

## Decay in chloride content of ground water due to excessive production of a well field near León, Mexico

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### RESUMEN

El campo de pozos de La Muralla, cerca de León, Guanajuato, México, extrae agua por medio de 19 pozos profundos. Los 629 análisis del cloruro del agua extraída entre 1994 y 1999 muestran una tendencia global decreciente de - 1.1 mg/L por año, estimada por regresión lineal. Si esta demineralización continúa, en pocos años el agua alcanzaría la misma composición de la lluvia. Los resultados sugieren una severa reducción en la reserva de agua del acuífero.

**PALABRAS CLAVE:** Agua subterránea, cloruros, campo de pozos, producción insostenible, Guanajuato, México.

### ABSTRACT

La Muralla well field near León, Guanajuato, Mexico, extracts water by means of 19 deep wells. 629 chloride analyses of the extracted water between 1994 and 1999, show a decreasing global trend of - 1.1 mg/L per year, estimated from linear regression. Should this demineralization continue, in a few years the water would reach the same composition of rain water. The findings suggest a severe reduction in the water reserve of the aquifer.

**KEY WORDS:** Groundwater, chloride, well field production, sustainability, Guanajuato, Mexico.

### INTRODUCTION

One of the sources that supply water to León, Guanajuato (Figure 1), is the well field La Muralla, in a barren hilly area near the city, with 19 wells at depths ranging from 165 m to 388 m.

Pumping has been almost continuous at over 700 L/s since installation in 1992. The static groundwater level of the wells dropped roughly 3 m per year between January 1992 and December 1997, as estimated from two measurements available to us (CNA, 1997). On the other hand, the hydrochemical evolution of La Muralla well field has been documented extensively by laboratory analysis of water samples taken approximately every two months by SAPAL, the Supply Water and Sewage System of León (<http://www.Leon.gob.mx>).

Our study is concerned with a set of SAPAL results of chloride analysis following Standard Methods (1999). The period of sampling is between January 1994 and December 1999. Our interpretation of this data time-series suggests that La Muralla well field is undergoing a subsidence of the static

level and a reduction in concentration of the chloride anion in the trapped water.

Because of intense extraction in La Muralla well field, the groundwater system seems to be unable to reach dynamical equilibrium described by

[imposed discharge by wells] = [induced recharge by the perturbed system],

which drives the affected region of the aquifer to exhaustion. This is a problem of sustainability of groundwater resources (Ally *et al.*, 1999) which has not been widely discussed in the Mexican hydrogeological literature.

### THE SCENARIO

The oldest geological unit in the study area outcrops at Sierra de Guanajuato, the highest area in the watershed (Figure 1). It is a compact red conglomerate called the Guanajuato Conglomerate (CEASG, 1999). Its hydrogeological relevance for the La Muralla field is its functioning as a buried low-permeability basement for the known aquifer units of the

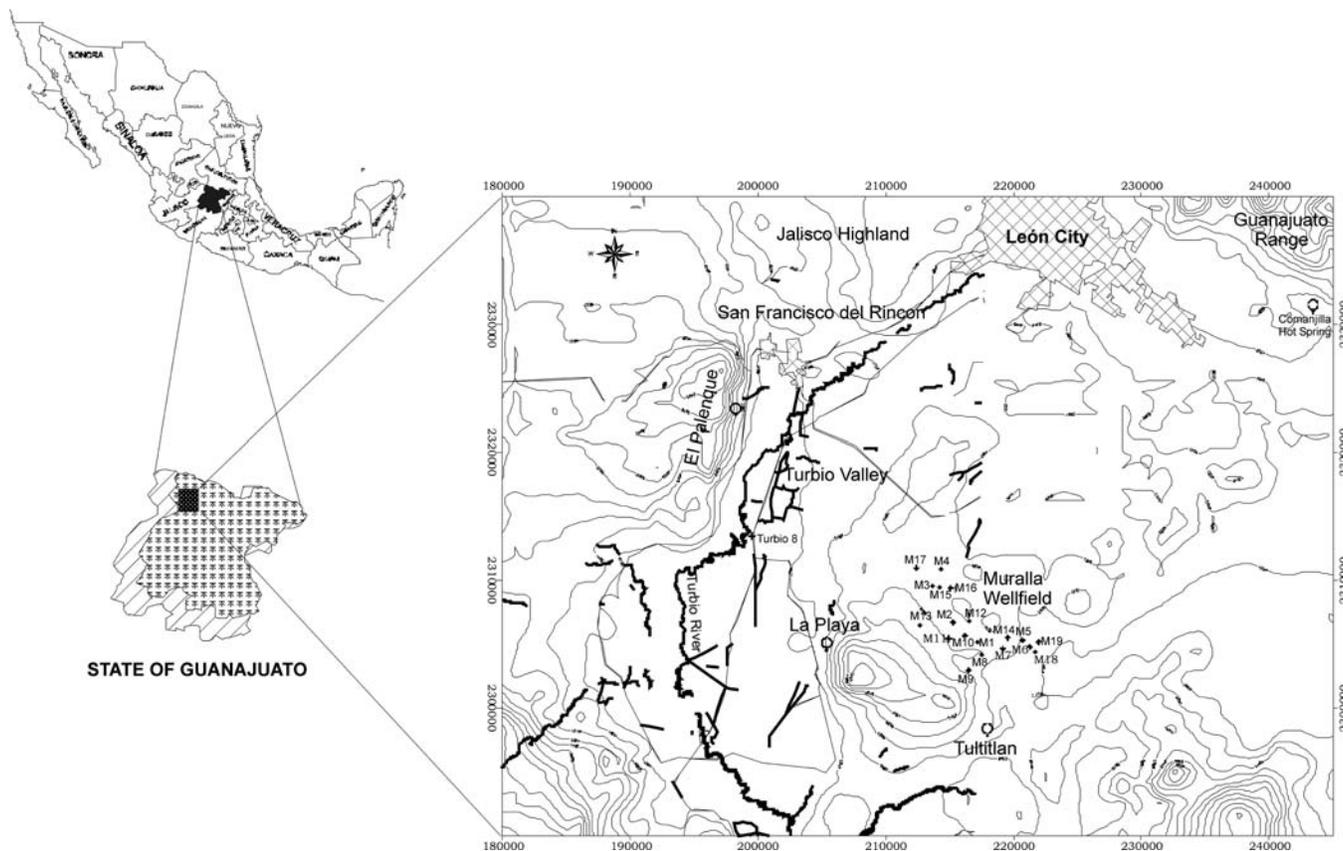


Fig. 1. Location map of the study area.

region. The Guanajuato conglomerate is covered by an ignimbrite that constitutes the main aquifer formation being exploited by the well field (Ramírez *et al.*, 1999). Under this conglomerate is a thick deposit of granular material. On the surface, the hilly landscape is formed by fractured basalts. The geology of the study area is shown in Figures 2 and 3.

The surface drainage in these hills contains a divide between the two main watersheds in the region, the basins of León and Silao. Hydrogeologically, La Muralla corresponds to an area of local recharge that contributes to deep groundwater flows originating in the high mountains of the watersheds. There is another divide underground corresponding to the drainage of the shallower groundwater flows (Ramírez *et al.*, 1999).

Two earlier hydrogeochemical studies (SAPAL, 2001; and Ramos *et al.*, 2001) concluded that the groundwater contains mixed waters from infiltrated rainfall and from local flows with a temperature similar to surface water, low in chlorides (0.8 mg/L), plus groundwater of non local origin, with higher temperature and stronger mineralization.

The climate is semiarid, with rains in summer. The long-term mean annual rainfall around La Muralla is 632 mm, with an annual variability of  $\pm 126$  mm; the mean temperature is 19 °C. The average chloride concentration in local rainfall, as measured at seven neighbouring sites in 1999, is 0.8 mg/L (SAPAL, 2001).

#### DEMINERALIZATION OF PUMPED WATER

We used 629 records corresponding to chloride concentrations of samples from January 1994 to December 1999. The results are shown in Figure 4. Note that the chloride concentration of the water from all wells fluctuates strongly, with a clear decreasing trend.

The influence of seasonal variability of chloride content may be defined by four-month periods as follows. Rainy season, from June 1 to September 30; beginning of the dry season, from October 1 to January 31 of the following year; and end of the dry season, from February 1 to May 31.

Figure 4 shows  $C(t)$ , the seasonal mean chloride concentration for all 19 wells of La Muralla. Using least squares, the following linear regression fit is obtained:

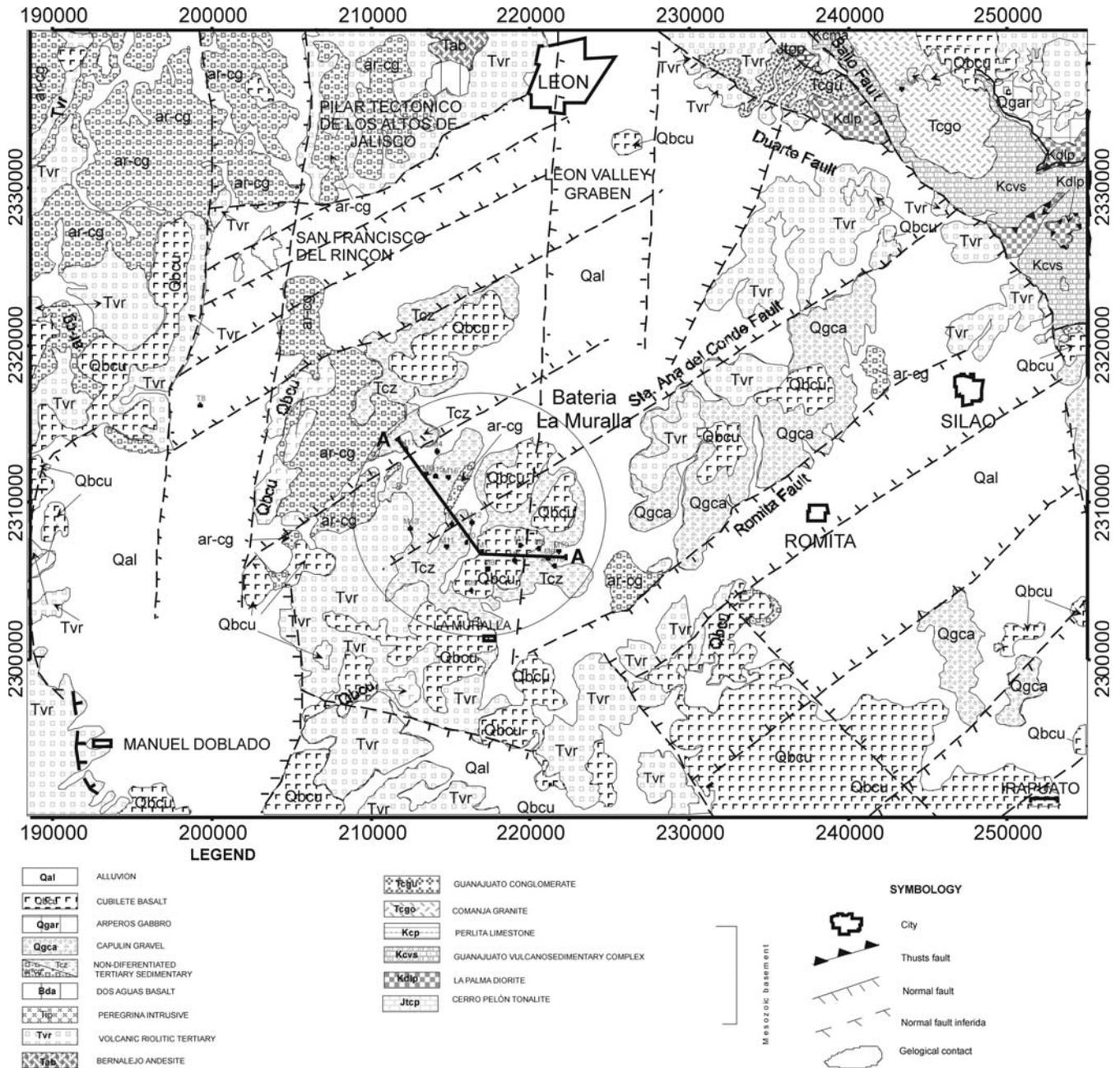


Fig. 2. Geology of the study area.

$$C(t) = -0.09 t + 16.1; \quad r = -0.71;$$

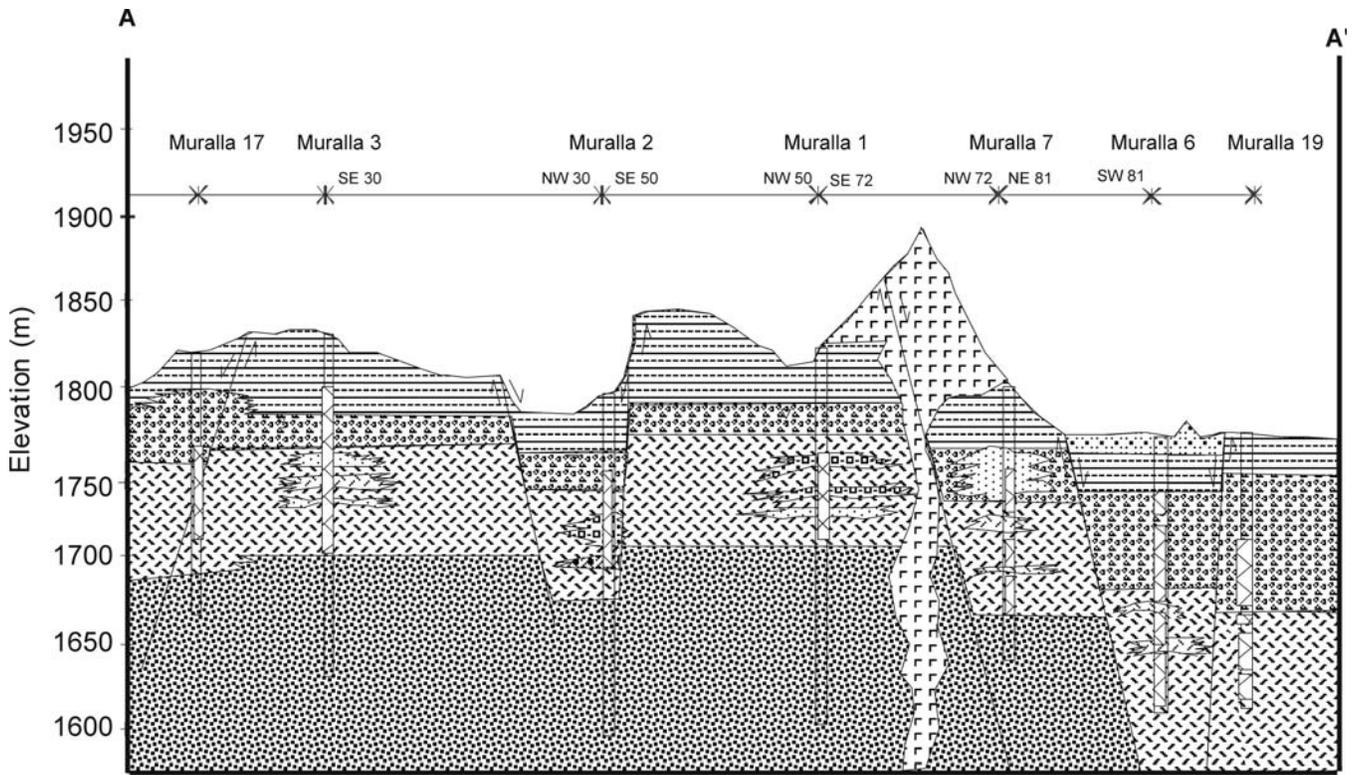
where C is in mg/L, t is in months and t = 0 is January 1994.

The fit provides a good correlation coefficient r. The evolution of the quality of extracted water in La Muralla, as reflected in the linear trend of C(t), reveals a significant drop of 1.10 mg/L per year in chloride concentration of the part of the aquifer being tapped for the period January 1994 to December 1999. If we may extrapolate this tendency towards

the future, and if the conditions of the system continue, independently of fluctuations, the chloride concentration in the ground water will reach 0.8 mg/L by 2009, the same value as found in rain water over the same region.

## DISCUSSION

Because of the intense ground water extraction in La Muralla, the drawdown of ground water level shows that the hydrogeological system is unable to reach a new state that



After Johansson et al. 2001.

### LEGEND

- Alluvium
- Cubilete Basalt
- Tertiary Lake Sediments
- Undifferentiated Sediments
  - Clay
  - Sand
  - Gravel
- Cuatralba Ignimbrite
- Guanajuato Conglomerate
- Normal Fault
- Well
- Screen Well
- Static Level

**HORIZONTAL SCALE 1:50,000**

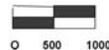


Fig. 3. Geological section and hydrogeological units.

might re-establish a dynamical equilibrium between the discharges of wells and the recharge in the system. Also, water demineralization shows that recharge from local infiltration, though scattered and insufficient, is becoming the more important source of water supply in the well field.

Both the sinking groundwater level and water demineralization show that depletion of the aquifer's water local storage is a process of exhaustion. The present production of 700 L/s in La Muralla will be an unsustainable yield in the short term.

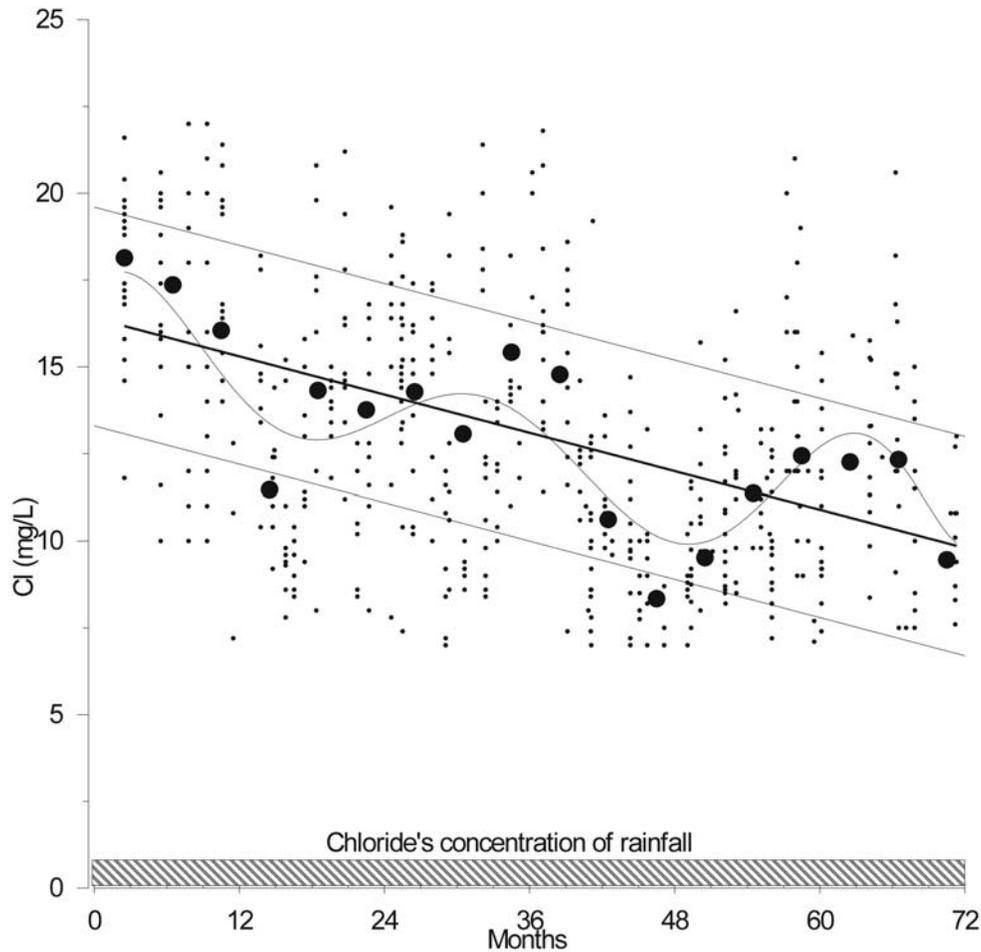


Fig. 4. Time evolution of water chloride in La Muralla well field, Mexico.

### CONCLUSIONS

La Muralla well field is evidencing a global decrease of approximately 1.1 mg/L per year in chloride concentration of the total extracted water. Under these external conditions, in 2009 local rainfall, though scattered and insufficient, will be practically the only source of water supply. The present production of the well field, 700 L/s, is non-sustainable.

### ACKNOWLEDGMENTS

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