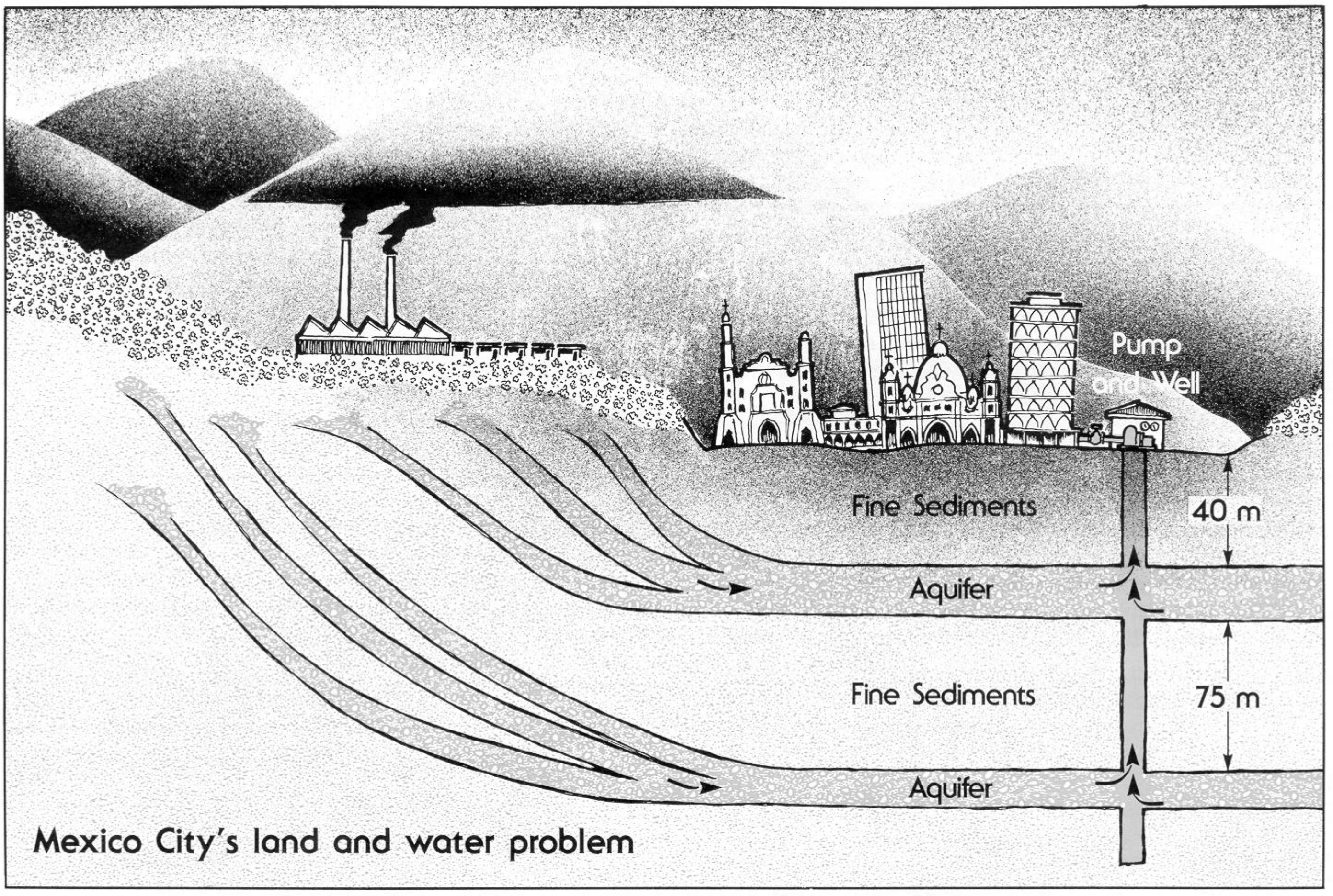
DWINDLING WATER IN THE SINKING CITIES

By DANILO ANTON



Aquifers, composed of gravel and coarse sand, are recharged naturally by water from the high ground. Excessive pumping depletes them and forces the water trapped in the fine sediments to flow into the aquifers. This loss of water causes the sediments to compact and the city land above them to sink, causing some buildings to shift and making them especially vulnerable to earthquakes. To make matters worse, polluted water from residential suburbs and industrial areas seeps into the aquifers.

The giant cities of Bangkok, Shanghai, and Mexico City are literally sinking and they face increasing difficulties with their water supply. Their major source of domestic and industrial water lies directly beneath them in the form of strata of permeable rock, sand, and gravel called aquifers. But the volume of water in these formations is steadily decreasing. A major disaster seems inevitable.

In these three cases, increased and concentrated pumping has considerably lowered the water table and led to the compaction of an important part of the sedimentary surface covering. As a result of the reduction in volume of water in the underlying aquifers, the soil has sunk several metres in those zones where compaction is most serious. Generalized subsidence has created serious flood problems in Bangkok and Shanghai, cities only slightly above sea level. In Bangkok, where the average elevation is less than 1 m above sea level and tides can rise above that, the rate of subsidence is as much as 12 cm a year.

Some Third World cities that depend directly or indirectly on their underground water face an additional problem where the recharge zones are in areas of urban and industrial development, or in areas of intensive agriculture. Since controls for disposal of sewage and industrial wastes are not usually very strict, local contamination of aquifers is rather common. For example, in Mexico City's neighbourhood of Xochimilco, it has been necessary to close several wells because of an excessive concentration of nitrates in the water, possibly due to pollution from the Chalco Channel which transports urban sewage. In the case of agricultural zones, the recharging of aquifers can introduce highly toxic pesticides and herbicides to the hydrogeologic system.

MORE RUNOFF, LESS RECHARGE

All of these phenomena tend increasingly to affect the quality of fresh water in large cities and surrounding areas. In addition, urbanization and agricultural overexploitation seriously affect the recharge characteristics of the aquifers. Superficial runoff frequently increases, affecting not only the agricultural productivity of soils (due to surficial erosion) but also the integrity of roads, bridges, and other structures, due to the catastrophic increase in the volume of river water during flood periods.

The increase in the amount of runoff flowing into the rivers, then, is preventing water from infiltrating the ground to replenish the aquifers. Accordingly, the renewability of the aquifer is adversely affected and the quantity of available water is reduced precisely where it is needed the most.

Although the seriousness of these phenomena is evident, the lack of information — and in some cases insufficient study of available information — prevent management decisions from being made which would alleviate the potentially disastrous effects of this situation.

THE CASE OF THE MEXICO VALLEY

A concrete example of environmental imbalance due to a complex history of man-made degradation of a basin can be seen in the Mexico City area.

The Mexico Valley, or Anahuac, is a basin of approximately 2000 km^2 surrounded by volcanic mountains located on the Mexican central plateau at an altitude of 2000 to 2500 m above sea level. The bottom of this basin was originally covered by a system of more or less interconnected lakes covering an area of about 500 km^2. Around these lakes there settled and developed an indigenous society whose livelihood was based on the cultivation of corn. Tenochtitlan, the capital of the Aztec empire, was built on a partially artificial island close to the western shore of the valley's main lake, Texcoco Lake.

The expansion of Mexico City, built on the ruins of Tenochtitlan, led to the gradual occupation of neighbouring bays and lowlands until the city finally encompassed a great part of the lake area. Due to difficulties with urban drainage, a channel was built in the early 20th century which finally drained most of the lake. This operation, however, was not entirely successful, since the dry lake bottom was transformed into a kind of chemical desert because of the extreme alkalinity of the soil (its pH is greater than 10). Since then there have been hazardous dust storms ("tolvaneras") associated with the northeastern winds.

The drying of the lake eliminated a major source of the city's fresh water just at a time when a demographic boom was beginning, a boom that pushed Mexico City's population from one million people in 1930 to more than 18 million in 1985.

As an alternative, the city had to collect surface water (mainly from the Lerma River basin) and use pump-equipped wells installed in the underlying aquifers. (See illustration.) The continuous and increased extraction of water from wells led to a rapid decrease in the piezometric surface, that is, the level to which water naturally rises due to the aquifer's pressure. At the turn of the century, many wells were artesian (naturally flowing out of the ground); nowadays the water level is several metres deep throughout the area.

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The recorded annual rate of subsidence due to excessive pumping is several centimetres, for a total of more than 1 m over the last 30 years. The sinking of the valley bottom shows that there is a strong deficit in the system's hydrological balance. Annual consumption reaches some 300 million m^3, but it has been estimated that the recharge rate is less than one third of that.

JOINT EFFORTS

IDRC is supporting a number of collaborative research projects on underground water in developing countries:

- In Bangkok, Thailand, a joint interdisciplinary team from the Geotechnical Research Centre of McGill University in Montreal, Canada, and from the Asian Institute of Technology is studying the present and future effects of water pumping in several suburban areas of the city.

  This study will examine the relationship between pumping and subsidence and provide some of the information required by the authorities to make decisions regarding future urban expansion.

- In Montevideo, Uruguay, a joint team from the Université du Québec à Montréal and the Dirección Nacional de Mineria y Geologia del Uruguay is about to begin a study of the influence of agricultural practices and urban expansion on the most important Uruguayan aquifers in the Santa Lucia River basin. This project will assist in evaluating the potential of those layers to supply Montevideo and its surrounding districts in the future.

- In Cotonu, Benin, the same Canadian team, in cooperation with the National University of Benin, is studying the hydrogeology of aquifers in the densely populated southern region to solve the problem of increased salinity of underground water. The results of the study will provide information useful in territorial planning and the provision of water in the future.

- A joint team from the University of Sherbrooke, Canada, and the National School of Engineering of Sfax, Tunisia, is conducting a study of the surface and shallow layers of this Mediterranean city in order to determine criteria for future territorial planning from a hydrogeological and geotechnical point of view. The city of Sfax has serious urban problems resulting from uncontrolled expansion in unsuitable areas.

All of these projects tend to emphasize an area of specialization with good potential for cooperation between Canada and developing countries. The studies are expected to lead to the establishment of a network of scientists and institutions specializing in hydrogeology and related fields.

WATER SHORTAGES

If water consumption continues at the present rate, the aquifer will be depleted within a relatively short period of time, thus exacerbating water shortages. Exactly when this will occur is not yet known.

IDRC is supporting efforts to formulate, study, and solve these problems. (See box.) Recently, it approved an ambitious joint project to study the Mexico Valley problem and propose solutions to it. This project is being conducted by the Groundwater Research Institute of the University of Waterloo, in Ontario, Canada, and the Universidad Nacional Autonoma de Mexico (UNAM). The research team's objective is to characterize the valley's underground waters to determine the renewability of the aquifer and any possible sources of pollution. The Waterloo and UNAM teams will use sophisticated isotopic and hydrogeochemical methods, as well as hydrogeologic mathematical models developed specifically for this particular case.

It is expected that this project will bring important benefits to Mexico City and neighbouring areas. For one thing, it will tell planners and decision-makers what pollutants are already in their drinking water. Perhaps even more important for the inhabitants of this city, whose population is expected to reach an astounding 30 million by the end of the century, the project results will give them a good idea as to when they will run out of underground water. □

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