The Hydrologic Reality of the Middle Rio Grande Basin – Jim Bartolino, U. S. Geological Survey

HYDROLOGIC REALITY, or BAMBI MEETS GODZILLA

Jim Bartolino received his degree in Geology and Civil Engineering from Texas Tech in Lubbock. He's been a hydrologist for the U.S. Geological Survey since 1991. Currently he's project groundwater specialist in New Mexico district. He's been project chief for the USGS Middle Rio Grande Basin Study; he's worked on using water temperature for describing groundwater-surface water interactions; describing aquifer geology with electromagnetic geophysical surveys, irrigation drainage water quality, transport and fate of agricultural chemicals, and several other projects. Currently he's studying East Mountain water resources. He'll tell us about the geophysical reality of the basin.

The title of the talk I was given was 'Hydrologic Reality.' I felt uncomfortable with that--there are fifty people in the state more apt to give you the hydrologic reality than me--so the title I came up with is "Bambi Meets Godzilla," for reasons that will soon become apparent.

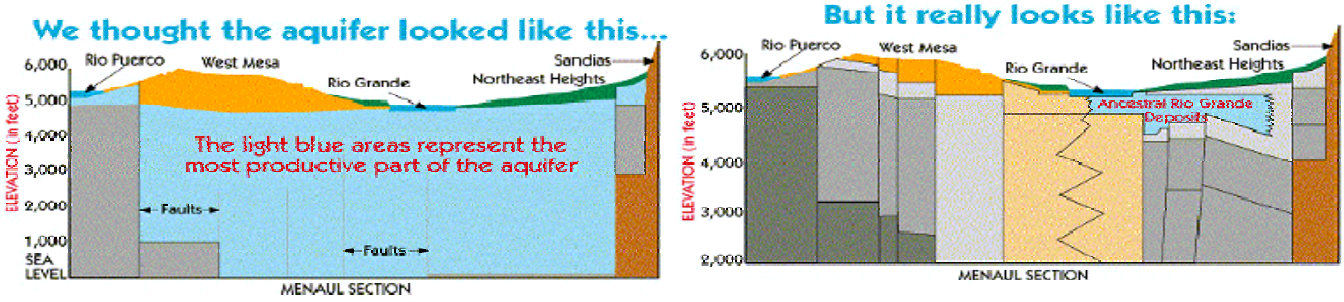
My involvement and the USGS involvement in the past few years has been part of the MRG Basin Study in which we looked at the hydrology, geology, and land characteristics in order to come up with information that planners, managers and lawmakers are going to need in order to make some of the decisions regarding water resources in the basin. We looked mostly at groundwater, but as you know by now, everything is tied together. Our main publication out of this study was this circular . We wrote this for an intelligent, lay audience; hopefully everyone who can read a newspaper can understand it.

Why Bambi Meets Godzilla? For years we wandered along with this understanding of the basin, just like Bambi in the forest, naively making plans, thinking there was an infinite amount of groundwater beneath Albuquerque, and that basically that we were living over a big bucket of wet sand. In the early 1990s, John Hawley and others, in the form of Godzilla, came stomping in and pointed out that there is a lot less high quality aquifer than we thought, and a lot less recoverable water beneath Albuquerque than

we thought. So on the basis of the groundwater flow model that Kernodle, McAda and Gore did, and with Hawley's work, we began making plans that recognize that we live in a desert and don't have an endless supply of groundwater.

To be fair, the writing was on the wall a lot earlier. In the early 1950s, some City of Albuquerque wells went dry and it caught the city flat-footed. C.V. Theis, who was one of the leading figures in the science of hydrology and worked for USGS, went to the Chamber of Commerce and said basically that the city had gotten a notice its bank account was overdrawn, and was complaining no one could have foreseen this because in effect, there was no bookkeeping system. At this point, USGS and others began working with the city to try and monitor the situation. Yet even into the 1980s, we saw advertising saying that Albuquerque was living over Lake Superior

> "What happened was that the city got a notice from its bank that its account was overdrawn and when it complained that no one could have foreseen this, only said in effect that it had no bookkeeping system" (C.V. Theis, 1953)

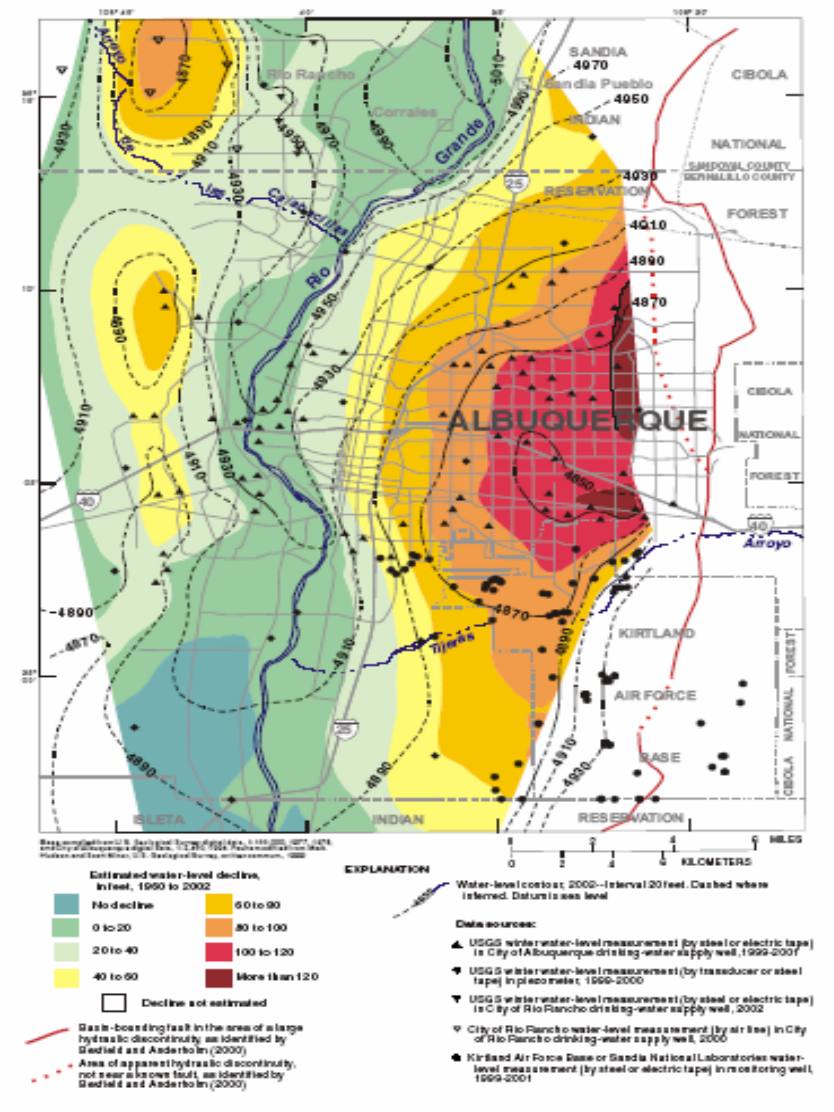


City of Albuquerque Public Works Department, Water Conservation Division

Ground-water depletion?

I'm going to introduce a term here--groundwater depletion. In a fact sheet a colleague and I wrote for congressional people, groundwater depletion is defined as "long term water level declines caused by sustained groundwater pumping." You've probably seen the map by Laura Bexfield and Scott Anderholm showing water level declines of over 160 feet beneath some parts of Albuquerque, so I think its fair to say that we're in a groundwater depletion situation.

Some of the common effects we see from this are water well problems, reduced surface water flows, subsidence, and deterioration of water quality, and I'll cover each of these.



Water-well problems

Water well problems--As the depth to water increases, we have to lift the water further to get it to the surface; that means more in energy costs. Another problem is that water levels can drop below existing pumps, meaning you have to lower the pump in the well, or drill a new well. Finally, sometimes with a lowering of the aquifer, the water that's down there gets tied up in fine-grained material and the well just won't produce.

Reduced surface-water flows

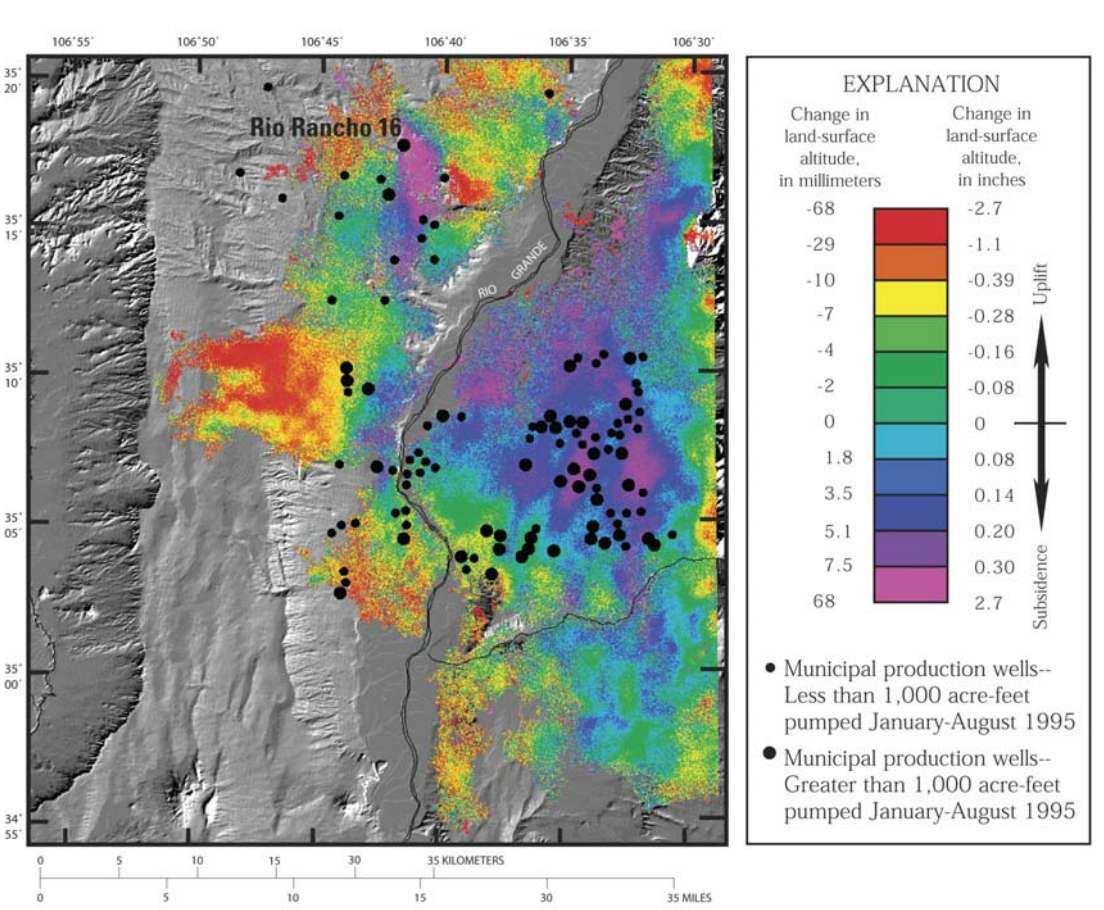
We can see a reduction to surface flow in several different ways. First of all, we can intercept groundwater that naturally flowed to surface water. In Albuquerque, that's what's happened. The aquifer used to discharge to the river, and by pumping, we're intercepting a lot of that water that was going to the stream. Another way it can happen is if the stream is a 'losing stream,' i.e., one that contributes water to the aquifer through an area. By lowering the water level in the aquifer we can increase the rate of water coming out from the stream. Another effect that we see contributing to a reduction in surface flows is that if we lower the water table far enough beside the stream, it can drop the water table out from under the riverside vegetation

that taps directly into the water table. This is a pair of repeat photographs from the Santa Cruz River south of Tucson. In 1942 there was lush riparian vegetation, big cottonwoods, a healthy riverside system. Forty-seven years later, after the valley had been developed pretty extensively for groundwater, you can see that all the cottonwoods are gone. Basically, they dropped the water table out from under those trees and that was it. On the model it's a hard number to come up with, but I think Doug McAda and Peggy Berol used a depth of twenty-five feet* as the shut-off for evapotranspiration, meaning the cottonwoods are dead.

Land subsidence

Subsidence is a gradual settling or sudden sinking of the earth's surface owing to subsurface movement of earth materials. We've all seen on the news these places in Florida where half the guy's swimming pool is seventy-five feet lower than it was the day before. We're not likely to see that kind of catastrophic subsidence here in Albuquerque, but we are seeing widespread, less drastic subsidence in most of the city. Using InSAR (Interparametric Synthetic Apature Radar) and satellite imagery, Chuck Heywood, Debbie Galloway and Nancy Store looked at changes in land surface elevation.

This image shows the land surface difference between July 2, 1993 and September 3, 1995. The cold colors—the blues and purples—show the land surface going down over that period of time. You can see in parts of Albuquerque and Rio Rancho you've got land surface decline of about two and a half inches. What does this mean? This is so widespread and so gradual it's not likely to impact any structures, and Chuck felt that this is a lasting compression. Notice that both these images were taken in the summer or toward the end of the high stress period on the wells. When the aquifer is stressed, the land surface drops, but in the winter as stress is decreased and the aquifer recovers a bit, the land surface comes back up. In a sense we have almost a breathing effect. At a given point, and it's hard to tell exactly what that point is, if you take enough pressure out of the aquifer the fine-grained sediment compacts to a more stable configuration. It's like when you have a house of cards on a table and you bump the table, that stack of cards is going to get more stable real quick. At that point, the aquifer can't recover. That substance is done, it's history, we're never going to get [its function as an aquifer] back. Chuck doesn't think we're at that point yet but we probably will get there if we keep lowering the water levels like we have been. Bill [unintelligible] formerly of the New Mexico Bureau of Geology and Mineral Resources figured we have about two hundred more feet of water level declines before we get an inelastic depression, but there's a lot of estimates in that and we don't really know what's going to happen.



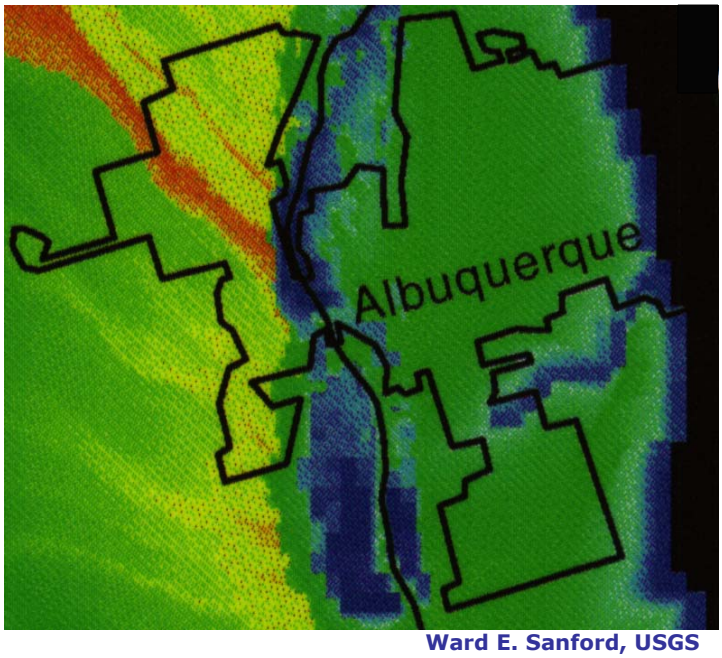
Heywood, Galloway, and Stork (2002) InSAR image of the Albuquerque area, 02Jul93-03Sep95. Maximum subsidence of 2 inches shown in Rio Rancho area in purple and blue.

Deterioration of water quality

Typically, water quality declines with depth. This can be from an upwelling of poor-quality water, or as we put our wells deeper and deeper into the aquifer as the water levels decline, we're actually in poorer quality water. We don't know what the water quality is in the lower part of the aquifer. There's no reason to put wells down there while we can get water from more shallow wells. We just haven't done the exploration. But it's almost a hydrologic truism that the water quality going to decline with depth. Another problem is that by lowering the water table, we can cause surface water to come into the aquifer. It's possible that we can degrade the water quality in the aquifer by pulling stuff into the water table that wasn't there to begin with, or by causing changes in the water chemistry--as in pH--that mobilize constituents in the aquifer that are already there, but tied up in sediments. Right now we don't have any clear evidence for either. Scott Anderholm and Laura Bexfield did a report looking at trends in City of Albuquerque wells, and there wasn't any clear evidence one way or the other that [the basin's degraded over time.]

This is a model of what Sanford did of groundwater flow in the Albuquerque area. The hot colors coming in from the northwest represent old water, ten thousand years and up, coming in and naturally discharging at the river. The cold colors indicate young water, one year or less, and we can see how we've reversed the flow directions: young water has moved out and cut off those

older flow lines. So we are drawing surface water back up into the aquifer. Are we going to see chemistry changes? We don't know.



Ward E. Sanford, USGS

Ground-water age 50-feet below the water table. Ground-water ages grade from greater than 10,000years old in the areas of warm colors to less than 1- year in areas of cool colors.

So the question is Bambi or Godzilla?

> **"As with other natural resources, society must weigh the benefits against the consequences of [ground-water] use. In order to provide the scientific information needed for informed decisions, these effects must be observed over time to determine their impact." (Bartolino and Cunningham, 2003)**

We've never heard a scientist or an engineer say they had enough data, but hopefully we've given you enough over the past few years that you're moving forward with making some decisions. But we can't just say, "We've got the answers--no more science." We're going to have to monitor these effects. You can see that we are going to have effects. Right now, some of these effects may be desirable. As the situation evolves down the road, we may not be able to live with them, and we'll have to manage the situation differently. Science is going to give us the answers.

Some of you may remember the short film "Bambi Meets Godzilla," made in 1969. It's a very idyllic Bambi, grazing, and all of a sudden, Godzilla just—squish. It's our choice whether or not we want to be Bambi.