MODEL PROJECT INFORMATION SHEET

GROUNDWATER RESOURCES IN THE CARACAS VALLEY

VENEZUELA - VEN/8/010

SUMMARY

A rapid increase in the population of the city of Caracas has led to a deficit in the domestic water supply of nearly 20%. Local authorities are investigating the potential of the Valle de Caracas aquifer to provide additional water for domestic, agricultural and industrial purposes. A second objective of this investigation is to lower the present groundwater level in the region. The assessment of groundwater dynamics and quality by means of geochemical and isotopic methods (including tracer experiments) will provide key information for the identification of the best areas for drilling additional wells. Basic data on the sources and mechanisms of groundwater recharge, the time span for renewal of groundwater and the vulnerability of the aquifer to pollution will be obtained. This information will be used by local authorities to make decisions on the exploitation of the aquifer and how it can best be protected from future pollution.

Project duration: 4 years. Total budget: US $261,900.

INTRODUCTION

The rapid population growth of the city of Caracas (from 800,000 in the early 1960s to an estimated five million in 1993) has led to a sharp increase in water demand. Water usage in Caracas is approximately 17 m^3/s at present, and the city relies for its water supply exclusively on surface water collected and held in several reservoirs. The present climatic trend, with more frequent drought periods (the average annual rainfall from the period 1985-88 was 999 mm, while from 1989 to 1993 it was reduced by about 10% to 908 mm) has led to a deficit in drinking water estimated as 3-4 m^3/s, which represents about 18% of the existing water supply. The deficit is more critical in marginal areas of the capital, which include about 30% of the population. Authorities have had to restrict the use of water, and several districts have access to it for only a few hours a day.

The shortage of water is frequently discussed in the media and is of major concern to the Government. With the explicit endorsement of the President, an effort is being made to reduce or eliminate the water deficit.

The best alternative source available to reduce the existing deficit is the Valle de Caracas aquifer, since the present use of groundwater is minimal. However, little is known of the physical properties of the aquifer and the quality of groundwater. The rational exploitation of groundwater resources in urban areas requires precise assessment of their hydrogeological properties and of the potential of the aquifer to supply drinking water.

Besides the scarcity of water, another engineering problem related to the Valle de Caracas aquifer is of concern to the local authorities. The groundwater level has increased during recent years owing to the effects of reduced exploitation of the aquifer and the progressive urbanization of the valley. Changes in the natural flow pattern of groundwater (mainly due to leakage from the distribution system, reduction of aquifer discharge and construction of underground barriers) have led to the progressive rise of the groundwater level. This has created serious engineering problems in the construction of new buildings including the necessity to pump significant quantities of water.

In order to reduce dependence on surface water and to cope with the increasing demand, local authorities propose to investigate the potential of the aquifer with a two-fold objective: (a) to reduce the existing deficit by increasing the use of groundwater and (b) to lower the present groundwater level, reducing the impact (and cost) of the presence of groundwater near the surface. In addition, owing to the nature of the aquifer, its vulnerability to pollution will be addressed as a key element for the actual exploitation of the aquifer in the future and in view of the possible uses made of the extracted water.

The Ministry of the Environment and Natural Renewable Resources (MARNR), in co-operation with other institutions and local municipalities, is currently following several approaches in the investigation of matters related to the exploitation of the Valle de Caracas aquifer. A good knowledge of the physical and dynamic properties of the aquifer and the quality of groundwater is one of the key prerequisites for rational exploitation of the resources. An assessment of the origin of groundwater, the fluxes involved, and the quality of water in different areas has to be completed in order to define its possible uses: either to increase the supply of drinking water to the existing distribution system, or only for irrigation or industrial purposes. If it should appear that the potential of the aquifer is limited, it may nonetheless serve as an alternative source of water in case of emergency, or as a local source in selected areas where the current distribution system is inadequate. The exploitation of the aquifer can contribute at the same time to the reduction of local problems caused by high water level.

THE CARACAS AQUIFER

Before the city of Caracas expanded to occupy the entire valley, groundwater drawn from wells was used as an additional source of drinking water and for agricultural purposes. During the 1950s and 1960s, however, the construction of reservoirs and the related distribution network led to a progressive closure of most wells; moreover, those

that were not closed are nowadays in poor operating condition. The city now extends over the entire aquifer, and the process of urbanization has severely altered the natural groundwater flow patterns. Under natural conditions, groundwater was discharged into the Guaire River, which provided natural drainage of the hydrological system. However, the construction of several structures below the surface (underground lines, distribution networks), the closure of most pumping wells, and the canalization of the river (thereby significantly reducing discharge to the river owing to the construction of impermeable walls) produced major change in the water balance of the system. All these actions led to a progressive rise in the water level in several areas of the city. Thus, groundwater must be continuously pumped and discarded into the sewage system while, at the same time, inadequate water supply is causing severe restrictions.

Urbanization has also changed the water balance in connection with the recharge pattern. However, the extent of this change is unknown; it is assumed that the contribution of rainfall precipitation to recharge through direct infiltration was important in the past. The construction of roads and buildings has reduced the area available for direct infiltration, and it is expected that lateral seepage from the mountains is at present making a major contribution to the recharge. Moreover, current discharge of the system after the impermeabilization of the natural drainage system, by canalization of the Guaire river, is also unknown.

The available hydrogeological studies of the aquifer were prepared more than 10 years ago; they will require updating and some additional basic information. The currently available data on the aquifer are considered inadequate for determining whether or not it can be used to alleviate the water crisis in the city of Caracas.

Investigations carried out by the Hydrology Department of MARNR, with Agency assistance, are primarily focused on the following objectives regarding future exploitation of the aquifer:

- Quantification of the groundwater volume available for exploitation,
- Identification of recharge sources and mechanisms,
- Assessment of water quality changes in the aquifer,
- Definition of flow paths and interconnection between aquifers,
- Evaluation of contamination risks and definition of protection zones.

THE ROLE OF NUCLEAR TECHNIQUES

While conventional techniques can adequately assess the static characteristics of an aquifer, they cannot fully determine its dynamic parameters. The combination of geochemical techniques with the use of environmental isotopes naturally occurring in groundwater can provide this information; use of environmental isotopes will provide insight into the origin of groundwater, flow patterns, interconnections between groundwater bodies and/or surface waters, recharge mechanisms and rates. The processes and pathways whereby pollutants are transferred to groundwater as well as the mechanisms of salination can also be determined by these techniques. The information

derived from these studies is critical for elaborating a conceptual model of the groundwater system, assessing its potential for extraction, and for making rational decisions regarding exploitation of the aquifer.

Environmental isotopes of oxygen and hydrogen are considered to be the best available tracers of water since the three isotopes regularly measured (oxygen-18, deuterium and tritium) are naturally present in the water molecule, and their concentrations do not change in the aquifer, as opposed to the chemical compounds dissolved in groundwater. In this regard, the isotope signature of oxygen-18 and deuterium can be considered as a label reflecting the origin of each water body. Other isotopes which will be of value in the study are carbon-14, which is used to determine the residence time of water in the system, and nitrogen-15, which can be used to identify the source of pollutants in groundwater. Basic questions regarding recharge and discharge of the system will be addressed by measuring the isotopic composition of the possible sources of recharge to the aquifer. Owing to the differences in the climatic parameters between the valley and the nearby mountains, the isotopic composition of precipitation in these two areas is different. This natural labelling of water is transferred to groundwater, and can be used to identify the origin of the waters that can contribute to the recharge of the aquifer: either direct infiltration from precipitation in the valley or lateral seepage from the mountains. Additionally, water leaking from the present distribution system could possibly also be involved in the recharge of the aquifer. Water from this source will also show a different isotopic signature since it is derived from surface water stored in reservoirs, and thus originates in a different basin.

Artificial tracers injected into the groundwater system combined with geophysical techniques will be used to study the local flow patterns and the interconnection between different water bodies, especially in areas where notable pumping efforts are necessary to lower the piezometric level. Fluorescent dyes can be used to determine the water velocity and other flow parameters and to prove the existence of a hydraulic connection between two points.

IMPLEMENTATION OF THE PROJECT

The project was already initiated in 1994, and this made it possible to start a systematic collection of groundwater and surface water samples during the drilling of additional exploratory boreholes. On the basis of available hydrological information, 15 new wells have been drilled, from which groundwater samples at different depths were collected with the objective of compiling information on the main physical and chemical characteristics of the water-bearing layers. During the initial stages of the project, the counterpart has been revising and compiling existing data (mainly maps describing the hydraulic properties of the aquifer) from previous and ongoing hydrogeological studies carried out in the Caracas Valley. This compilation, combined with the hydrogeochemical and isotopic results of the first sampling campaign, has permitted the definition of a working hypothesis on past and present circulation patterns of groundwater.

Although the staff of the Hydrology Department has been involved with the Agency in the implementation of projects based on the use of isotope techniques, there is a need for additional training, particularly in the interpretation of geochemical and

isotopic data. Experience in the use of most conventional techniques is adequate, but experience with application of the techniques required in this project is limited. Training on the use and interpretation of geochemical and isotopic data was therefore considered a high priority activity for 1994. To this effect a national seminar with the co-operation of several Agency experts was held in Caracas from 24 October to 4 November. The main topics addressed were (a) groundwater dynamics and the origin of groundwater in urban aquifers and (b) isotope techniques applied to pollution studies in urban aquifers.

Two sampling campaigns were foreseen for the initial stage of the project; one was already carried out at the beginning of the rainy season (May-June 1994), and the second will take place during the dry season (December 1994 to January 1995). The geochemical and conventional information gathered after the conclusion of the second campaign will be processed to evaluate the existing hypothesis about the system and to determine the potential of the aquifer to supply water for various uses. It is expected that the interpretation of these data will permit the definition of the strategy for additional drilling of new wells in the metropolitan area. The results of a preliminary campaign indicate the presence of water derived from the water distribution system in several sectors of the aquifer, while the presence of polluted waters was identified in the shallow portions of the aquifer.

A geophysical campaign including a well-logging survey is foreseen for the second half of 1995, which could be followed by a new sampling campaign, depending on the previous evaluation. On the basis of the results obtained (hydrogeological, geophysical and geochemical) the potential of the aquifer will be assessed and, if positively evaluated, may lead to the undertaking of a more comprehensive well-drilling programme in selected areas.

SOCIOECONOMIC IMPACT

The assessment of groundwater dynamics and quality characteristics by means of geochemical and isotopic methods (including tracer experiments) will provide key information for the identification of the best areas for drilling additional wells that would contribute to reducing the existing water deficit in the metropolitan area. Basic data on the sources and mechanisms of groundwater recharge, the time span for renewal of groundwater and the vulnerability to pollution will also be evaluated for a proper management of the water resources in the Caracas Valley. On the basis of this information, local authorities dealing with water resources management will be able to make decisions on the exploitation of the aquifer and regarding the definition of protection zones to avoid contamination of areas where groundwater is used for the supply of drinking water. At best the outcome of the project will significantly contribute to improving the situation by reducing the deficit of water supply for human consumption, irrigation and industrial uses and, at the same time, will curtail problems caused by the presence of groundwater near the surface.

The planning of future exploitation strategies for the Valle de Caracas aquifer will greatly benefit from information gained through this project on the physical properties of the aquifer and its vulnerability to pollution. While additional water supply for the population in the Caracas Valley, for domestic, agricultural and industrial uses, could be

seen as directly related to work performed in the framework of this project, its economic benefits would be tangible even without achieving swift solution to the water problem.

Identification of the most appropriate locations for additional well-drillings would significantly reduce the number of unsuccessful attempts and thereby cut the costs involved. There would also be an overall reduction of costs both through curtailment of the time needed for completing the studies and by using the relatively inexpensive nuclear techniques involved in the framework of this project. If necessary, alternative strategies for solving the existing water supply problem could be devised at an earlier stage and at lower preliminary costs, thereby limiting the deterioration of local living conditions for the population as well as the negative economic impact of an inadequate water supply for local agriculture and industry.

FINANCES

The budget allocation for the project is US $261,900, distributed as follows:

Year	Experts		Equipment	Fellowships		Scientific Visits		Grp trg.	Sub-contr.	Misc. Comp.	Total
	M/D	US $	US $	M/D	US $	M/D	US $	US $	US $	US $	US $
1994	2/0	21,600	31,000	0/0	0	0/0	0	0	0	0	52,600
1995	2/0	22,800	87,000	8/0	26,400	0/0	0	0	0	0	136,200
1996	1/0	12,000	23,000	2/0	6,900	0/0	0	0	0	0	41,900
1997	1/0	12,600	15,000	1/0	3,600	0/0	0	0	0	0	31,200
Total	6/0	69,000	156,000	11/0	36,900	0/0	0	0	0	0	261,900

Source of funding: Reserve Fund for 1994 and TACF for 1995 - 1997