Socio-economic constraints of groundwater in Capital La Rioja, Argentina

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Abstract: Groundwater functioning was defined to establish a reliable reference for possible scenarios of feasible economic activities in harmony with the aptitude of the environment: fish farming, export of natural fluorine mineralised water, farm of endanger terrestrial species, eco-tourism, where social participation is to be acknowledge.

Key words: Groundwater flow, social participation, development, fluoride, eco-tourism

Introduction

Historically, the arid conditions of La Rioja, have been the main control of its development. The shortage of surface water makes groundwater a potential source for development. In 1979 the Law N° 22021 related to the economic development of the Province of La Rioja, was issued when the surface water resources were fully used to satisfy the city needs (187 l/s) and irrigation (210 l/s) of inner city allotments. The water required for population growth, industry and agricultural activities beyond 1980, was covered with groundwater; the increase in abstraction to cope with this growth created social unrest derived from negative hydrological balances. Bounds for development were put forward fearing water depletion was taking place. The objective of the study was to find groundwater functioning to establish a reliable reference for development and to find possible scenarios of feasible economic activities in harmony with accessible water resources and environment capacity.

Results and discussion

The study area is located on the lowest sierras related to the eastern part of the Andes. The site has a surface area of 4,624 km^2 and is located between 29° 00' and 30° 00' south-latitude and between 66° 00' and 67° 18' west-longitude. Limits that incorporate, to the west the low part of the basin of Los Sauces river and the south of Sierra de Velasco; to the north-east the sierras of Ambato and Mazan; to the south-east the saline flat area of La Antigua (Fig. 1). The city of La Rioja is at an altitude of 475 m a.s.l. with a population of 170,000 inhabitants.

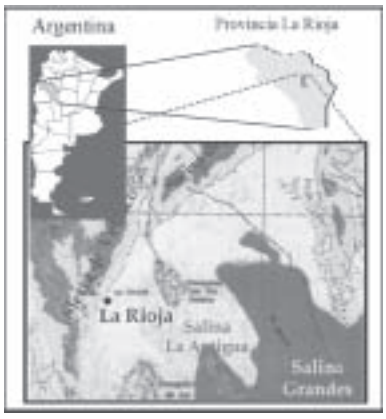

Figure 1. Location of La Rioja

Scientific paper

The 2,900 inhabitants in the rural communities are widely dispersed. Annual average temperature is 19.6 °C. The rainy season is from October to March (85-90 % of a total of ≈340 mm), rainfall is winter is negligible. Los Sauces river has a basin area of ≈1,200 km^2, its perennial flow was collected with the construction of dams (Sanagasta and Los Sauces) and related cannals. The average base-flow is ≈500 l/s, while storm-flow could reach up to 2,044 l/s (HIDROMEDITERRÁNEA, 1998). The eastern non-perennial streams in Sierra de Velasco are controlled to irrigate small alotments and to assist in the water suply of the city. Other non-perennial streams also reach the flat part of the study area and discharge in the Salado river. Estimates of water usage vary from author to author: the city water supply is from 540 to 878 l/s, for agriculture is 762 to 458 l/s, for industry 127 to 136 l/s. The total yield is ≈1,450 l/s. Estimates suggest that abstraction increased from 76 l/s in 1974 to 1,473 l/s for 1998. Depth to the water-table is unchanged, a drawdown of 0.5 m in 17 years was registered. However, salinity of abstracted groundwater has increased twofold.

Geological Framework- The stratigraphic column outcrops partially in the highland terrain of the area. Major outcrops are those of intrusive (granite) and metamorphic rocks that are considered as hydrogeological basement. Tertiary sedimentary rocks (mainly sandstones) are observed in restricted zones in the eastern side of Sierra de Velasco. Quaternary deposits are widely exposed and cover above units with up to 500 m of alluvial sediments forming the plane of the study area. The combined thickness of Tertiary and Quaternary material is about 750 m, this is considered the main aquifer in the region.

Hydrogeological Framework- Available studies related to water resources in the area dealt separately with the various components of the hydrological cycle, computing a water-balance which, however, failed to provide with the groundwater functioning of the region from where flows and sources, and impacts due to abstraction may be defined and a sustainable groundwater management may be anticipated. A recent study by MARTINEZ ET AL. (2001) defined a dynamic groundwater conceptual model in 3D based on the flow-system theory (TÓTH, 1995), which incorporated information on geology, groundwater hydraulics geochemistry as well as soil characteristics and vegetation. Recharge and discharge elements were defined at the highlands and La Antigua salt plane, respectively. For instance, water levels are at around 150 m depth in the city of La Rioja and about two metres deep in La Antigua. The general horizontal direction of groundwater flow is from the highlands to the salt plane (Fig. 2). The flow of Los sauces river bears little relation with recharge as boreholes down gradient from the dam-site produce water with lesser salinity than the water stored in the dam. A discharge zone is represented by about 300 km^2 of the salt plane and related vegetation where roughly >0.65 m^3/s of water are transferred to the atmosphere, leaving a salt crust behind; larger salt planes than La Antigua (Salinas Grandes and Ambargasta) located beyond the eastern limit of the area, suggest the presence of flows of larger path to those ending in La Antigua.

Flow systems- The local flow system are those represented by springs reported in Sierra de Velasco which provide with the water stored in Los Sauces dam. Intermediate flow systems (Fig. 2) were defined with an interpretation of chemical results of groundwater samples (MARTINEZ ET AL., 2001) from abstraction boreholes along the flow path, which suggest that

used water in the area of La Rioja derives from groundwater in Sierra de Velasco that discharges in La Antigua. Its chemical nature defines three groups. Group I has high As (0.048-0.379), total dissolved solids, TDS (662-2,296 mg/l), Cl (37-398 mg/l), Li (0.029-0.059 mg/l) and relative low F (1.1-1.2 mg/l) content and discharge temperature of 26.8-33.0 °C. This flow is inferred to travel via metamorphic rocks in the southwest of the study area. Group II has high F (2.0-3.1 mg/l), and lower TDS (504-1,759 mg/l) Cl (31-143 mg/l), Li (0.024-0.085 mg/l) and As (0.010-0.082) content than Group I, the discharge temperature is of 21.3-30.3 °C. This flow travels along weathered sections of granite rocks in the north-west of the study area. Group III, was defined in the urban area, it has high F (1.3-2.3 mg/l) and low TDS (456-931 mg/l), Cl (20-146 mg/l), Li (0.067-0.141 mg/l) and As (0.007-0.012) content, the discharge temperature is 20.4-30.3 °C. This flow travels along granular quaternary deposits and is considered a mixture of groups I and II in different proportions. The chemistry of surface water from Los Sauces river (TDS 740 mg/l, Cl 30 mg/l, Li 0.066 mg/l, As 0.009 mg/l and F, 1.45 mg/l) suggests this water is not recharging the groundwater flow collected by boreholes downstream forming defined groups I-III. Regarding a regional flow, chemical and hydrogeological data show no clear indications of such a flow; but, high Li (0.1-0.25mg/l) and temperature (33.0 °C) suggest that Group IV is a regional flow discharging in the area of La Antigua where U (0.362 mg/l) is up to 10 times as much that in other groups.

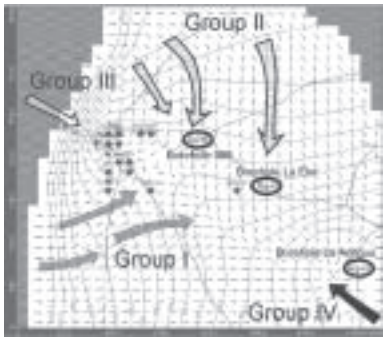

Figure 2. Groundwater groups and flows

Water quality evolution- A comparison of chemical data for 1997-1998 with that of 1985 show an increase in salinity content and temperature (Fig. 3), these suggest obtained groundwater is a mixture of different flows. High salinity poses a threat to irrigation, similarly high F^- and As^- restrict water usage for drinking purposes for long period of time.

Groundwater Circulation Depth- A strict application of geothermometers was not attempted, but an initial calculation was made using Na-K-Mg geothermometer computing a minimum equilibrium temperature of about 50 °C. If a gradient of 3 °C/100 m and an ambient temperature of 20 °C are considered, these imply a circulation depth of about 700-900 m, which agrees with mathematical modelling where an aquifer thickmeness of about 750 m was defined (Hernandez et al., 2002).

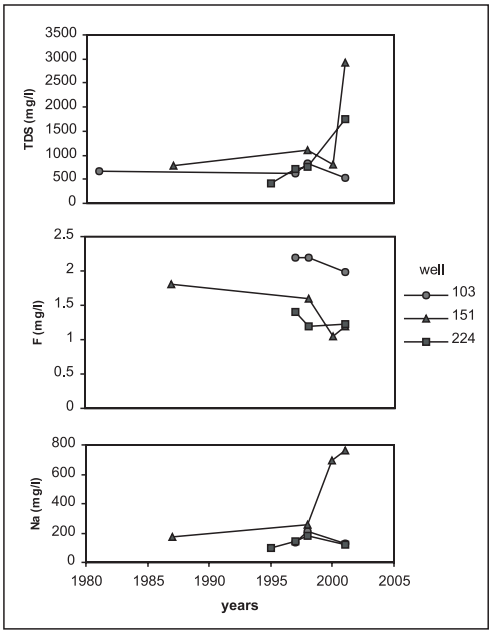

Figure 3. Relation of Na, F and TDS with time

Social and economic concerns- Following the issue of Law No. 22021 in 1979, 62 new industries were settled in La Rioja with an investment of $190'801,475US and the creation of 2,567 new jobs. Industrial activities are mainly textile (44 %), agro-industry (15 %), factories (10 %), plastics (8 %), and paper, chemical products, cosmetics, tetra-brick and others (23 %). The paper industry is a main water consumer (≈86 l/s) (HIDROMEDITERRÁNEA, 1998). The industrial development produced a higher population growth (from 69,504 to 105,996 inhabitants) as compared to that of the province, and Argentina. Estimates show an increase in water usage of ≈20 times as compared to that in the early 1970's. Agricultural activities started in the 1990's were based solely on groundwater. Landowners carry out all necessary activities from drilling to irrigation practices. Both, water conduction and utilisation are made through a highly efficient systems, but for groundwater abstraction it is not necessarily so. Out of the total land (19,543 ha) use for the new industrial activities some 10,470 ha are used to cultivate olives trees with an investment of US$ 268.358,211 this generated 646 and 339, permanent and temporal jobs, respectively. As olive plants grew groundwater requirements increased from 458 l/s for 1998, to 879 l/s for 2000. Average yield provided by a borehole is about 42 l/s which may be used to irrigate 70 ha of adult olive trees; this rate yield/irrigated-ha is more efficient to that of vegetables or grain grow, where water requirements are double. Although the tax-exemption programme gave momentum to investment and industrial development in the province, the Government concluded that this economic growth failed to both, improve employment facilities according to population growth, and to enhance their quality of life.

CONCLUSIONS

Low income populated rural areas may be developed through action based not only on the traditional high quality and abundant quantity of water concept, but on available water and sorrunding environment. From this perspective there are various possible options. *i*) use of salty water for shirmp-farming, an investment of $212,568US could yield a production of 37,000 kg/annum , *ii*) export of natural fluoride water (900 to 1,800 US$/m^3) is worth more than 1 m^3 of petrol , *iii*) thermal and curative spa and ecoturism activities, *iv*) identify and cultivate endengered species which could be >$100 a piece, *v*) increase agriculture and industrial actions and *vi*) incorporate water management with social participation.

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