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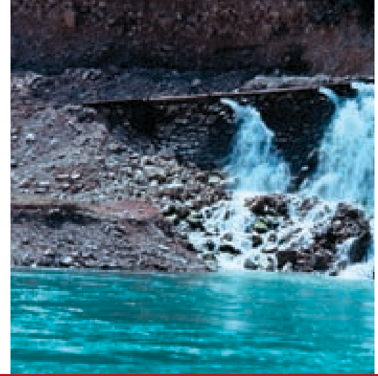

Groundwater in Urban Development:
Assessing Management Needs & Formulating Policy Strategies

People have clustered at the water's edge throughout civilization for the most fundamental of reasons: without water there is no life. Every major city in the world has a body of water or aquifer nearby, since although rivers and lakes predetermined where people would gather and dwell, groundwater constitutes about 98 percent of the fresh water on our planet (excepting that captured in the polar ice caps). This makes it fundamentally important to human life and to all economic activity.

Groundwater resources in and around the urban centers of the developing world are exceptionally important as a source of relatively low-cost and generally high-quality municipal and domestic water supply. At the same time, the subsurface has come to serve as the receptor for much urban and industrial wastewater and for solid waste disposal. There are increasingly widespread indications of degradation in the quality and quantity of groundwater, either serious or incipient, caused by excessive exploitation and/or inadequate pollution control. The scale and degree of degradation varies significantly with the susceptibility of local aquifers to exploitation-related deterioration and their vulnerability to pollution. Management strategies need to recognize and to address the complex linkages that exist between groundwater supplies, urban land use, and effluent disposal.

Groundwater tables have become the focus of keen interest in recent years, as the supplies of water underlying urban areas have dwindled and deteriorated, threatening the millions of people who live above. When conditions are right, aquifers refill regularly from infiltrating rainfall and runoff, although sometimes with a substantial time lag. But those favorable conditions are severely altered when the ground above is overbuilt.

The threat of urban groundwater degradation

That major cities affect the aquifers they overlie can be taken for granted, since water supply, sanitation, and drainage are inextricably linked with groundwater and are an essential part of the urbanization process (figure 1). That urbanization should change an aquifer for the worse, however, need not be inevitable. The key to avoiding this is not to lose sight of the subsurface environment when planning the urban water infrastructure.

Individual waterwell diggers and municipal authorities like good groundwater for the same reasons: it is cheap, clean, and reliable—at least at the initial stages of urbanization. So pumping groundwater makes good sense. But over time the rate of exploitation (or groundwater abstraction) must be adjusted to the replenishment (or groundwater recharge) rate. The ability of society to adjust and adapt, therefore, becomes the critical factor. Cities and their surrounding jurisdictions must make the right decisions on infrastructure development, for example ensuring that industrial effluents and solid waste are handled in ways that do not threaten the aquifer on which the city is built.

Water sustains urban life and the soil has to absorb much of it after use. Whether, how quickly,

Excerpted from *Water in Urban Development: Assessing Management Needs and Formulating Policy Strategies Ground* by Stephen Foster, Adrian Lawrence, and Brian Morris (World Bank Technical Paper 390, March 1998)—a GW-MATE publication. Visit www.worldbank.org/gwmate/ for more information. The publication is available for download in PDF format from www.worldbank.org/water.

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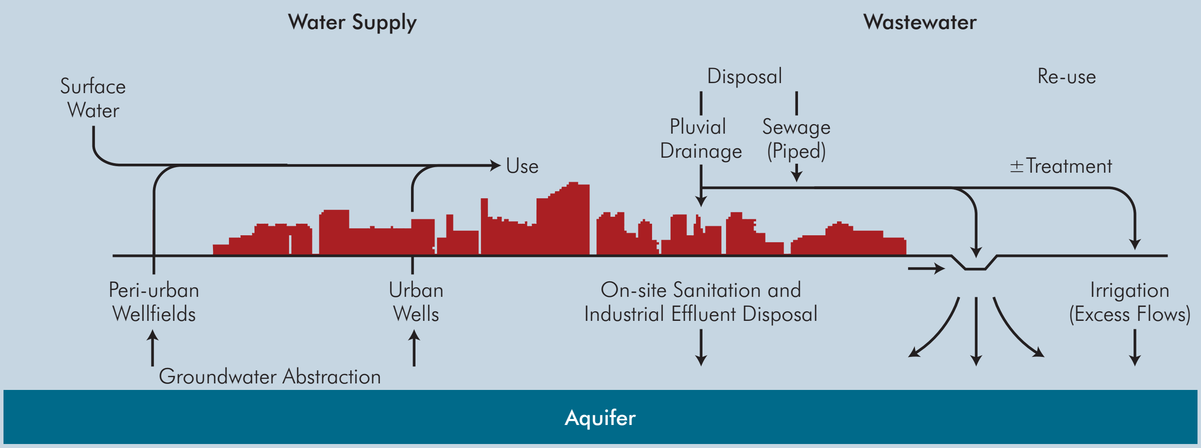
Figure 1. Interaction of groundwater supply and wastewater disposal in a city overlying a shallow aquifer



and in what state that water returns to aquifers is a question urban planners and managers must address. Heavy rains and prolonged droughts are obvious variables that affect groundwater levels—but they are not the only ones.

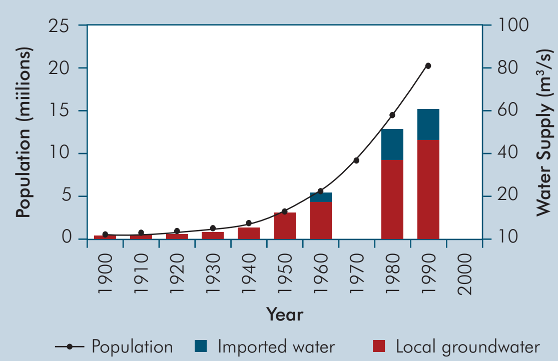
During the early stages of urbanization, a suitable subsoil can be the best natural receptor for wastewater and on-site sanitation is the preferred solution that need not necessarily impact adversely on groundwater quality at depth, but in unfavourable conditions other arrangements must be made. Where the subsoil shows adequate filtration capacity, the ground will also be the most appropriate receptor of urban runoff, so as to avoid or reduce the need for costly surface drainage systems. But as cities grow, and building and population density increase then on-site solutions may no longer be feasible or appropriate.

But sewage and/or industrial effluents, if allowed to percolate into the ground above vulnerable aquifers in excessive amounts, can cause serious problems and ruin what had been a source of clear, clean water. Lack of responsible environmental management can thus make the precious groundwater resource unsafe for consumption. In coastal areas in particular, aquifer degradation by salinity poses an equally serious threat if groundwater abstraction is not regulated and over-pumping is allowed to occur.

Groundwater over-pumping may lead to a sinking city

Mexico City, one of the world's largest, serves as a dire warning of what can happen when groundwater is over-pumped (figure 2). From before the Spanish conquest Mexico depended upon groundwater to slake its enormous thirst. But from the 1950s onwards with escalating population and mushrooming water demand, groundwater abstraction increased rapidly, even with supplementary water-supplies brought in from afar.

Figure 2. Population growth and water demand in Mexico City



Source: Mazari and Makay, 1993.

Mexico sits astride an aquifer whose groundwater was depleted to such an extent that compaction of the soft ground in sections of the historic city occurred and the land surface has sunk 8 meters or more over the last 60 years. A professor at Mexico's National Autonomous University brought this phenomenon to the world's attention more than a decade ago when he pointed to a waterwell casing protruding high into the air near the National Revolution Monument, the top of this 'pipe' having been at ground level when the monument was built in 1934.

Managing groundwater for future use

The principal aim of this publication is to draw attention to the need always to integrate consideration of groundwater, when making decisions on urban infrastructure planning and investment. This is not as simple as it might first appear, and even with well qualified people at hand, there needs to be keen awareness of the importance of building a network of specialists to ensure sound evaluations.

People and institutions concerned with urban water supply and environmental management often have a poor understanding of groundwater. And in most sprawling cities, population growth *precedes* construction of mains sewerage and wastewater treatment facilities—and in the meantime shallow groundwater can become contaminated from in-situ sanitation. It may be years before the full extent of pollution becomes apparent, because contamination of large aquifers is a gradual and hidden process. And full remediation of entrenched problems may be prohibitively expensive, even for high-value public water supply use—thus it is critically important to recognize the incipient signs of groundwater pollution.

Knowledge of the danger of groundwater pollution and fundamentals of groundwater protection are now widely accessible, putting the onus on environmental managers both to think ahead and to respond coherently. There is no time to waste. Half the world's population already live in urban areas, and the need to shield aquifers from pollution and depletion is self-evident.

Municipal, provincial and national governments (supported by international institutions) must find the political will, and the practical means, to control groundwater demand, to limit groundwater abstraction by socio-economic and/or regulatory measures,, to provide alternative water supplies where necessary, and to handle and treat sewage and industrial effluents adequately (table 1). To be

Table 1. Urban groundwater supply management: objectives, problems, and mitigation measures

Objectives	Problems	Targets	Mitigation measures
Maintain groundwater supplies	Decline in well yields due to falling water table	Constrain groundwater levels	Redistribute or reduce abstraction (e.g., by reducing water-main leakage)
			Increase urban recharge
Safeguard groundwater quality	Unacceptable quality of drinking water	Moderate subsurface contaminant load	Restrict contaminant loading from identified sources
			Restrict residential development in vulnerable areas
			Control industrial effluents
			Zone land for different uses
			Control landfill location and design
			Separate waste disposal from groundwater supply
	Increasing salinity due to sea water intrusion	Constrain groundwater levels	Redistribute or reduce abstraction
			Modify depths of water supply boreholes
	Contaminants brought in from contaminated land by rising water table	Constrain groundwater levels	Increase abstraction of shallow polluted groundwater for nonsensitive uses
			Reduce urban recharge

effective all such measures need to be based upon a sound hydrogeological framework.

Even after a regulatory agency has defined a rational policy for groundwater management, challenges remain. No matter how rational such policies appear to be, they may not be considered politically attractive or acceptable, especially in the case of groundwater, which is "out of public sight," and therefore "out of political mind." Moreover, powerful groups can interfere with the regulatory process.

In finding a way forward, the environmental regulatory agency needs to build social consensus to overcome resistance to the introduction of scientifically and economically logical policies, and use its regulatory powers effectively. A key factor is the formation of well-informed water user interest groups along with more general groups of groundwater stakeholders. Such groups can act as vehicles for policy implementation and operational management at the practical level when adequately coordinated. An absolute requirement for the practical definition and implementation of groundwater management policies is to set priorities systematically and clearly.

An essential need for public and stakeholder communication is a clear explanation of the consequences of 'non-intervention'. Groundwater is often degraded because of a lack of knowledge of the aquifer system, coupled with uncontrolled groundwater abstraction and urban wastewater disposal. Little consideration is given to the costs that may be incurred either to reverse the deterioration or to replace the lost asset. The marginal cost of replacement water supply sources is invariably high; and action to reverse degradation, especially when it is advanced, is generally a long term and costly process. The stakes are high. Unless groundwater is protected, in terms of quality and quantity, it will become scarce, expensive, and hazardous to human health.

The Water Sector Board Practitioner Notes (P-Notes) series is published by the Water Sector Board of the Sustainable Development Network of the World Bank Group. P-Notes are available online at *www.worldbank.org/water*. P-Notes are a synopsis of larger World Bank documents in the water sector.

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