on climate. In some countries with abundant precipitations, irrigation needs are very low, but in some more arid countries irrigation accounts for 90 percent of groundwater use [2]. In general, irrigation activities consume the largest part of the groundwater used in the world, following uses such as domestic uses in large cities, livestock, aquaculture, mining, thermoelectric power generation, and self-supplied industrial use [3].

Water quality is an essential aspect of all groundwater resources. It indicates how suitable the water is for different uses, each with their own criteria expressed as water quality standards. In Argentina more than 1.2 million people depend on groundwater whose quality problems are partially known. In some areas the total salinity, Arsenic, fluorides and nitrates contents are usually above the quality standards of the Argentinean Food Code (AFC) [4, 5]. In Córdoba province, different studies have been made to determine the groundwater aptitude for different uses [6] - [7], whose results are widely used by the regional community. The Campus of the National University of Rio Cuarto (UNRC) is located near to Rio Cuarto city (Córdoba, Argentina). A total of 15,000 people compound the staff of students, professors and administrative persons, although fewer people are circulating daily. Even though the Campus has a distribution of potable water supplied by the Municipal Company (EMOS), there was a lack of detailed studies in relation to the potential of own supply for different activities, both in relation to the available resources as well as to the quality and aptitude of groundwater use. The surface water of the Rio Cuarto River is discarded as the probable source of water, whose impact due to human activities and high load on suspended solids make the water use for various purposes less feasible. Thereby, this study focused on groundwater, which at the moment is used on the campus for recreational, experimental (cattle and crop studies) and garden irrigation activities. Thus, the objective of this work is to assess the hydrogeological and geochemical aspects of the unconfined aquifer of the Campus of the UNRC and its surroundings to determine groundwater reserves and the groundwater quality for irrigation, cattle and human consumption (Fig. 1).

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II. METHODS

The research was carried out in an area of 17 km^2, based on the analysis and compilation of satellite images (Google Earth, Landsat ETM) and topographic sheets from National Geographic Institute (NGI) at 1: 50,000 scale. Background information (geological, geomorphological, climatic, etc.) of the study area was collected and analyzed [4], [5]. The precipitation data was analyzed and interpreted using a local 43-year series (1974-2017). The geological and hydrogeological features were identified at field. The geological and geomorphological study was performed through the description of the relief and the outcropping lithological profiles. The hydrogeological data were obtained surveying 18 wells which penetrate the upper 50 m of the unconfined sedimentary aquifer. Information from a deeper borehole (300 m deep) that was made in the Campus was also available [8]. Fourteen groundwater samples were obtained and field parameters were measured in situ: pH, electrical conductivity (EC) and temperature (T) using a multiparametric portable probe with GPS, Hanna HI 9829. The samples were collected in 1 L plastic bottles and were analyzed within 24 h of collection, in the laboratory of the National University of Rio Cuarto. The following parameters were analyzed: Na^+, K^+, $HCO3^-$, Cl^-, Mg^{2+}, Ca^{2+}, $SO4^{2-}$, NO_3^-, As and F^- [9]. The mean percentage error of the analysis did not exceed 8 %. For the determination of groundwater suitability uses, the following standards were taking into account: the Argentinean Food Code (AFC) [10] for human consumption (Table 1), veterinary recommendations [11] for cattle uses (Table 2) and FAO (Food and Agriculture Organization) [12] for irrigation practices (Table 3). To calculate groundwater reserves, the guidelines of [13] were taken into account, which consider regular (RR), geological (GR) and total reserves (TR) and estimate them by means of the calculation of the water volume using the thickness, the effective porosity and the area covered by the unconfined aquifer. The effective porosity was estimated from tables [14] using values of hydraulic conductivity (K). The latter were estimated from textural analysis by means of sediment samples extracted from the entire unconfined aquifer, using the HydroGeoSieveXL software [15].

III. CLIMATIC AND GEOLOGICAL CHARACTERIZATION

The regional climate is of mesothermal sub-humid-dry type with little to no water excess. The distribution of the precipitations exhibits a very marked seasonality, with a concentration of 74 % from November to March (spring-summer), with an average precipitation of 787 mm.

The study of the regional and local framework, allows affirming that, although the igneous and metamorphic bedrock does not appear in the study area, it constitutes the base of the stratigraphic sequence [4]. The sedimentary formations recognized in the outcropping materials and up to 300 m deep in boreholes are of Cenozoic age [4]. Given the important structural control of the surrounding region, which influences the studied area, it can be affirmed that the stratigraphic sequence represents the climatic changes and the variations that occurred in the regional geological context (pulses of uplift of the mountain ranges and periods of greater stability). The climatic variations corresponding to the Quaternary period can be identified especially in the outcropping sequences and they extend in depth in the upper 150 m of the stratigraphic sequence. It is an alternation of sedimentary formations representative of a succession of wet and dry cycles. The first are related to interglacial periods during which the Rio Cuarto River deposited fluvial sediments [4], [16], [17]. The dry cycles are coincident with cold glacial epochs and were characterized by the deposition of important loessical sequences, being important the outcropping "Laguna Oscura" Formation from the Upper Holocene [18], that covers part of the study area and almost the whole South plain of Cordoba province. With the establishment of the current humid climate (1,100 BC), soil

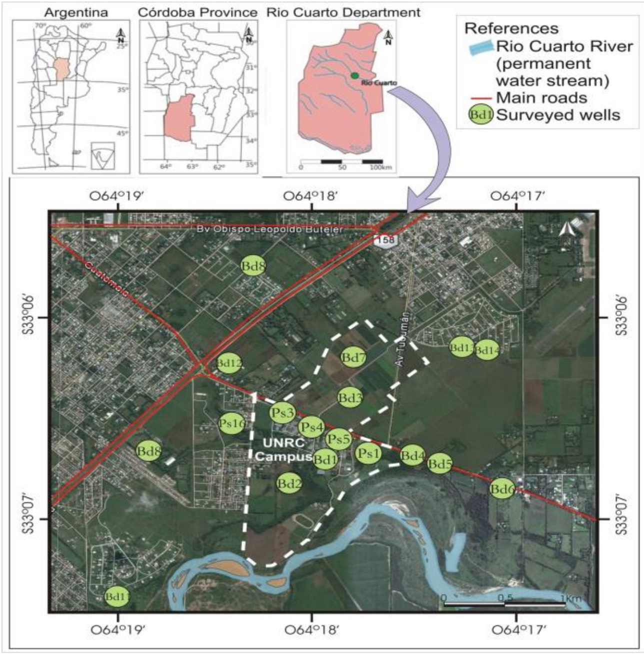

Fig. 1. Location of study area and surveyed wells.

Table 1. Admissible limits for human consumption according to [10].

Parameter / Element	Unit	Limit
pH	-	6.5-8.5
TDS	mg/L	1,500
$SO4^{2-}$	mg/L	400
As	µg/L	10
Cl^-	mg/L	350
Total hardness	mg/L $CaCO_3$	400
F^-	mg/L	1,3 at 16ºC of medium Tº
NO_3^-	mg/L	45

Table 2. Admissible limits for cattle uses on the basis of [11]

Breeding	Dairy	TDS (mg/L)	ClNa (mg/L)	SO_4^{-2} (mg/L)	Mg^{+2} (mg/L)	NO_3^- (mg/L)
Deficient	Deficient	<1,000	-	-	-	-
Satisfactory	Very good	>1,000	600	500	200	50
Very good	Good	<2,000	1,200	1,000	250	200
Good	Acceptable	< 4,000	2,400	1,500	300	300
Acceptable	Bad usable	<7,000	4,200	2,500	400	400
Bad usable	-	<11,000	6,600	4,000	500	500
Conditioned use	-	<13,000	10,000	7,000	600	-

profiles were developed and, at the same time, the fluvial belt of the Rio Cuarto River was developed.

The geomorphological and lithological structural characteristics of the area allowed defining two large environments: fluvio-aeolian and fluvial. The first one presents a pattern whose most outstanding features are constituted by very fine silty sand dunes from the Upper Holocene ("Laguna Oscura" Formation) superimposed on fluvial deposits. The second is linked to the Quaternary activity of the Rio Cuarto River, determining fluvial geoforms associated with different hydrodynamic stages (different levels of terraces, meandering paleo-channels of different size, meander migrations, channel bars, spills, among others).

IV. HYDROGEOLOGICAL CHARACTERIZATION

The studied unconfined aquifer, formed by Neogene sediments, has a thickness of approximately 70 m. The depth of the water table varies between 5 and 15 m. From the hydrogeological point of view, and conditioned by the local geomorphology, two more important hydrogeological units were distinguished: one of fluvial origin (UHA) and another of fluvio-aeolian origin (UHC). Towards the West and East of the studied area appear typical pure loessical formations that make up the hydrogeological unit UHB [16], which was not identified in the studied area. Taking into account the drilling information, a noticeable aquifer heterogeneity must be highlighted in the studied sector, characterized by sediments of variable hydraulic conductivity (*K*). In the fluvial environment, the unconfined aquifer is formed by intercalations of sands, gravels and pelitic sediments although there is a domain of psefitic material (K = 5 to 70 m/d). The UHA was subdivided in two sub environments (UHAa and UHAb) being UHAb characterized by more abundance of fine sediments. In the fluvio-aeolian environment, fluvial sediments lie under the mentioned eolian sediments whose typical hydraulic conductivity (*K*) is 0.8 to 2.5 m/d). In both units heterogeneities also appear as a result of differential carbonate cementation of sediments. Fluvial sediments are characterized by a dominance of quartz grains (K feldspar and micas subordinated). Eolian sediments present a typical mineralogy dominated by volcanic glass and, in a subordinate way, Fe oxides, pyroxenes, amphiboles, feldspars and illites [19]. The groundwater flow direction is Northwest-Southeast as is showed in the Fig. 2, where the lithological and topographical control is evident. The groundwater contributes to the Rio Cuarto River base flow, being the stream an obvious local hydrological discharge area. The largest hydraulic gradients (1 %) and groundwater velocities (0.2 m/d) are related to the fluvial unit (UHA) and are affected by topographic changes, mainly conditioned by the presence of terrace levels pertaining to the Rio Cuarto River.

Fig. 3 shows that in the whole area the groundwater are fresh, expressed by electrical conductivities values that cover a small range from 397 to 600 µS /cm. The map also shows moderately fresher groundwater in the central sector with moderately fresher groundwater in the central sector with values between 397 µS /cm to 450 µS /cm related to wells that have the screens in very coarse sandy-gravel materials.

Taking into account the total samples (Table 1), 64.28 % are of calcium bicarbonate geochemical type, 28.57 % correspond to calcium-sodium bicarbonate type and 7.14 % to sodium-calcium bicarbonate type. In the case of the UHA unit, HCO_3 and Ca ions dominate due to the presence of coarse sediments with a high recharge rate [20] and higher groundwater flow velocity, which partially decreases the weathering processes that allow the passage of other ions and compounds to the solution. Also calcium bicarbonate water types were obtained in those wells that extract water from layers with very coarse sediments located in the UHC hydrogeological unit. Calcium-sodium and sodium-calcium bicarbonate water types are linked to the UHC unit, specifically to those sectors where thicker eolian layers appear. Thus groundwater has a longer interaction time with the solid phase of the aquifer which would explains processes of cation exchange (Ca x Na). The measured values of Arsenic and fluorides are very low (1 to 10 µg/L and 0.12 to 0.6 mg / L, respectively). This is due to the scarce estimated interaction time between the groundwater and the coarse sediments in an aquifer where the groundwater velocities are high and the possible source minerals are scarce, especially in the fluvial aquifer layers from which water is extracted. As and F^- are positive correlated each other, a relationship that was found in other areas of the Pampean plain. This close relation may be showing that they have similar origin (lithological control) and enter in solution under similar

Table 3. Classification of irrigation quality [12]

	Restriction use grade		
	None	Low or moderate	Severe
Potential problem: Salinization			
E.C. (µS/cm)	<700	700-3,000	>,3000
Potential problem: Infiltration			
SAR: 0-3 and E.C. =	>700	700-200	<200
SAR: 3-6 and E.C. =	>1,200	1,200-300	300
SAR: 6-12 and E.C. =	>1,900	1,900-500	<500
SAR: 12-20 and E.C. =	>2,900	2,900-1,300	<1,300
SAR: 20-40 and E.C. =	>5,000	5,000-2,900	<2,900

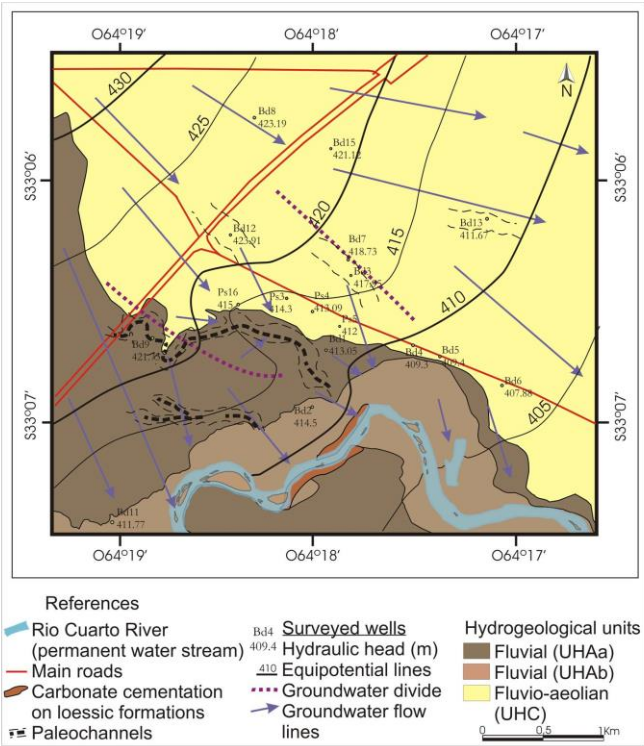

Fig. 2. Map of hydrogeological units and equipotential lines for the unconfined aquifer.

Table 4. Groundwater physico- chemical results

Date	Nº Sample	pH	CE [µS/cm]	SDT [mg/L]	$CO_3^{=}$ [mg/L]	CO_3H^- [mg/L]	$SO_4^{=}$ [mg/L]	Cl^- [mg/L]	Na^+ [mg/L]	K^+ [mg/L]	Ca^{+2} [mg/L]	Mg^{+2} [µg/L]	As [µg/L]	F^- [mg/L]	NO_3^- [mg/L]
29/09/2017	Bd1	8.2	419	293	0	145.0	60.77	17.14	18.20	6.15	45.60	5.85	5	0.18	11.5
29/09/2017	Bd2	7.6	571	400	0	197.5	43.27	17.14	18.20	7.03	57.60	5.85	5	0.15	27.0
23/08/2017	Bd3	8.0	453	317	0	240.0	22.81	8.57	42.47	8.50	54.40	7.80	8	0.40	30.0
23/08/2017	Bd4	7.8	460	322	0	247.5	14.95	11.43	38.42	8.06	56.80	4.88	8	0.26	15.0
23/08/2017	Bd5	8.1	557	390	0	300.0	10.62	14.29	55.61	8.94	60.80	6.34	3	0.24	28.0
23/08/2017	Bd6	8.0	509	356	0	297.5	14.55	11.43	69.77	7.62	51.20	7.32	6	0.20	5.0
29/09/2017	Bd7	8.3	440	308	2.42	162.5	5.51	11.43	16.68	6.45	45.60	3.90	4	0.35	13.2
03/10/2017	Bd8	7.9	536	375	0	212.5	83.45	8.57	32.86	7.62	51.60	10.00	6	0.26	9.00
03/10/2017	Bd9	7.0	437	306	0	150.0	56.24	11.43	13.14	7.33	51.20	9.76	4	0.15	21.0
03/10/2017	Bd11	7.4	501	351	0	162.5	42.87	14.29	35.39	8.06	60.00	3.90	3	0.12	32.0
03/10/2017	Bd12	8.1	397	278	0	145.0	56.24	8.57	26.29	6.59	48.00	4.39	3	0.13	13.0
03/10/2017	Bd14	8.2	431	301.7	0	177.5	105.14	8.57	36.40	7.03	44	10.24	1	0.14	1.5
01/03/2017	P4	7.5	485	340	0.00	233.0	33.0	14.30	63.7	5.10	40.8	10.20	10	0.60	19.0
01/03/2017	P5	7.6	410	287	0.00	215.0	37.0	14.30	45.50	5.60	40.00	8.80	8	0.40	10.5

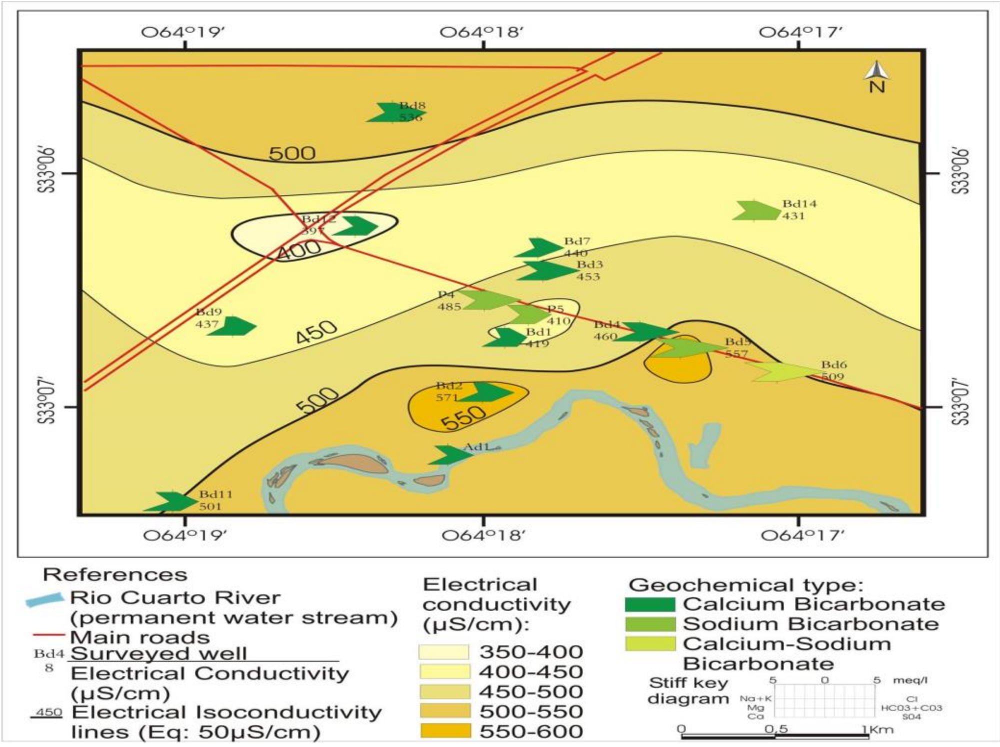

Fig. 3 Map of Electrical Conductivity and geochemical groundwater types.

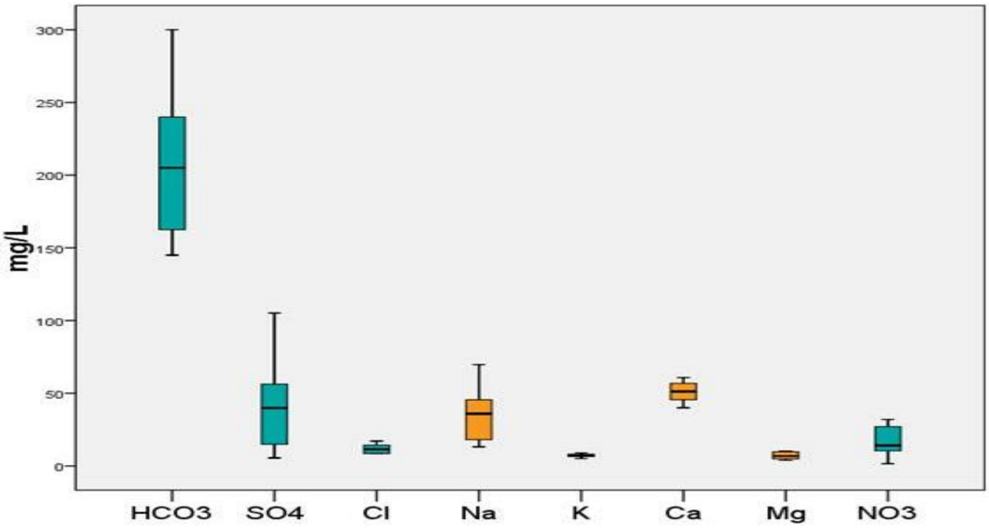

Fig. 4. Box plots for groundwater chemical variables.

geochemical aquifer conditions [20]. The Nitrate values are in general low, between 5 and 32 mg/L, but some of them above the natural background regional values (10 mg/L, [4]) as a consequence of contamination processes that results from the local human activities (fertilizers uses, livestock, and so on.).

A. *Groundwater suitability for different uses*

All the groundwater samples were qualified with the mentioned standards obtaining different groundwater suitability maps (Fig. 5, 6 and 7). Thus, for human consumption, the 100 % of samples have permissible water quality (Fig. 5), taking into account that all the analyzed variables are under the established limits by the AFC. Since the groundwater is fresh, it may be used for livestock too (Fig. 6), but veterinaries must decide about supplementary food in each case, because the intake levels are subject to large variation related to environmental temperature, humidity, water quality, diet composition and animal performance level. Following FAO standards for irrigation purposes and according to electrical conductivity and sodium adsorption rates (SAR) values (Fig. 7), which take into account hazards related to soil chemical and physical properties, the groundwater of the studied area is also within the permissible values (Fig. 8).

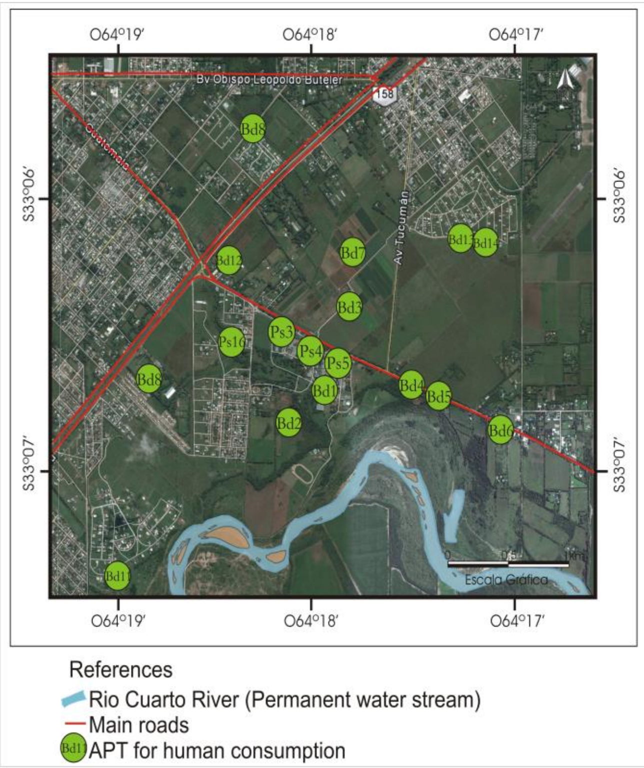

Fig. 5. Map of groundwater aptitude for human consumption.

B. *Estimation of groundwater volumes*

Knowing the water reserves of the unconfined aquifer allows determining and quantifying the extraction possibilities for different purposes, establishing general management guidelines. As was stated previously, to estimate the RR, the GR and the TR the criteria of [13] were considered. These authors establish also that the Extraction Reserves (ER) is the volume of water that results from adding the RR and a part of the GR. Then the ER are a function of economical, social and technical factors, that must be taking into account by managers during different extraction periods (Fig. 9).

a. Regular reserves (also called generating or fluctuating reserves): it is the amount of groundwater stored in the unconfined aquifer during a significant recharge by means of natural recharge. They therefore suffer the consequences of the seasonal or inter annual rate of precipitations and are closely related to the variations of the water table. It is usual to calculate these inter annual variations taking into account the volume of water contained in the aquifer between the historical minimum level (HMiL) and the historical maximum level (HMaL). Given the regional background, it is considered that between the HMiL and the HMaL there is a difference of 3 meters [4]. Then, taking into consideration the water table depth (in the order of 15 m) and the upper part of the aquifer, along which the water table can fluctuate (3 m), the estimated specific porosity for lithology found at this depth, is in the order of 18%. The following equation was used:

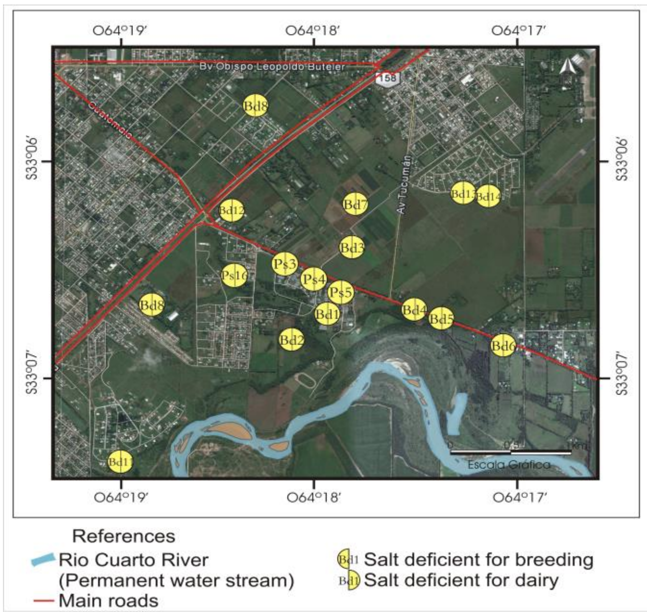

Fig. 6. Map of groundwater aptitude for cattle uses.

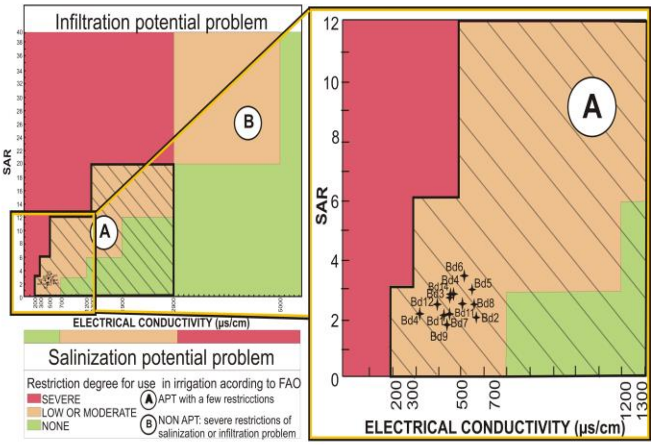

Fig. 7. Irrigation diagram prepared on the basis of FAO standards.

Regular Reserves (RR) = A. E. Sp

Being:

A: area of UNRC Campus [Km^2]

E: difference between historical minimum level (HMiL) and the historical maximum level (HMaL) [km]

Sp: Specific porosity

$$RR= 2\ km^2\ .0.003\ km.\ 0.18 =0.00108\ km^3 =$$
$$RR = 1.08\ Hm^3$$

b. Geological reserves (also called permanent or secular Reserves): it is the quantity of extractable groundwater from an aquifer, located between the minimum water table level and the base of the aquifer (minimum thickness). This will allow the extraction of large volumes, but they should not be extracted entirely, by sustainability reasons. The estimation was made with the following equation:

Geological Reserves (GR) = A. Mat. Sp

Being:

A: area of UNRC Campus [Km^2]

Mat: minimum aquifer thickness [Km]

Sp: specific porosity

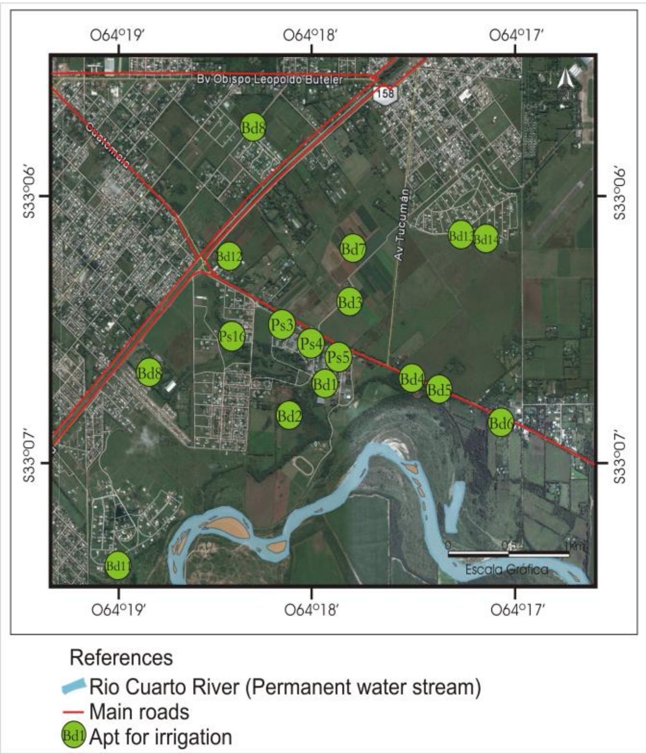

Fig. 8. Map of groundwater aptitude for irrigation.

For this calculation the total aquifer thickness (57.6 m) was confirmed during drilling of Ps1 well (between 15.4 and 73 m depth). The specific porosity estimated for the entire aquifer was 22 %, an average value resulting from the previously mentioned textural analysis. The minimum aquifer thickness considered for the calculus was 56 m (from the aquifer base to the minimum water table position, that is, 17 m deep, considering that in a dry cycle it could reach down to that depth. This is based on previous regional data [4] [5] [21] and the local behavior of the water table in a monitoring well Ps1 located in the campus (Fig. 1), where in just 9 months of a drier year the water table dropped almost 0.60 m (Fig. 10).

$$GR = 2\ Km^2.\ 0.056\ Km.\ 0.22 = 0.2464\ km^3 =$$
$$GR = 246.4\ Hm^3$$

c. Total reserves (TR): is the result of adding the RR plus GR:

$$Total\ Reserves\ (TR) = RR + GR$$
$$TR = 1.2\ Hm^3 + 246.4\ Hm^3$$
$$TR = 247.6\ Hm^3$$

An important mention that must be made for this aquifer is that it has a remarkable rate of water replenishment. Recent studies of the aquifer recharge rate, carried out with the water table fluctuation method and the chloride method, indicate

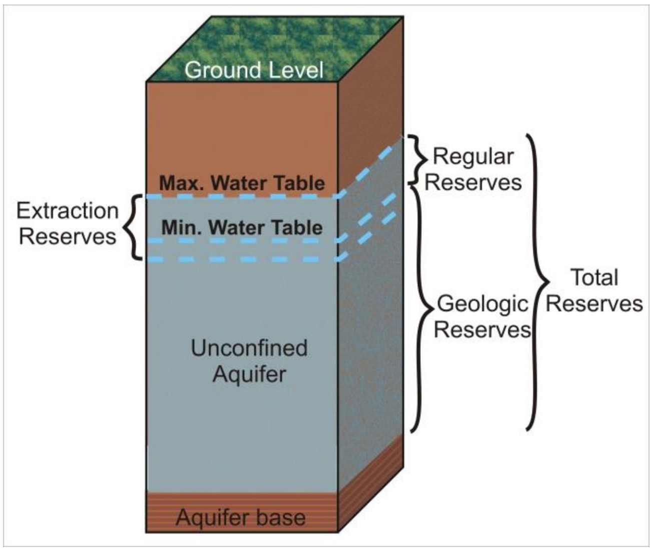

Fig. 9. Reserve types using criteria from [13].

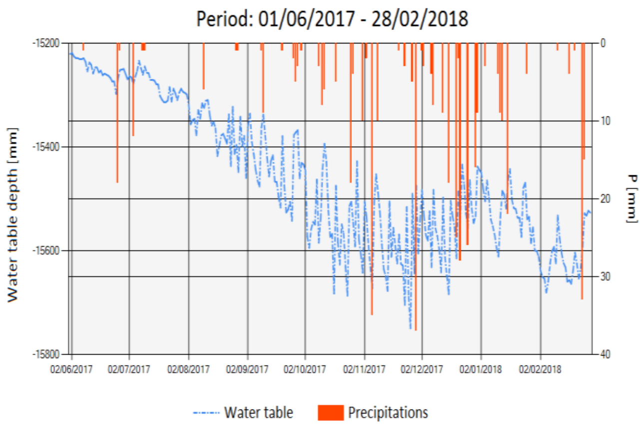

Fig. 10. Water level and precipitation on monitoring well *Ps1*.

that in the order of 20-28 % of precipitations feeds the aquifer annually [22]. Taking into account the mentioned recharge rate and the mean Precipitation (787 mm), the annual aquifer replenishment for the studied area is in the order of 0.31 to 0.44 hm^3/year. Considering that there are only 7 wells in the Campus, which only few days a month are being used, the groundwater annually spent for recreation, irrigation and experimental activities is in the order of 0,02 hm^3/year or less. Thus, there is enough water from annual replenishment to be used for all the activities including human consumption. Moreover, only the annual water recharge ensures that more than 50 L/inhabitant /day may be available if 15,000 persons would circulate daily in the UNRC Campus.

V. CONCLUSIONS

The results show that there is an important geochemical homogeneity in the studied area and all the water samples are fresh showing a high suitability for different uses. Fresh water is strongly related to the paleo-channels from which the groundwater is extracted, which are made up of very coarse sediments and a predominant inert mineralogy (quartz). These features and the high groundwater velocities decrease the weathering processes that contribute ions and chemical compounds to the solution. With regard to the trace elements, the Arsenic and fluoride values are very low (1 to 10 μg /L and 0.12 to 0.6 mg/L respectively) as a result of the scarcity of source minerals. The nitrate values are in general above the natural background, but, as it happens with the remaining variables, they not surpassed the established guidelines for human consumption. Also the groundwater of the Campus shows excellent aptitude for irrigation use and may be used for cattle.

There is an encouraging scenario with regard to the available groundwater volumes. Considering that the aquifer is made up by coarse fluvial sediments and has high hydraulic conductivity and specific porosity the estimated regular and total reserves were very plentiful. The regular reserves are enough to supply water to the different activities in the Campus (people consumption, garden irrigation and experimental tasks). Although more exact estimations of groundwater reserves may be made, it may be highlighted that the unconfined aquifer shows an important rate of water annual replenishment from precipitations. This aspect ensures that, only with the annual water recharge, a sustainable use of the groundwater resource may be done in the UNRC Campus, even considering that more activities depending of the unconfined aquifer (for example people consumption) can be planned.

VI. REFERENCES

[1] J. Margat and J, van der Gun, *Groundwater of the world: A Geographic Synopsis* (eBook). CRC Pree/Balkema. ISBN: 978-1-138-00034-6 (Hbk); 978-0-203-77214-0 March 2013.341p.

[2] NGW, *Facts About Global Groundwater Usage.* National Groundwater Association, U.S.A. October 2016.

[3] UNESCO, *Managing Water under Uncertainty and Risk.* United Nations Educational, Scientific and Cultural Organization, France. ISBN 978-92-3-104235-5. 405 p. 2012.

[4] M. Blarasin, A. Cabrera, E. Matteoda, M. Aguirre, J. Giuliano Albo, F. Bécher Quinodóz, L. Maldonado and H. Frontera. *Recursos hídricos subterráneos Parte II: Aspectos geoquímicos, isotópicos, contaminación y aptitudes de uso*. In Roberto D. Martino and Alina B. Guereschi (Eds), Relatorio del XIX Congreso Geológico Argentino: Geología y Recursos Naturales de la Provincia de Córdoba Asociación Geológica Argentina, Córdoba, 2014.

[5] M. Blarasin, A. Cabrera, E. Matteoda, *Aguas subterráneas de la Provincia de Córdoba* (Ebook), Ed. UniRío, Universidad Nacional de Río Cuarto, 2014.

[6] Lutri, V., E. Matteoda, M. Blarasin, 2016. *Cuadernos de uso y manejo de aguas subterráneas: Cuenca alta y media del Arroyo Cabral, Córdoba, Argentina*. Ed. Uni Río, ISBN 978-987-688-179-1. 24p.

[7] J. Giuliano Albo, M. Blarasin, A. Cabrera, J. Felizzia, L. Maldonado y F. N. Becher Quinodóz, *Cuadernos de uso y manejo de aguas subterráneas: Cuatro Vientos- La Barranquita*, Córdoba, Argentina. Ed. Uni Río, ISBN 978-950-665-709-3. 29p. 2012.

[8] M. Blarasin, A. Cabrera, E. Matteoda, J. Felizzia, L. Maldonado and F. Becher Quinodoz**,** Hidroestratigrafía, sistemas de flujo y geoquímica isotópica de acuíferos sedimentarios cenozoicos, Córdoba, Argentina. *Revista Latinoamericana de Hidrogeologia.* Vol. 10, n0. 1 pp 76-85. Issn: 1676-0999, 2016.

[9] APHA (American Public Health Association), AWWA (American Water Works Association), WPCF (Water pollution Control Federation). *Standard methods for the examination of water and wastewater*, 21th edn. Washington. 2005.

[10] *Código Alimentario Argentino*, 1994. Res. 494/94. Boletín Oficial Nº 27.932, 1º sección. Art. 982 modificado.

[11] G. A. Bavera, *Manual de Aguas y Aguadas para el ganado.* Editorial Hemisferio Sur, S.A. ISBN 987-43-2856-8. 387p. 2001.

[12] R.S.Ayers, and Wetscot, D.W., *Water quality for agriculture. FAO Irrigation and Drainage*. Paper 29 Rev. 1, Roma, 174 p. 1985.

[13] Feitosa and Filho, Hidrogeologia: conceitos e aplicações, Servicio geológico brasilero. p. 81-102. 2000.

[14] E. Custodio and M. R. Llamas, *Hidrogeología Subterránea*. (2nd Edition) Omega, S.A. Barcelona. 1983.

[15] J. F. Devlin, HydrogeoSieveXL: an Excel based tool to estimate hydraulic conductivity from grain size analysis. Hidrogeology Journal. DOI 10.1007/s10040-015-1255-0.

[16] S. Degiovanni,, M. Villegas, M. Blarasin and G. Sagripanti, *Hoja Geológica Río Cuarto-3263-III*. (Secretaría de Minería de la Nación – SEGEMAR, 2005).

[17] G. Chebli, M. Mozetic, C. Rossello and M. Bühler, Cuencas Sedimentarias de la Llanura Chacopampeana. In Ramos (Ed.), *Geología Argentina* (Instituto de Geología y Recursos Minerales, Buenos Aires, Anales 29 (20), 1999, 627-644).

[18] M. Cantú, Holoceno de la Provincia de Córdoba. Manual*: Holoceno de la República Argentina. Tomo I.* Simposio Internacional sobre el Holoceno de América del Sur, Paraná, Argentina, 1992.

[19] H. Nicolli, J. Suriano, M. Gómez Peral, L. Ferpozzi and O. Balean, Groundwater contamination with Arsenic and other trace elements in an area of the province of Córdoba. Argentina. *Environmental Geology and Water Sciences*, *14 (1),* 1989, 3-16

[20] D. Giacobone, M. Blarasin, E. Matteoda, A. Cabrera, V. Lutri, J. Felizzia. Arsenic and Fluoride in Groundwater of the Sedimentary Aquifer in The Campus of the National University of Rio Cuarto, Córdoba, Argentina. *Journal of Environmental Science, Toxicology and Food Technology.* Volume 12, Issue 4 Ver. I. p. 71-77 April 2018. DOI: 10.13140/RG.2.2.13312.33280

[21] M. Blarasin, F. Bécher Quinodoz, A. Cabrera, E. Matteoda, J. Felizzia, J, Arsenic and Fluoride in Groundwater of a Loessical Unconfined Aquifer, Cordoba, Argentina. *IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG).* 4. 59-65. 2016.

[22] D. Giacobone, *Caracterización hidrogeológica y geoquímica del agua subterránea en el ámbito del campus de la Universidad Nacional de Río Cuarto*, (Unpublished Lic. Thesis, Universidad Nacional de Río Cuarto, Córdoba, Argentina) 2018.

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