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Chapter 2

GROUNDWATER MANAGEMENT IN THE REGION OF LA PLATA, PROVINCE OF BUENOS AIRES, ARGENTINA

Eduardo E. Kruse[1,2], Patricia Laurencena[2], Marta Deluchi[2], Jorge L. Pousa[2,*] and Dardo O. Guaraglia[1,3]

[1]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Buenos Aires, Argentina
[2]Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, La Plata, Argentina
[3]Facultad de Ingeniería, Universidad Nacional de La Plata, La Plata, Argentina

ABSTRACT

The paper describes actions applied to the management of water resources in the region of La Plata (Buenos Aires Province, Argentina). The overexploitation of groundwater has modified the hydraulic conditions and, at the same time, has affected the hydrochemical characteristics by favoring contamination from human wastes. At present, the average exploited groundwater volume for human consumption is 73 hm^3/y and since a substantial increase of demand for water is predicted in

* Corresponding author E-mail: jlp@fcnym.unlp.edu.ar.

future years, sustainable groundwater exploitation becomes essential. Rational management is necessary to reach a balance between water demands and groundwater conservation to avoid the extreme deterioration of water quality.

Keywords: groundwater management, Buenos Aires Province (Argentina), water balance, hydrologic modification

INTRODUCTION

Groundwater exploitation in La Plata started in 1885 to meet the needs of an increasing population. Through the years, the intense exploitation imposed a hydraulic regime characterized by depression cones in constant expansion that modified natural hydraulic gradients. The original flow direction of groundwater discharge towards the Rio de la Plata became altered, with a subsequent inversion of flow direction that caused salt water intrusion into the producing area.

As a result, in 1945 some exploitation wells had to be abandoned because of their increasing salinity. To compensate this loss and to keep pace with demand, in 1955 the drinking water supply was reinforced with fresh water from the Rio de la Plata, delivered to the city through a 9 km long pipe. At present, water supply is provided jointly from surface water and groundwater.

There is, however, a need for adopting reviewed techniques of groundwater management in agreement with the current demands. Problems derived from depletion of groundwater reserves tend to be solved with the increase, conservation and relocation of drinking water sources (Konikov and Kendy, 2005). However, such management policies have to be considered in a scenario of sustainable groundwater exploitation based on the quantification of the hydrological balance on a basin scale (Kalf and Wooley, 2005). Moreover, problems of water quality, pumping economy, ecological constraints and social and environmental effects of overexploitation should also be accounted for (Custodio, 2002).

This chapter aims to analyse the hydrological conditions in the region of La Plata, and recommends management methods for sustainable groundwater exploitation.

STUDY AREA

The city of La Plata, located to the northeast of the Buenos Aires Province, was founded in 1882 (Figure 1). Urbanized, industrial and rural zones coexist in its area of influence. The population of La Plata is now over 687 000. There are about 1000 manufacturing industries related to food, metal, and automotive (Figure 2).

The city area spreads over the Arroyo del Gato (literally, Cat's creek) basin with a drainage network altered with canals, rectifications, culverting, etc. The upper Arroyo del Gato basin has developed into a suburban zone with low population density where the primary economic activities are horticulture and floriculture, with a few industries. In the mid creek basin there is a significant increase in urbanization and population density, in addition to a larger number of industries, service activities and districts of precarious housing settled next to the stream. In the lower creek basin the watercourse crosses a low population density zone (Varela et al, 2002).

Geomorfologically, the study area is a typical flatland (topographic slope 0.1%) with its drainage basin developed between 0 and 25 meters above MWL (mean water level of the Rio de la Plata). The average discharge is 0.08 m^3/s. Two morphologic units (Figure 3) are clearly defined: the inland zone and the coastal plain (Fidalgo and Martinez, 1983). The interior zone extends between 5 and 25 m above MWL, where soils are well drained and infiltration processes predominate. The coastal plain is below 5 m above MWL and constitutes a zone of partial discharge of the groundwater system.

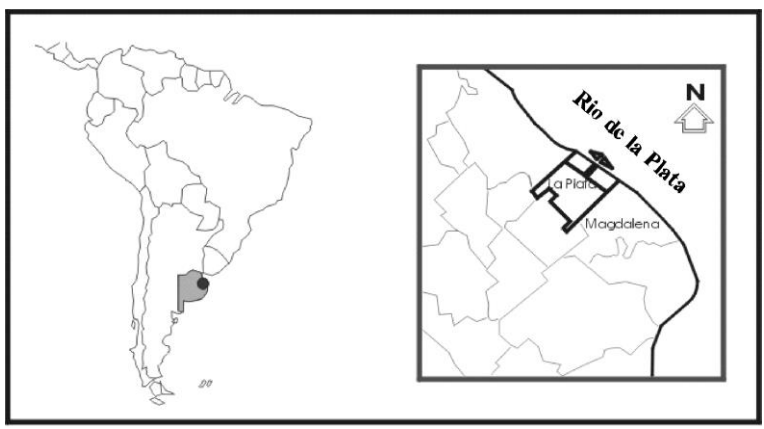

Figure 1. Study area.

Figure 2. Land uses of the Arroyo del Gato Basin.

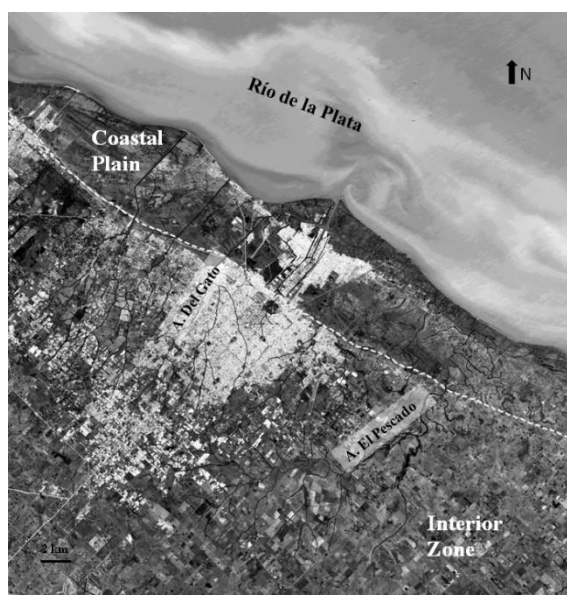

Figure 3. Morphologic units.

GENERAL HYDROGEOLOGY

Hydrogeologically, there exist two units of practical importance: Puelches Formation (sands) and Pampeano Formation (loess, sand, silt and clays) (Figure 4). These units have alternating water producing sections separated by sediments of low permeability, all of them forming a multilayer aquifer. The upper aquifer known as Pampeano (Pampian) is composed of silts with subordinate sands and clays, with a thickness of around 50 m and a transmissivity of 200 m^2/d. The Pampeano includes the water table at a depth varying between 5 and 10 m under natural conditions. The Puelches sands underlie the Pampeano Fm and represent the most important aquifer in the northeast of the Province of Buenos Aires; they are composed of a sequence of fine to medium quartz sands with approximately 20 m in thickness and a transmissivity of 500 m^2/d (Auge, 1995, 2005). The regional recharge of the Pampeano is of meteoric origin, whereas the Puelche aquifer is indirectly recharged by the Pampeano through downward vertical filtration (Sala and Auge, 1973). Local groundwater discharges into the main streams, whereas regional groundwater discharges into the Rio de la Plata (Laurencena et al, 1999).

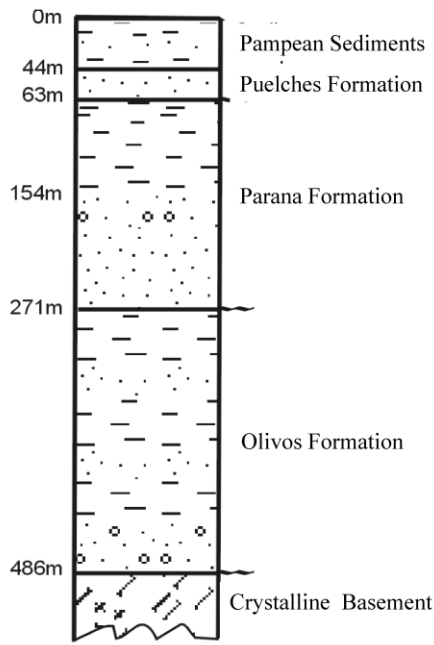

Figure 4. Stratigraphic column of the study area.

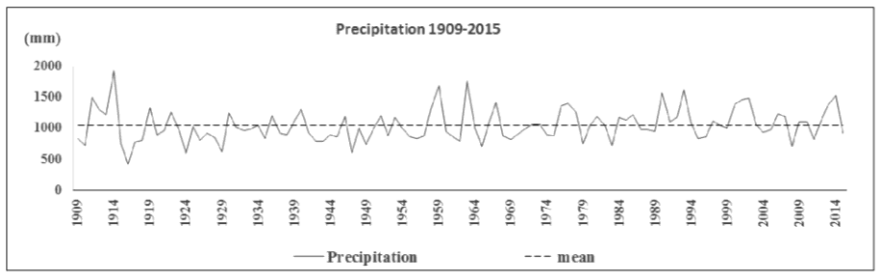

Figure 5. Typical annual precipitation of the La Plata (1909 – 2015). The dash line represents the mean precipitation.

HYDROLOGIC CHARACTERISTICS

The region is characterized by its climatic homogeneity. The annual precipitation shows alternating dry and humid periods (Figure 5). The annual mean temperature increased from 15.8ºC in 1988 to 16.8ºC in 2002. Background studies have shown that this increase was not due to the urbanization of the area.

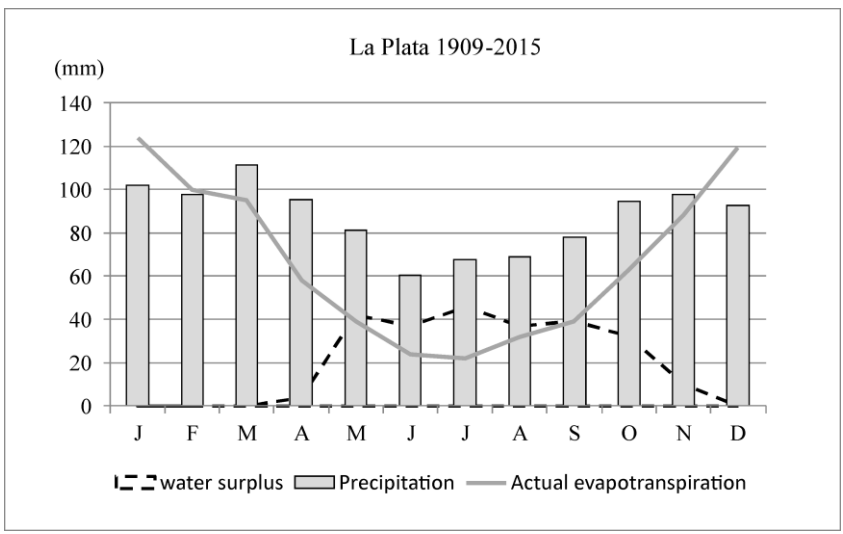

Figure 6. Water balance of La Plata (1909 – 2015).

The mean annual precipitation from 1909 to 2015 was 1048 mm/y. The actual evapotranspiration, obtained from the water balance (Thornthwaite and Matter, 1955), is 783 mm/y. Fluvial drainage and infiltration reach 53 mm/y and 225 mm/y, respectively (Figure 6).

The natural hydrologic behavior was analyzed through the evaluation of the water balance in a neighboring river basin (Arroyo El Pescado) with similar hydrologic characteristics, but without the effect of human impact. The Arroyo El Pescado is effluent with respect to groundwater, and without intensive groundwater exploitation. The runoff for significant rainfall events (above 120 mm and five-day duration) varies between 1% and 60% of precipitation (Kruse et al. 2004). The analysis of the water table variations (1989-2000) shows clearly changes connected with meteorological oscillations. Recharge estimations in daily periods give values between 20% and 65% of rainfall above 150 mm and five-day duration, associated with important water excesses for dry prior conditions of the soil (Laurencena et al. 2002).

The phreatic water chemical composition of Arroyo El Pescado is sodium bicarbonates with salinities between 370 and 1600 mg/L, evolving to sodium chloride with 8,000 mg/L in the regional discharge zone (coastal plain). The surface water presents the same composition, with smaller salinity values varying between 400 mg/L in the upper creek basin to 950 mg/L in the coastal plain. The progressive increasing salinity, particularly of chloride contents, is noticeable downstream, which is an evidence of groundwater discharge into the stream (Gonzalez and Laurencena, 1988).

The Arroyo del Gato basin presents changes in natural water balance and the interrelation of surface water and groundwater. The existence of impervious zones (urban areas) diminishes the water availability to compensate the actual evapotranspiration, thereby causing an important increase in the excesses of the water balance, with the subsequent increase in volume and speed of runoff. It must be pointed out that the present stream regime is characterized by important floods of short duration (1 or 2 days), favored by drainage from the urban zone. The runoff in the urbanized area for storm events lasting 5 days and greater than 120 mm, oscillates between 23% and 90% of the precipitation. The smaller values correspond to dry conditions of preceding humidity, whereas the larger ones correspond to humid conditions. These magnitudes of runoff in the hydrologic balance allow deducing a decrease of excesses capable of infiltrating (Kruse et al. 2004).

Chemically, groundwater of the Arroyo del Gato basin is of similar major ionic characteristic to the Arroyo El Pescado. On the other hand, there is a

marked increase in nitrate content reaching values higher than those recommended for human consumption; in many cases, more than 100 mg/L, forcing the abandonment of exploitation wells (Kruse et al. 2003). Surface water presents a high coloring and content of suspended substances, product of spills of human activities in the area (industrial effluents, sewer, etc.). The degree of contamination is verified by the high concentration of phosphorus (>0.25 mg/L of phosphates), organic substances and some pesticides. Since in this case there is a flow from the stream towards groundwater, the polluting agents can migrate towards the phreatic aquifer.

GROUNDWATER EXPLOITATION

In the urban area the Puelche aquifer is overexploited, which has generated depression cones exceeding 70 km^2. Due to hydraulic interconnection between aquifers, this deepening of levels affects the water table.

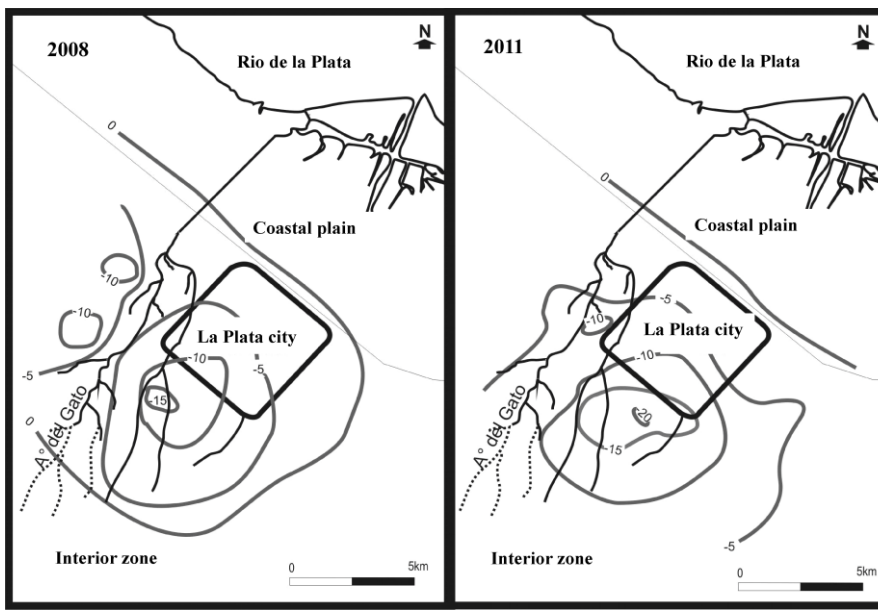

Figure 7. Piezometric map of La Plata. 2008 and 2011.

At present, the development of relatively stable depression cones has produced a change in the natural hydraulic gradients of the water table, thereby modifying the natural interrelation between surface water and groundwater. This alteration becomes evident in the upper and mid creek basin where there is a clear influence of the watercourse on the water table (Figure 7). The average groundwater volume withdrawn for human consumption is 73 hm^3/y. The direct contribution of the aquifer is approximately 70% (51 hm^3/y) of the total exploited volume. The remaining 30% is supplied by infiltration of water seepage from gutters, water mains, sewer systems and urban irrigation. This means values on the order of 22 hm^3/y (314 mm/y) (Facultad de Ingeniería, 1994).

DISCUSSION AND CONCLUSION

The above factors show the complexity of the environmental hydrogeology problems and the fragility of the system to external agents. Remediation actions are to be carried out against past abuses that were both a direct consequence of the lack of a clear management policy on the use of natural resources, and the wrong belief that water resources were inexhaustible. To mitigate further economic losses and environmental damages, water management policies must be adopted. Policies have to be directed to conserving the resources, protecting the groundwater reserve and avoiding all possible source of contamination. The application of plans to reach a balance between the water demand and environmental protection is essential, and represents a fundamental base for a sustainable exploitation that will preserve freshwater reserves for future generations. Recommended actions include the exploitation of freshwater resources of rural areas, preventing their urbanization and development from potentially polluting activities.

At present, there is an overexploitation of the Puelche aquifer that has modified the natural hydraulic conditions, collaterally affecting the hydrochemical characteristics because of contamination from human wastes. A lack of sewer systems in some areas, as well as spills from water distribution networks favour accumulation and/or enrichment of polluting agents. Since a significant increase in the demand for water, particularly drinking water, is predicted in future years, it is essential to intensify groundwater assessment to get insight in water reserves, to protect recharge areas and delimit discharge zones. The suggested actions include:

1. Concentrate most groundwater exploitation in rural areas such as the Arroyo El Pescado creek basin), limiting their urbanization and the development of potential polluting productive activities.
2. Groundwater exploitation should be aimed to satisfy drinking water demand.
3. Impose the use of surface water from the Rio de la Plata for all the water needs not requiring drinking properties.
4. Optimize groundwater volumes allocated for potable, industrial and irrigation uses and balance them with groundwater discharge and natural recharge.

Based on the vulnerability and risk of the resource, it is necessary to expand the sewer network in the urban zone, as well as to limit the use of herbicides, pesticides and fertilizers in the countryside. In addition, it is necessary to establish a monitoring network to control groundwater and its withdrawn volumes.

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