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Title: **Albuquerque, New Mexico, USA: A Sunbelt City Rapidly Outgrowing its Aquifer**

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Albuquerque, New Mexico, USA: A Sunbelt City Rapidly Outgrowing its Aquifer.

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ABSTRACT: Albuquerque, New Mexico, is located along the Rio Grande in central New Mexico, at an elevation of 5280 feet. Albuquerque's climate reflects its high desert setting; average annual precipitation in the basin is only 8 to 10 inches. The Albuquerque metropolitan area is part of the rapidly growing "sunbelt" region of the southwestern United States and is undergoing rapid development. The municipal, industrial, and residential water needs of the entire population are currently met by groundwater, while agricultural needs within the basin are met by surface water diverted from the Rio Grande. While the city is blessed with an extremely productive aquifer, current metropolitan area annual groundwater extractions of 170,000 acre-feet far exceed the sustainable yield of the aquifer. Continued drawdown will lead to greater pumping costs, ground surface subsidence problems, and eventual aquifer depletion. At the same time, industrial and non-point-source contamination and naturally occurring arsenic levels are raising concerns about groundwater quality.

New Mexico water law has required the City to acquire surface water rights and allocations on the Rio Grande sufficient to offset estimated losses from the river induced by the City's groundwater extraction. It has become increasingly clear that the induced recharge had been greatly overestimated, and that the City is thus not actually consuming its surface water as intended. The City, in cooperation with local, state, and federal agencies, has explored a variety of conjunctive use proposals, all designed to permit the City to use its surface water more directly. The City Council is presently considering a strategy calling for full use of the city's surface water resources and creation of a groundwater drought reserve. Implementation of this strategy will require regulatory approval and major capital investment, both of which require political support. The City is pursuing a major effort to educate the public and involve all interested parties in the decision-making process.

1 INTRODUCTION

Albuquerque was founded in 1706 along the Rio Grande in the Spanish province of New Mexico (Fig. 1). After over a century of Spanish rule, Albuquerque was part of the newly independent nation of Mexico from 1821 until 1848, when New Mexico was ceded to the United States as a result of the Mexican-American war. Albuquerque's emergence as an major city began with the arrival of the railroad in 1880. The town's population grew from 1,300 in 1880 to 12,000 by 1892 (Summers 1995). Steady growth continued into the 20th century, with the city population reaching 35,000 by 1940. World War II and the Cold War brought new federal installations (including an air force base and a nuclear weapons laboratory) to Albuquerque, and settlers began flocking to the area, both for the employment opportunities and for the increasingly well-publicized quality of life. Dramatic population growth since the 1940s continues today; the 1990 city population stood at 385,000, while the Albuquerque metropolitan area was home to 480,000 people, almost one third of the entire New Mexico state population. As Fig. 2 shows, this population growth is expected to continue

Figure 1. Location of Albuquerque and the Rio Grande.

well into the next century (Gregory 1996).

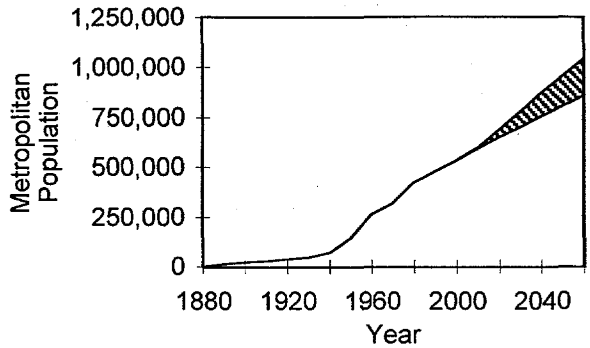

Figure 2. Population trend for metropolitan Albuquerque (CH2M HILL 1995; Summers 1995; Gregory 1996). Hatched area shows range in projections.

2 HYDROGEOLOGIC SETTING

The city is located in the middle Rio Grande Basin, and extends from west of the river east to the Sandia Mountains. The basin, part of the Rio Grande Rift, is a major structural basin that has been subsiding and filling with sediments for about 30 million years (Thorn et al. 1993). These sediments, including both fluvial deposits laid down by the ancestral Rio Grande and locally derived material from the Sandia Mountains, comprise the Santa Fe Group, which today forms the aquifer supplying the entire metropolitan area. This is a highly productive aquifer, especially below the city where transmissivities as high as 80,000 ft^2/day have been measured (Thorn et al. 1993), and individual wells pump as much as 3000 gpm. This world-class aquifer occurs in an arid region with an average annual precipitation of only 8 to 10 inches, with higher values in the adjacent mountains. The aquifer is recharged by the mainstem Rio Grande, which carries snowmelt from high mountains in southern Colorado and northern New Mexico, and local tributaries draining nearby ranges. Since 1972, an average of 96,000 acre-feet/year (afy) of water has been imported to the basin through the San Juan - Chama project, a Bureau of Reclamation project that diverts water from streams feeding the San Juan River, a tributary of the Colorado River, into the Rio Chama, a tributary of the Rio Grande (Shupe & Folk-Williams 1988).

3 ALBUQUERQUE'S WATER SUPPLY

The first irrigators in the area were Pueblo people, who probably arrived sometime after the year 1100. Elaborate irrigation systems consisting of canals and acequias flourished during the Spanish period, and by 1880 over 124,000 acres were under irrigation (Thorn et al. 1993). Shallow wells met most of the growing city's municipal and industrial needs until the late 1940s, when an integrated system of large deep water-supply wells was developed (Summers 1995). Based on the contemporary hydrogeologic understanding and the pro-growth economic climate of the time, the aquifer was widely believed to be practically inexhaustible. In particular, it was believed that the Rio Grande was well-connected to the aquifer and recharge from the river rapidly replaced groundwater pumped from the aquifer. Through the 1970s, the aquifer system was being described as comparable to Lake Michigan in extent and capable of supporting a population of 1½ million (J.M. Kernodle, pers. comm.; Grant 1995).

In the mid-1980s, a number of disturbing developments began to cast doubt on this comfortable illusion. Heavy pumping caused some wells to experience unexpectedly large declines in water level, and new wells drilled on the west side of the city did not encounter the expected highly productive zones. Under most of the city, present-day aquifer drawdown ranges from 100 to 150 ft (Fig. 3); a drawdown of approximately 260 ft is predicted to cause the widespread onset of irreversible surface subsidence. At the same time, a number of productive wells along the river have been removed from service due to industrial contamination and 2 wells have been shut down due to naturally occurring arsenic in excess of the current Environmental Protection Agency (EPA) standard of 50 ppb. The EPA is considering decreasing the arsenic standard to a range of 2 to 20 ppb; meeting a 5 ppb standard would require treatment of most of the City's groundwater at an estimated capital cost of \$300 to \$370 million (CH2M HILL 1995).

In response to these warning signs, the City of Albuquerque, in collaboration with private consulting firms and State and Federal agencies, began a major investigation of the geologic and hydrologic characteristics of the aquifer system. The two major findings to date are that the top quality aquifer is far less extensive and the Rio Grande / aquifer connection is much weaker than previously thought. A three-dimensional numerical model has demonstrated that if current trends in population and pumping rates continue, aquifer drawdown will accelerate, resulting in rapid aquifer depletion, increased pumping costs, major problems with ground subsidence, and increased water-quality problems as deeper, arsenic-rich water is drawn into wells (Kernodle et al. 1995). Fig. 3 shows that if current trends continue, large areas of the city will experience drawdown in excess of 260 ft by the year 2060. Inaction will inevitably bring a major water resource crisis, but because of its existing unused surface water resources, the City has a unique opportunity to address these issues. To understand the City's options, we need a brief introduction into the legal and regulatory structures built around water in the west.

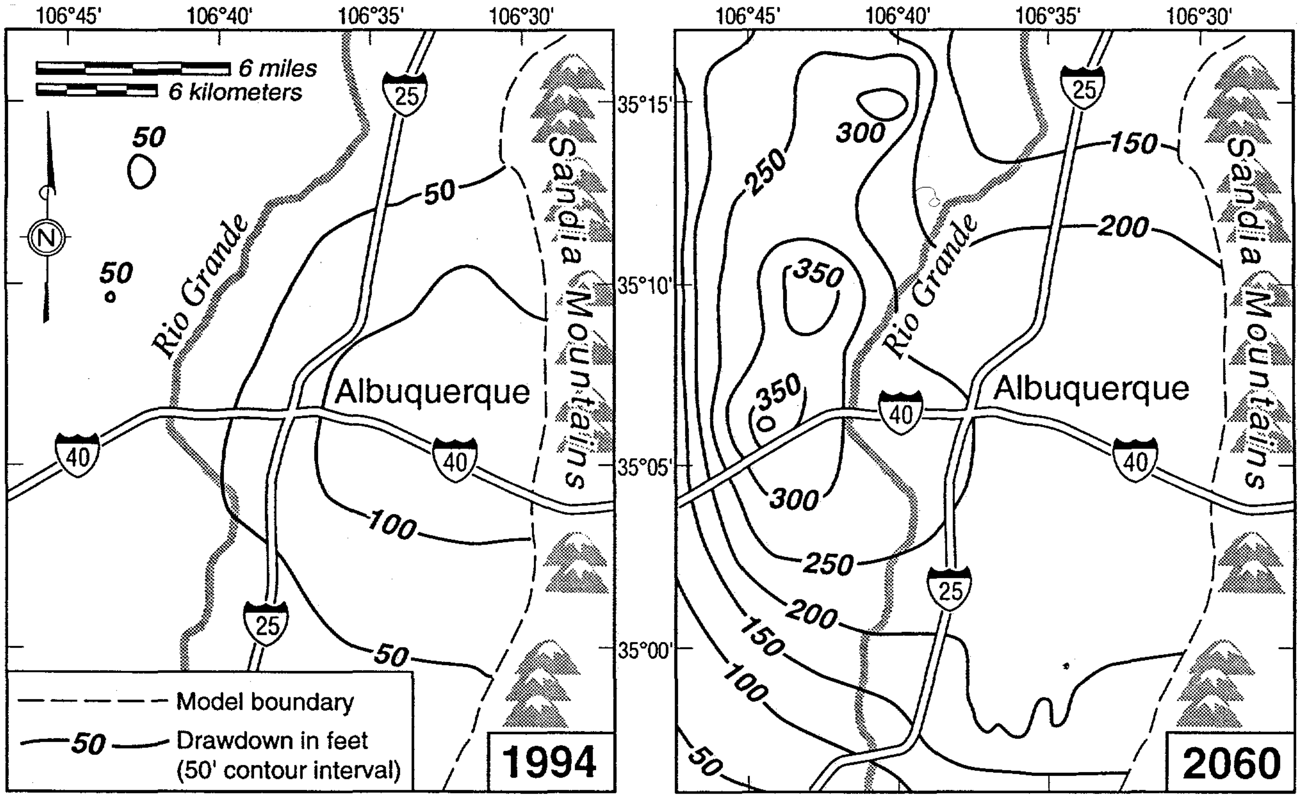

Figure 3. Simulated 1994 and predicted 2060 aquifer drawdown (ft) beneath Albuquerque (CH2M HILL 1995; Kernodle et al. 1995). 2060 prediction assumes present population and water use trends continue.

4 WATER LAW AND REGULATORY CONTEXT

Water resources in the western United States are subject to strict and sometimes conflicting regulatory controls at both the Federal and State level. The Federal government has jurisdiction over international and interstate affairs. On the Rio Grande, foremost is a 1906 treaty between the United States and Mexico, guaranteeing a certain amount of Rio Grande water to Mexico. In 1939, the U.S. Congress and President Franklin Roosevelt approved the Rio Grande Compact, allocating the river's water between the states of Colorado, New Mexico, and Texas (Shupe & Folk-Williams 1988). These two historic Federal regulations restricting use of the Rio Grande have been joined by a third, the Endangered Species Act. This Federal legislation prohibits any action that harms or disturbs an endangered species or reduces or destroys habitat. The U.S. Fish and Wildlife Service declared the Rio Grande Silvery Minnow an endangered species in 1993, and added the Southwestern Willow Flycatcher to the list in 1995. Much of the Rio Grande through central New Mexico may be declared critical habitat for these species. The full implications of this action are not yet clear but it is apparent that all future decisions pertaining to Rio Grande water resources will need to consider possible impacts on these species and their habitats.

Within the constraints of Federal regulation, the states are free to establish their own water laws. New Mexico's water law is based on the Doctrine of Prior Appropriation. Under this system, the right to use surface water is considered property, which can be bought and sold and transferred from one piece of land to another, regardless of proximity to a stream. Originally, a water right could be claimed by simply diverting water from a stream and putting it to beneficial use. By the early 1900s, the Rio Grande became "fully appropriated," with no unclaimed water available.

A consequence of the prior appropriation doctrine is that a water right in no way guarantees actual delivery of water. The date of the original water claim is critical, because it is this appropriation date that determines the seniority of a water right. In the event of a water shortage, senior water rights have priority over junior water rights, and junior right owners may run dry.

This system was originally applied to surface water. Its extension to groundwater is based upon the concept of "keeping the river whole." Because most rivers in the state are fully appropriated and groundwater pumping will eventually decrease stream flow, that pumping will adversely affect older, senior water rights holders. Therefore, the groundwater developer must acquire sufficient surface water rights to offset the anticipated impacts of pumpage. The State Engineer has traditionally determined the necessary surface water rights using the Glover-Balmer equation (Sophocleous et al. 1995).

Based on these calculations, the City of Albuquerque has acquired about 70,000 afy of Rio Grande surface water, including both purchased rights and an allocation of 48,200 afy of San Juan - Chama water. If the aquifer / river system behaved in accordance with the Glover-Balmer equation, this surface water combined with 60,000 afy of reclaimed wastewater discharge to the river would recharge the aquifer, completely compensate for the City's current groundwater pumpage of 125,000 afy, and maintain stable groundwater levels. This was a beautifully simple solution to Albuquerque's water supply: the aquifer would supply the City, the river would resupply the aquifer, and the City's purchased water rights would resupply the river. Unfortunately, it was based on an imperfect understanding of the aquifer / river system.

Since groundwater levels beneath Albuquerque are dropping more rapidly than expected, something is clearly wrong. The problem lies with the Glover-Balmer equation. This method is based on an analytical approach involving numerous simplifying assumptions, including a homogeneous, isotropic, semi-infinite aquifer, a fully-penetrating stream and well, and perfect hydraulic connection between the stream and aquifer (Sophocleous et al. 1995). These assumptions all tend to overestimate the effect of pumping on streamflow, which, from a surface water rights point of view, is a conservative error that provides an additional margin of protection to the water rights holder. However, it also greatly overestimates recharge to the aquifer. Recent three-dimensional numerical modeling of the aquifer / river system that eliminates many of these simplifying assumptions confirms that less than half of the City's pumping is being replaced by recharge. So, rather than resupplying the aquifer, the City's Rio Grande water is simply flowing downstream or being stored in upstream reservoirs for future use. Here lies Albuquerque's hopes for the future.

5 FUTURE PLANS - A SOLUTION IN SIGHT

Based on findings and recommendations of recent interagency water resource investigations the City has proposed an ambitious new approach to water resources development and management (City of Albuquerque 1997; Hansen & Gorbach 1997). The strategy is based on conjunctive use of surface water, ground water, and impaired-quality waters to better distribute demand across a broader range of available supplies. Key provisions include:

- Direct use of surface water. This will require construction of infiltration galleries along the Rio Grande, a water treatment plant, and transmission pipelines.
- Establishment of a groundwater reserve for drought years. This will involve both active and passive groundwater recharge projects using surface water supplies.
- Appropriate use of a combination of reclaimed (recycled) water, surface water, shallow groundwater, and deep groundwater, in which the various qualities of water available are matched with the needs of different users. For example, lower quality waters could be used for irrigation and some industrial supplies, while high quality water from the deep aquifer should be reserved when possible for domestic use. This will require additional water recycling facilities and new transmission pipelines for recycled water.
- Continued emphasis on water conservation, with the ultimate goal of reducing gross community water use by 30% from the current 250 gallons per capita per day to 175 gallons per capita per day.

Most of these measures are expensive, and all require public support and regulatory approval. The City is committed to a major public involvement and public education program, and is working closely with the State Engineer Office, the federal Bureau of Reclamation, and other local, state, and federal agencies to make this plan a reality.

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