

*Lee Wilson is President of Lee Wilson & Associates, a water resource consulting firm head-quartered in Santa Fe. A certified professional hydrogeologist, he earned his geology degrees at Yale (B.A.) and Columbia (Ph.D.). In his 35-year career, he has completed 300+ technical studies of surface and groundwater resources for government and industry; prepared more than 50 environmental impact statements and ecosystem reports for the U.S. Environmental Protection Agency; and provided expert witness services in some five dozen proceedings. Lee currently provides advice on water supply, water rights and water quality to more than a dozen municipalities and tribes along the Rio Grande, including Taos Pueblo, Santa Fe, Albuquerque, and Las Cruces.*



**Surface Water Hydrology of the Rio Grande Basin**

I have been asked to present everything I know about the surface water hydrology of the Rio Grande Basin in 15 minutes. That's no problem. To begin, we need to look at the location of the basin. Much of the world mistakenly believes the Rio Grande Basin includes all the area shown in Figure 1, and extends from the Colorado headwaters to the Gulf of Mexico. However, everyone at this conference knows the REAL Rio Grande Basin ends at Ft. Quitman.

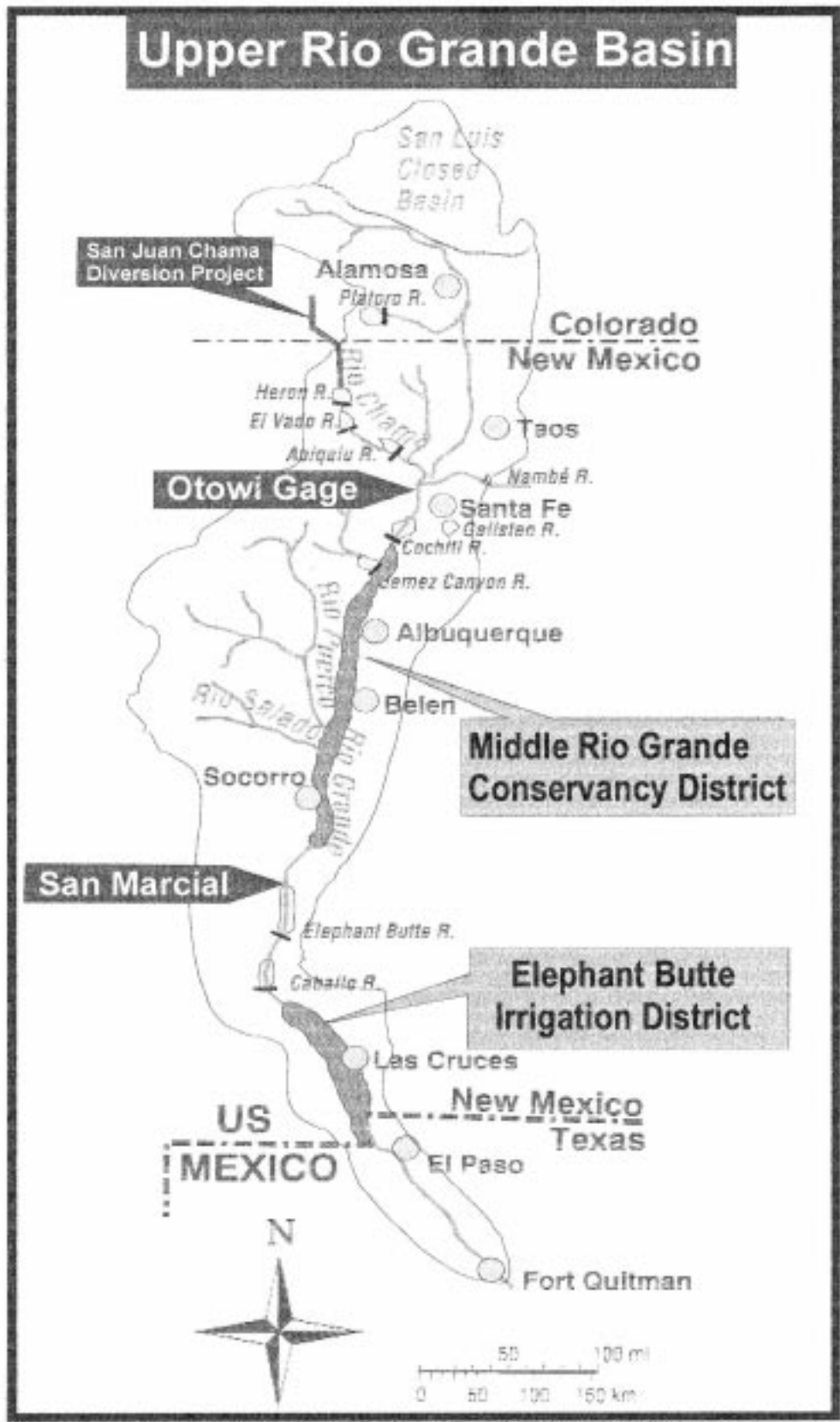
Figure 2 shows some important features in the New Mexico part of the basin: two irrigation districts, the San Juan/Chama import project, Compact accounting points at Otowi and (formerly) San Marcial, reservoirs (the largest being Abiquiu, Cochiti and Elephant Butte), cities (the largest being Santa Fe, Albuquerque and Las Cruces, but these are small compared to downstream El Paso and Juarez) and more than a dozen tribes.

The renewable water supply for the Basin originates mainly from mountain snowmelt in Colorado and northern New Mexico (Figure 3),



Figure 1. The Rio Grande Drainage Basin

Surface Water Hydrology of the Rio Grande Basin



Courtesy NMOSE/ISC Waterline & Kenesson Design

Figure 2. Upper Rio Grande Basin

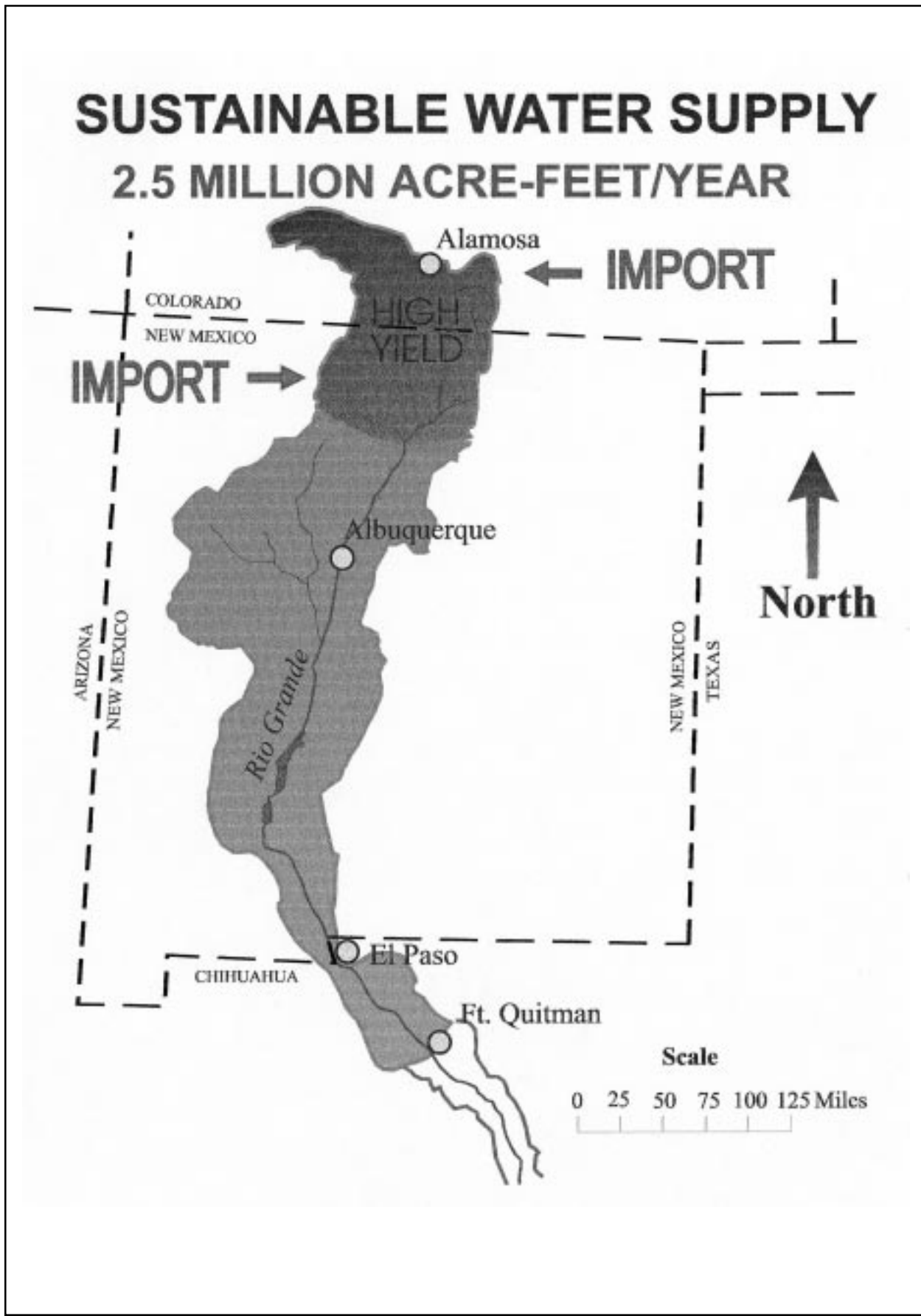


Figure 3. Sustainable water supply for the Rio Grande Basin (2.5 million acre-feet/year)

and averages about 2.5 million acre-feet (af) per year. There is an additional 5% supply provided by importation of San Juan/Chama water and the Closed Basin project in Colorado. The annual hydrograph reflects the snowmelt source

with most of the natural flow occurring from April to July (Figure 4). For virgin flow conditions, I estimate the average May peak at more than 600,000 af. The virgin flow data also can be graphed on a flow-duration curve that shows

Surface Water Hydrology of the Rio Grande Basin

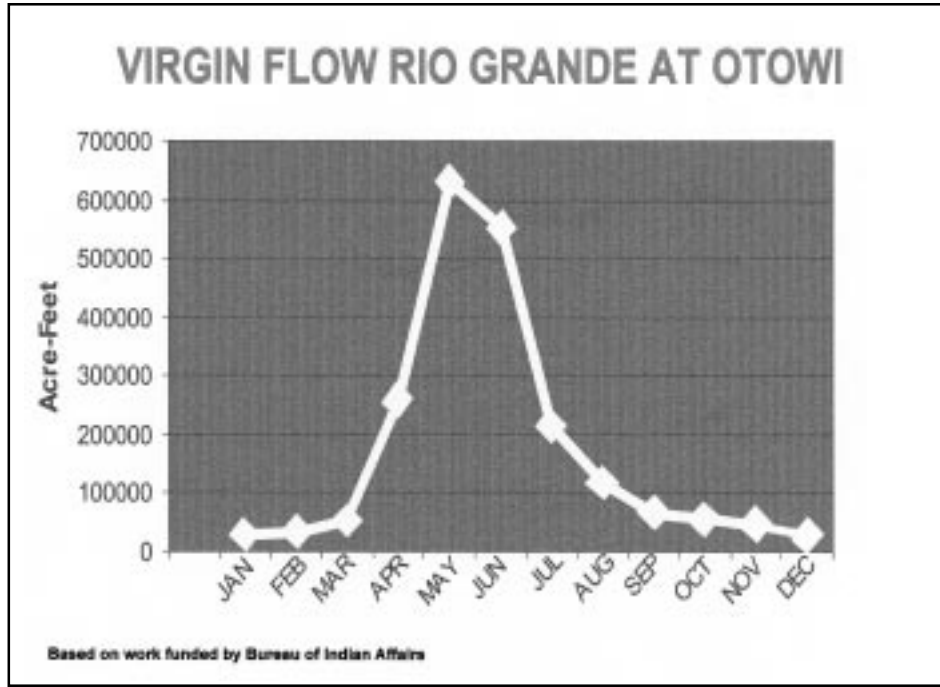


Figure 4. Rio Grande virgin flow at Otowi Gage

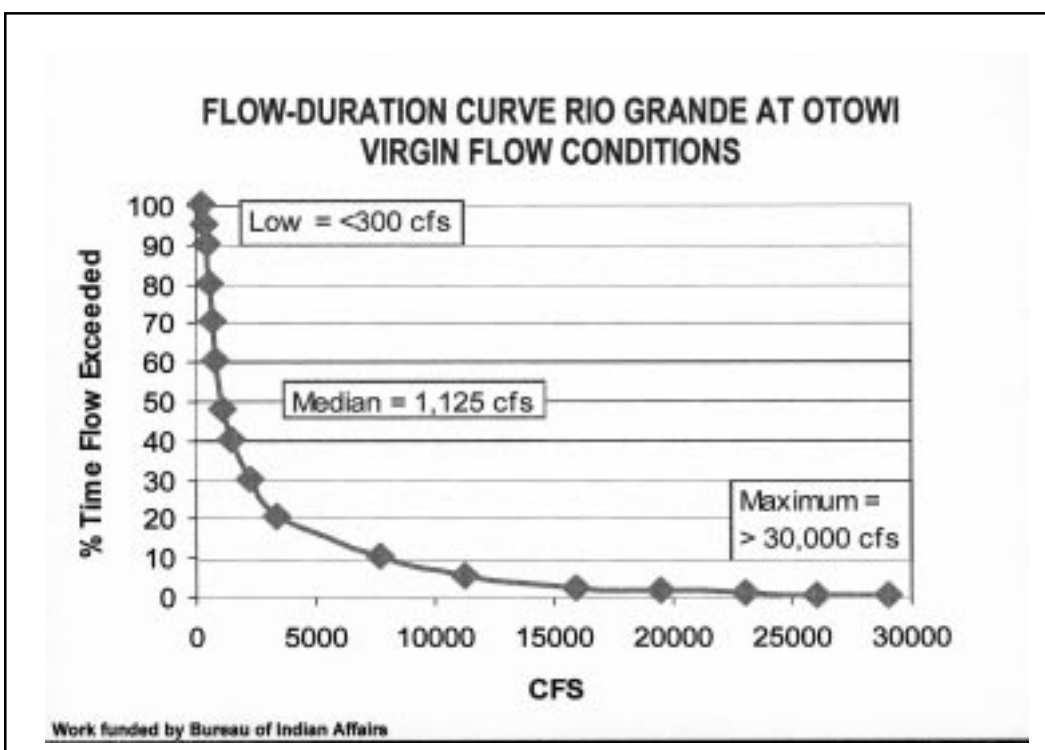


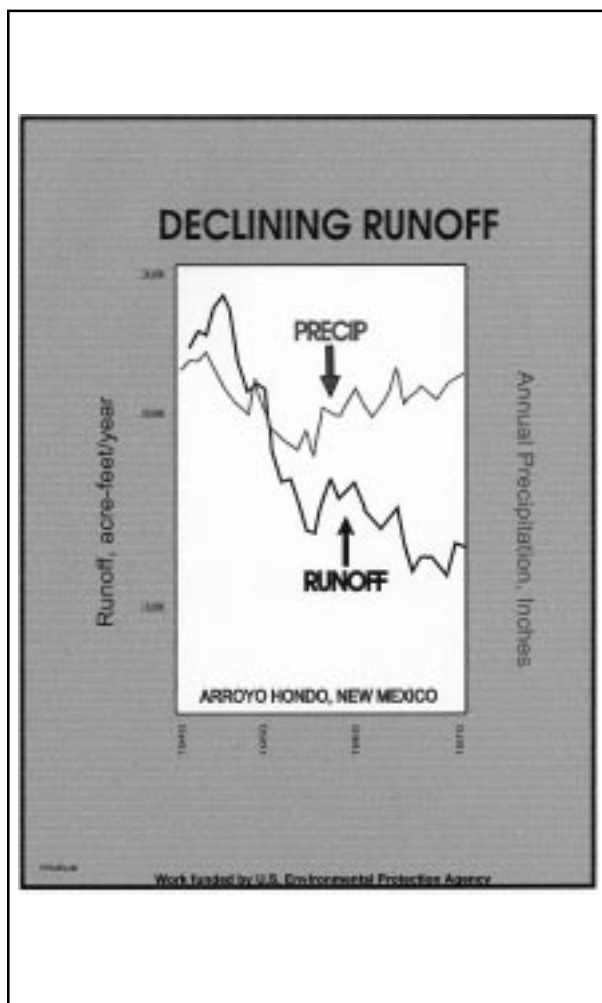
Figure 5. Rio Grande flow-duration curve at Otowi: Virgin flow conditions

more than a 100-fold range from the low of <300 cfs to the high >30,000 cfs, with a median above 1000 cfs (Figure 5).

As important as the overall supply is the great variability from year to year. Figure 6 shows runoff patterns in the Rio Pueblo de Taos for the last 1000 years, based on tree-ring records. Early this century when Rio Grande waters were being allocated, climate conditions were relatively wet and more water was available than normal. The '50s drought, in comparison, was severe—exceeded only by the one in the 1100s that was so disastrous to Pueblo Indians.

And also, the forest cover was in poor condition in the early part of the century, which meant that runoff was unusually large. Reforestation and watershed recovery promoted by the Forest Service and others has caused a net reduction in the runoff supply in recent decades. Figure 7 is typical; for the Taos area, it shows how much the runoff has declined even under relatively steady precipitation conditions.

Even with all the variability, 2.5 million acre-feet per year is quite a bit of water. Far and away the main use of this supply is for irrigation—a total of nearly one million acres, with the main areas as shown in Figure 8. Unfortunately for New Mexico, more than 600,000 of those acres are in the San Luis Valley of Colorado. I will comment on the three main areas of irrigation use.



Surface Water Hydrology of the Rio Grande Basin

Figure 7. Declining runoff for the Taos area acre-feet/year

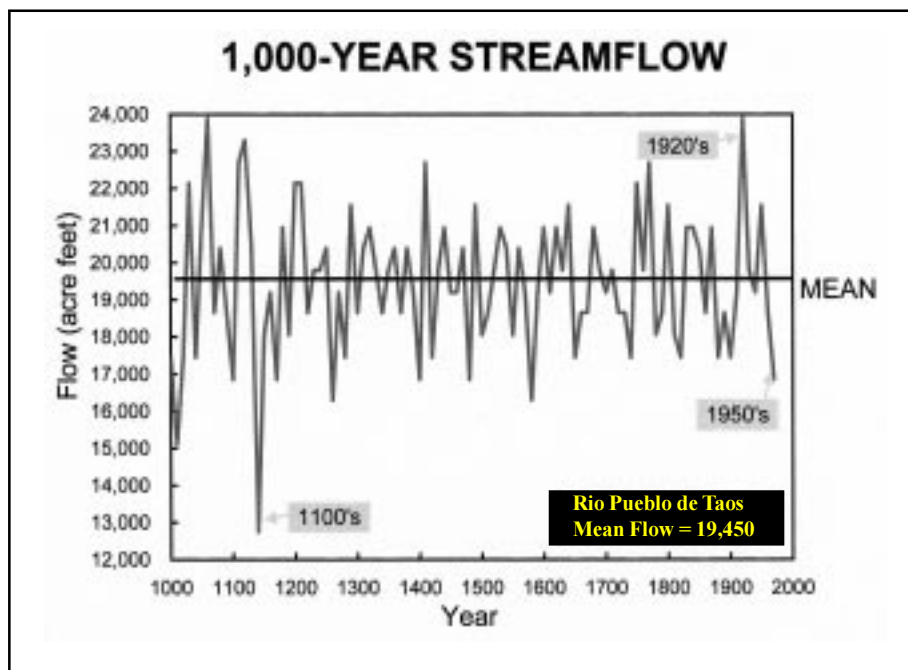


Figure 6. 1,000-year streamflow for Rio Pueblo de Taos

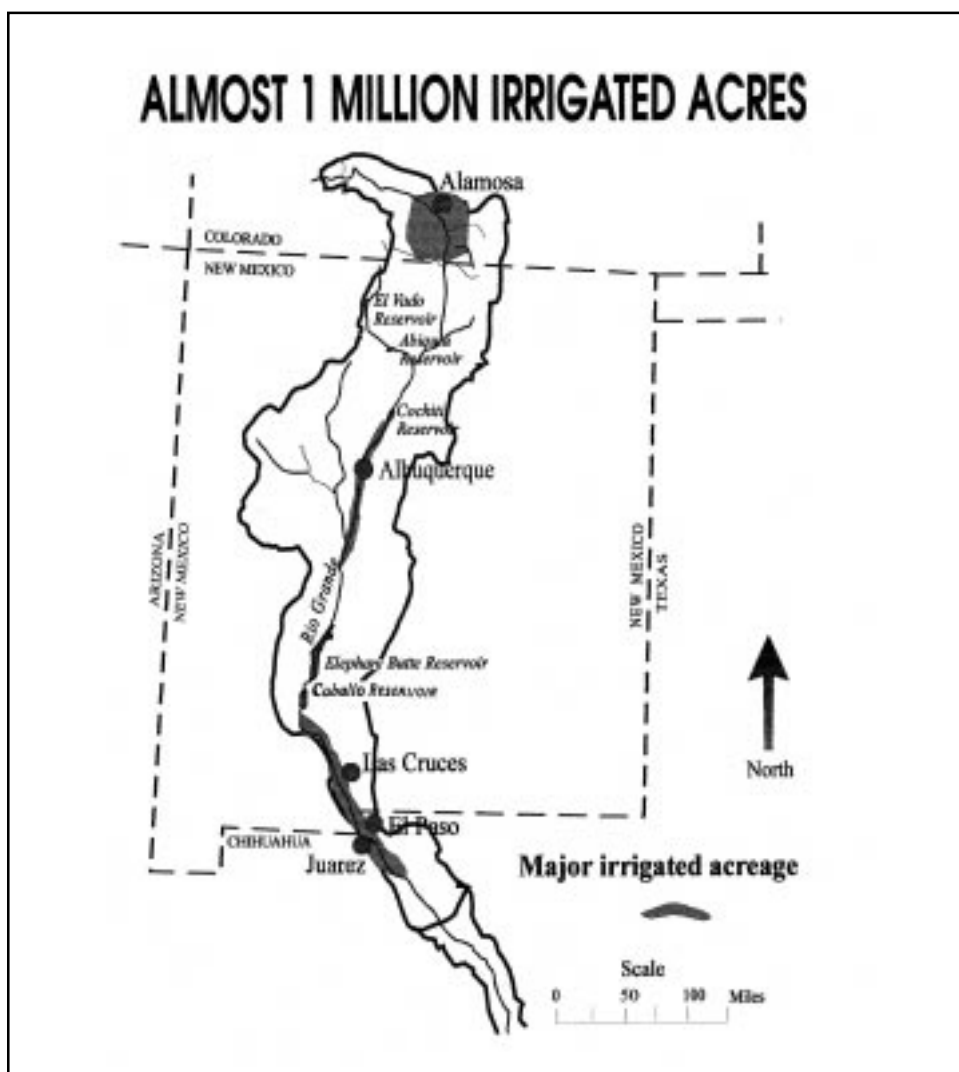


Figure 8. Major irrigated acreage in the Rio Grande Basin

The impact of Colorado is shown by comparing the virgin flow hydrograph at the Otowi gage, near Santa Fe, to the current flow (Figure 9). Of course the substantial reservoir storage upstream is partly responsible for the reduction in peak flow, but the overall reduced flow is mostly because of the use in Colorado. Winter flows are actually higher now than for virgin conditions, due to irrigation returns.

After Colorado, the next big straw in the system is the Middle Valley, where use is strictly controlled by the Compact. Figure 10 shows that roughly 60 to 80% of the Otowi flow must be bypassed down to Elephant Butte Reservoir. The Middle Valley is allocated about 300,000 AFY, which it fully uses, mostly through phreatophytes and irrigation. Because municipal wells tend to be far from the river, and wastewater discharges are direct to the river, you see little if any net use by the urban centers in this reach.

The final straw is the Rio Grande Project and the Treaty delivery to Mexico. Figure 11 shows how the Project supply was very short in the '50s-'70s, but has been full for two entire decades now. In dry years, nothing gets past Ft. Quitman. In wetter years, a little does. Every now and then we have a really wet year when the reservoir spills and water actually flows out of the basin. The long-term average flow at Ft. Quitman, which is mostly in a few wet years, is only about 140,000 AFY, or barely 5% of the total water supply. Steve Reynolds would be very proud: there is no question that in this basin, the users collectively do *use it*.

While some reservoirs have been built for flood control, the main factor has been that irrigation demand peaks in summer, after the runoff season, as shown in Figure 12. Shortages are a way of life on most tributaries, but they have been largely fixed on the mainstem.

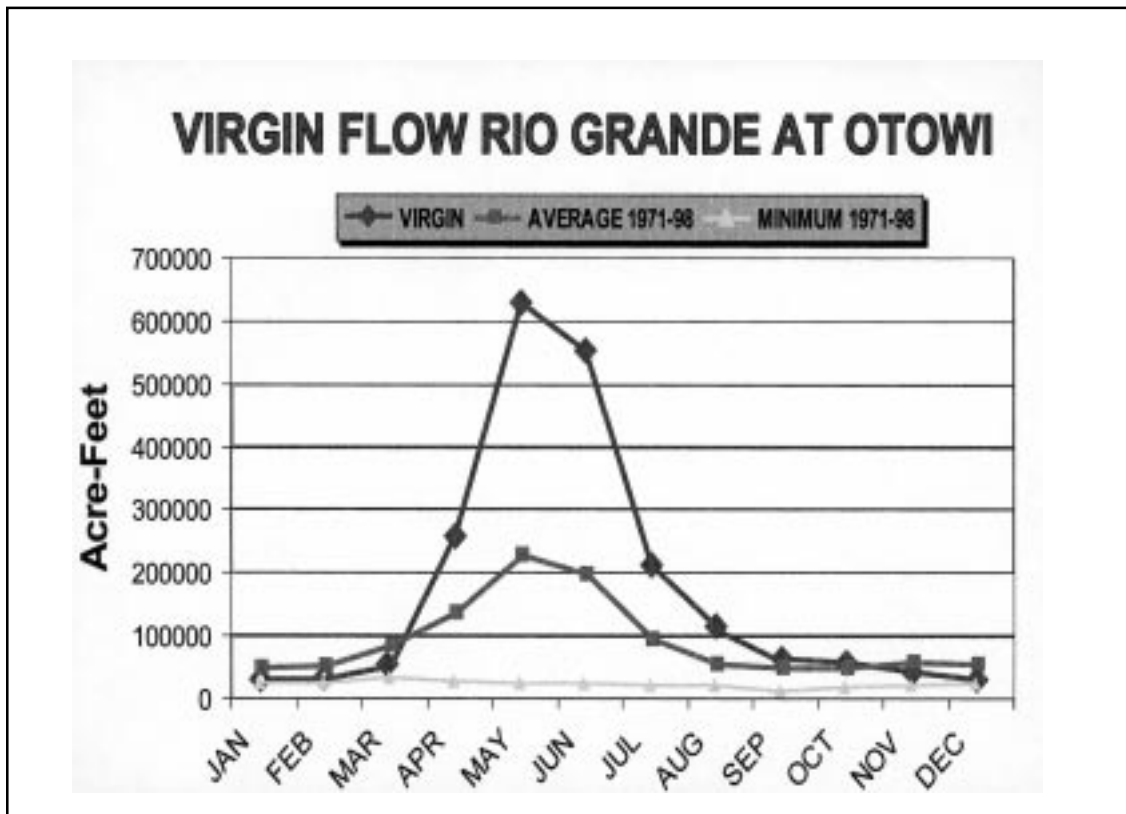


Figure 9. Virgin flow of the Rio Grande at the Otowi gage (acre-feet)

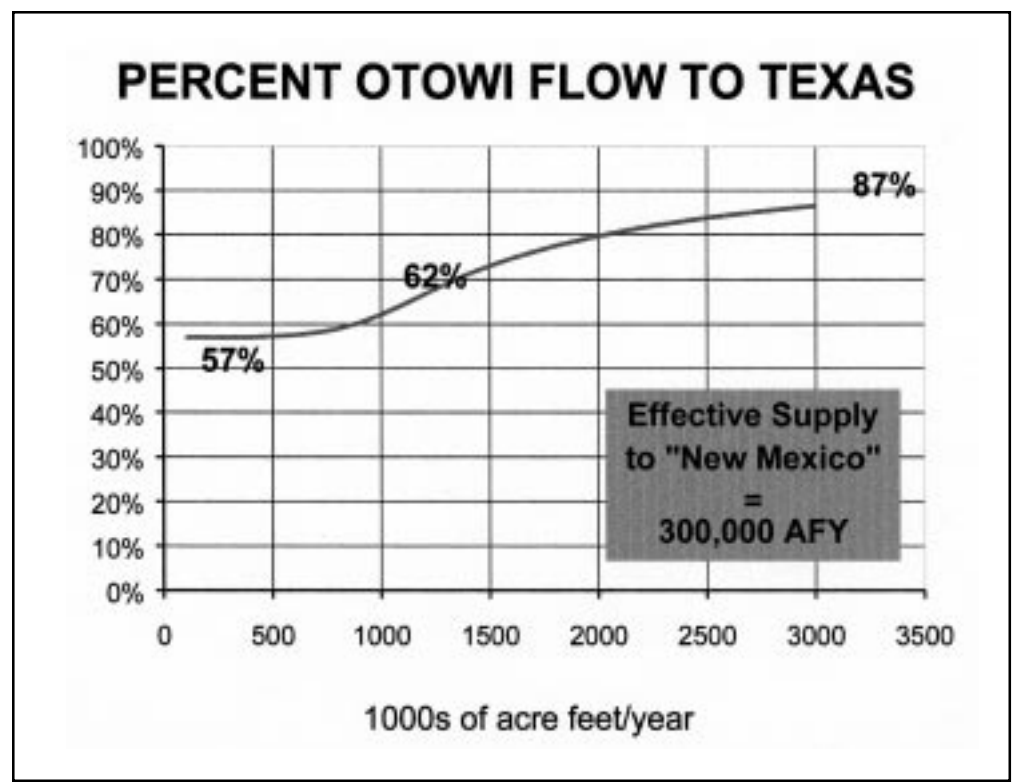


Figure 10. Percent of Otowi flow to Texas

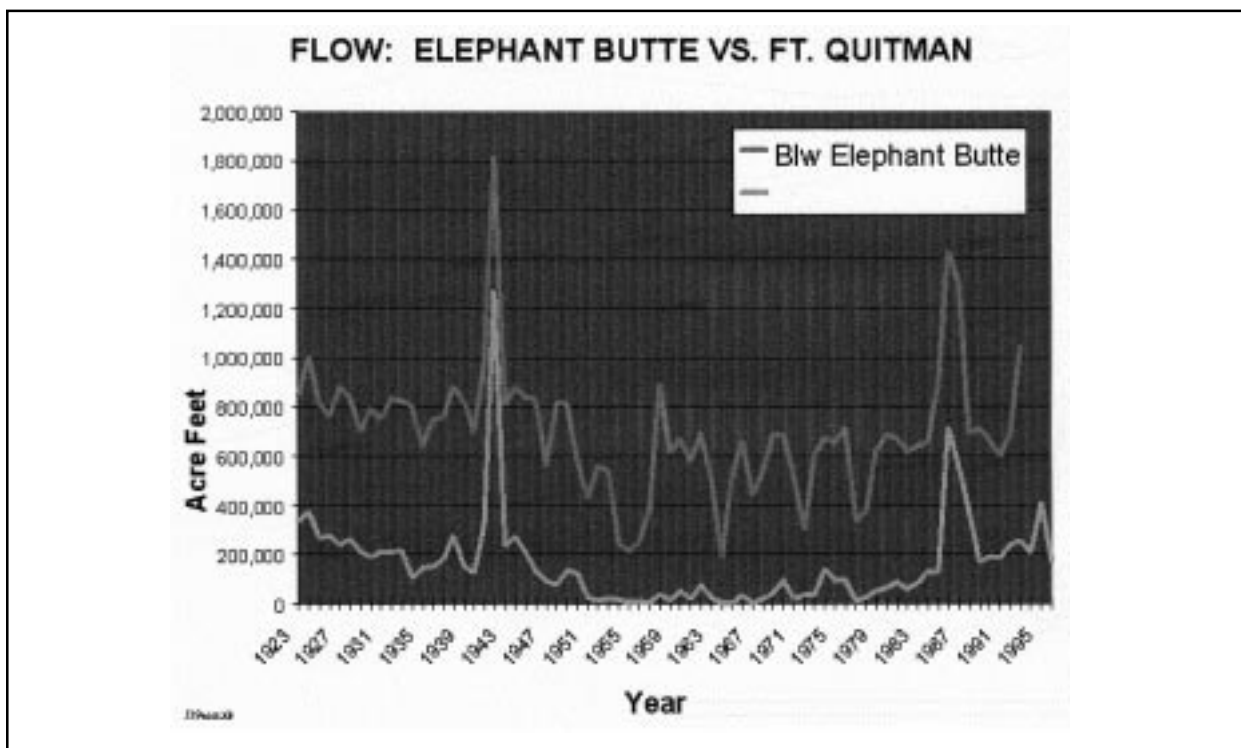


Figure 11. Rio Grande flow measured below Elephant Butte and at Ft. Quitman for 1923-1995

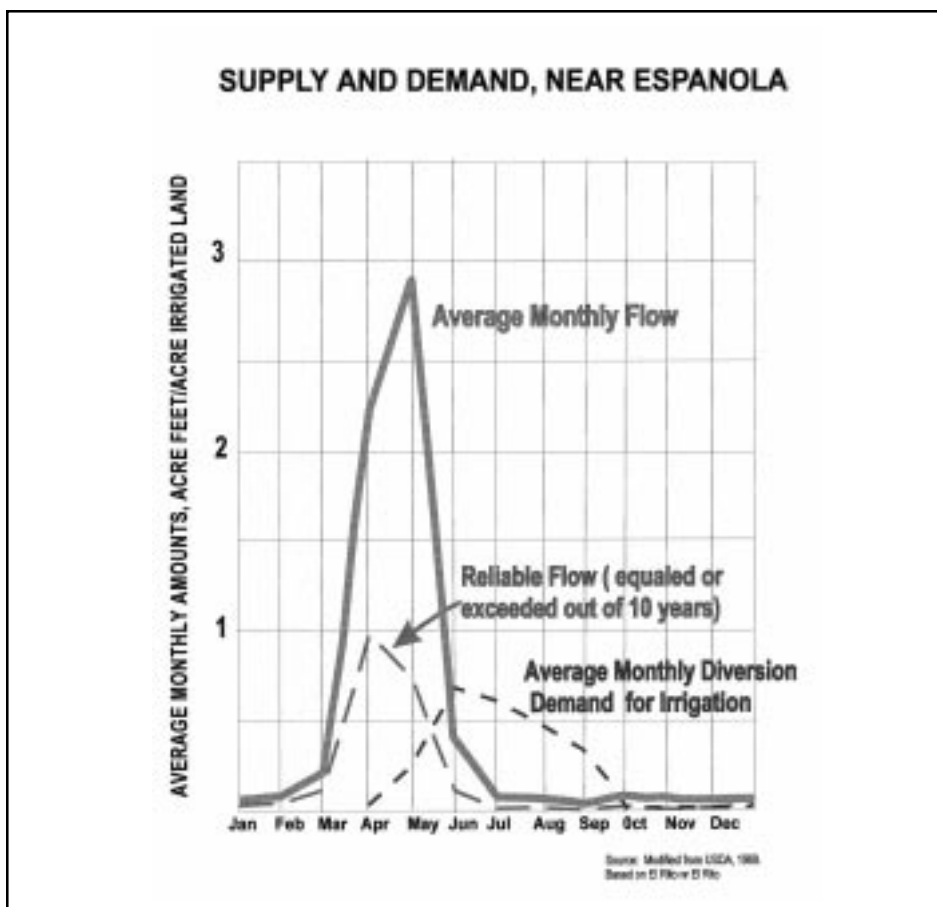


Figure 12. Supply and demand of Rio Grande water near Espanola



From a hydrologic perspective, the reservoirs have had lots of effects, such as evaporation. Figure 13 shows that evaporation rates are small in the northern reservoirs, but very large down south. Because Elephant Butte has a high rate and a huge area, it accounts for the bulk of the more than 340,000 af evaporated from the New Mexico reservoirs each year.

Another change has been to eliminate the highest runoff peaks (see Figure 14). It takes more than 11,000 cfs passing Albuquerque to really alter the channel and we haven't had a flow that large at Otowi since World War II. Since Cochiti was built, the actual flows at Albuquerque have been kept well below the 11,000 number.

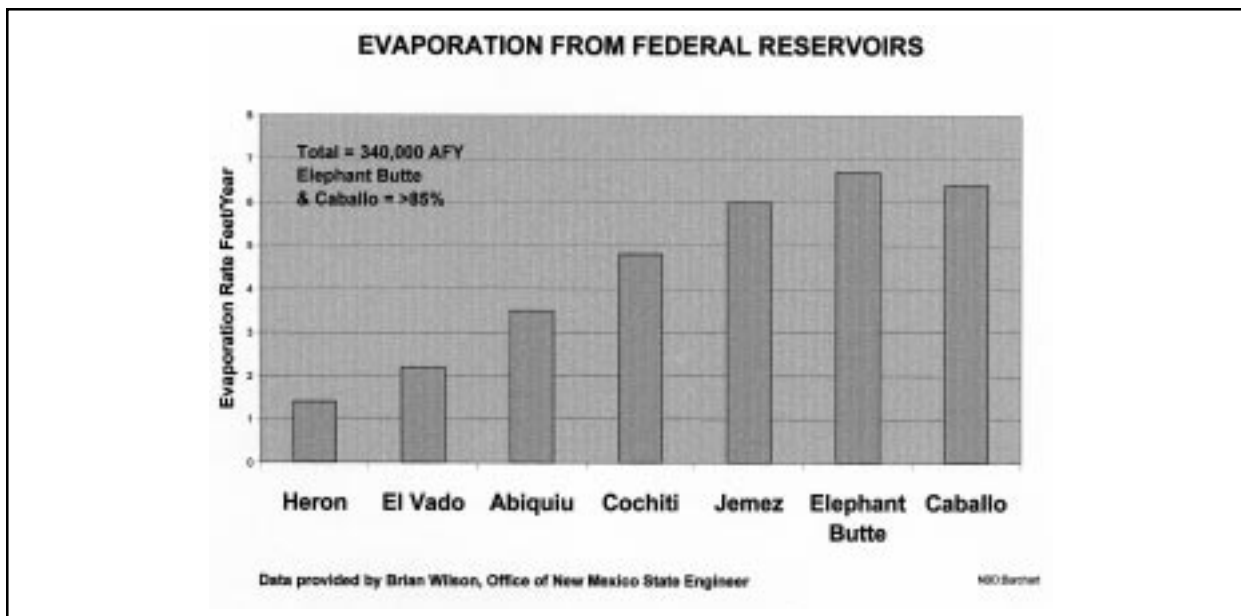


Figure 13. Evaporation rate for federal reservoirs in New Mexico

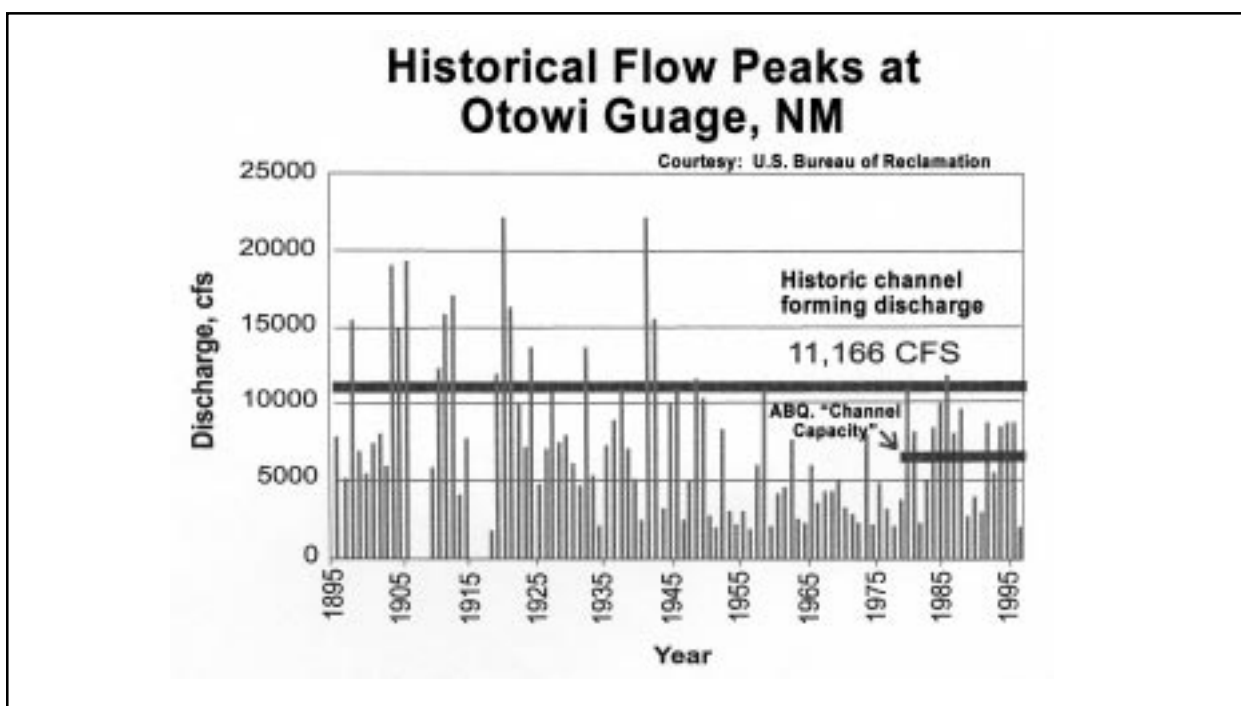


Figure 14. Historical flow peaks at Otowi gage for 1895-1995

With lower flood peaks, there has been a pronounced narrowing of the channel—below Albuquerque, the channel is only one-third or one-quarter its natural width (Figure 15). Levees and other structures have contributed to this effect, but the narrowing was inevitable once the dams were built and the flood peaks brought under control. Interestingly, if we draw a similar graph to show channel straightness, there isn't much change; the Rio Grande never did a whole lot of meandering.

Another important feature of the river has been its tendency to aggrade—to drop sediment, fill in the valley and get ever higher in elevation (Figure 16). The channel at San Marcial is 25 feet higher now than it was at the beginning of the century. This is largely a natural problem, as evidenced by the fact that thousands of feet of sediment have accumulated in the Rio Grande valley over the past few million years.

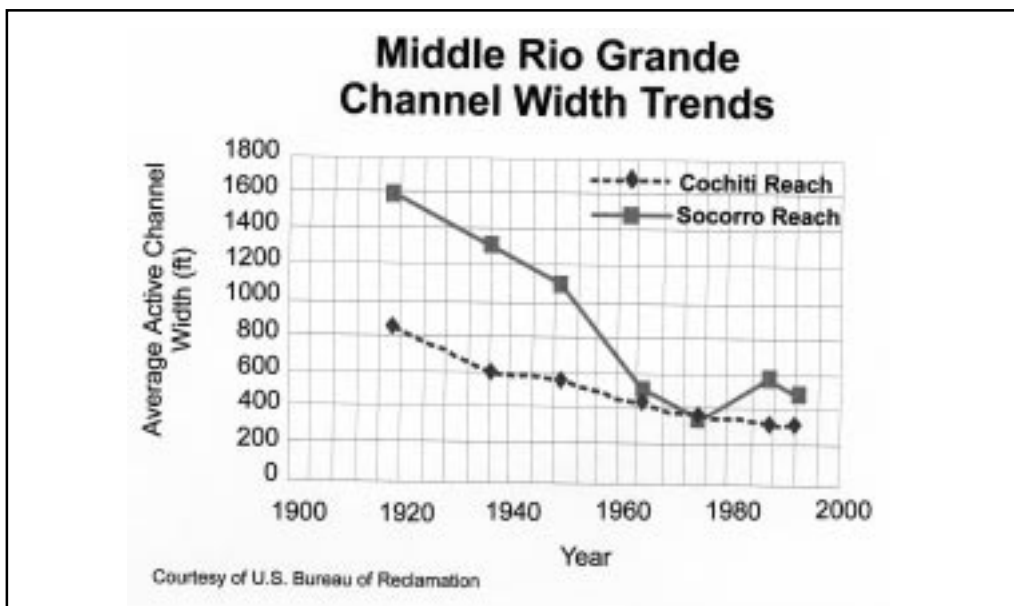


Figure 15. Middle Rio Grande channel width trends for Cochiti and Socorro reaches, 1920-1990

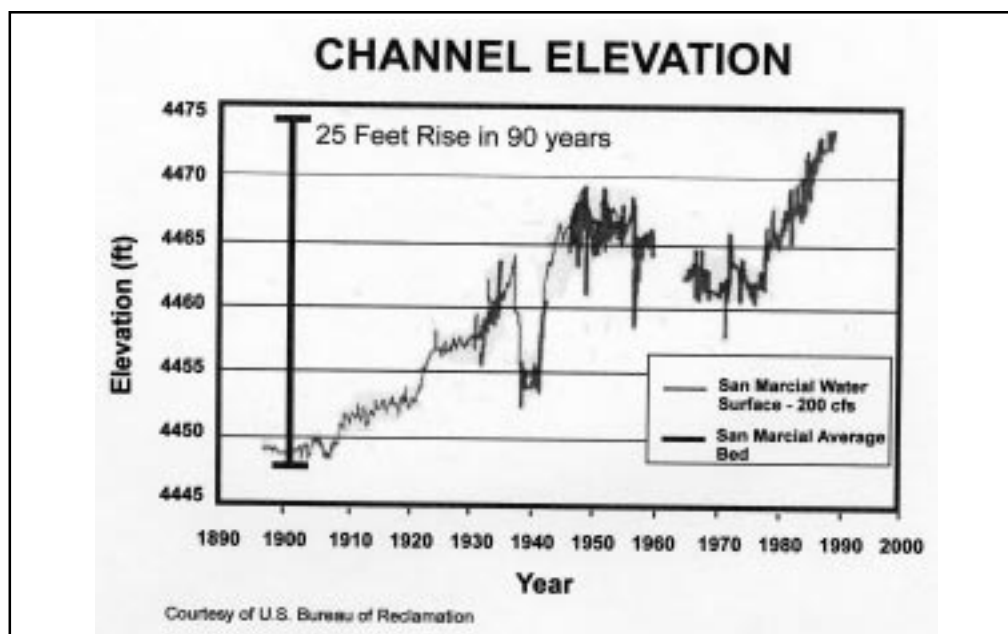
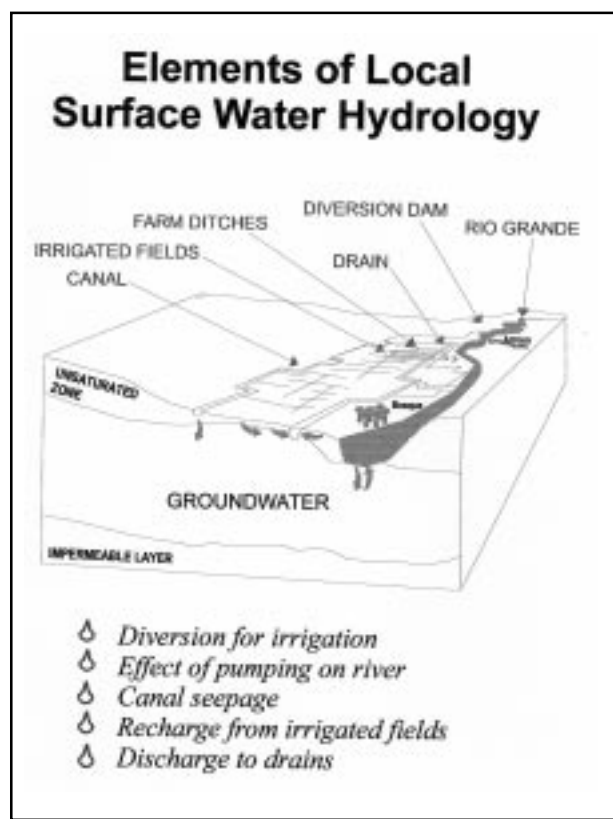


Figure 16. Change in San Marcial channel elevation over the past 100 years

Finally, I want to remind you all that most of my talk has been at the basin scale. But the hydrology of the real-world system has many localized components that can be critical in addressing specific issues (Figure 17). Most of the local effects reflect the diversion of water into canals and onto farms, or pumping effects by wells, along with the return of water through drains or wastewater effluent.

Much of our current research deals with studying the details of these more local relationships. Figure 18 is an example that comes from Bureau of Reclamation research. It shows how the tendency of the river to gain or lose water changes from one reach to another, and also over time.



Surface Water Hydrology of the Rio Grande Basin

Figure 17. Elements of local surface water hydrology

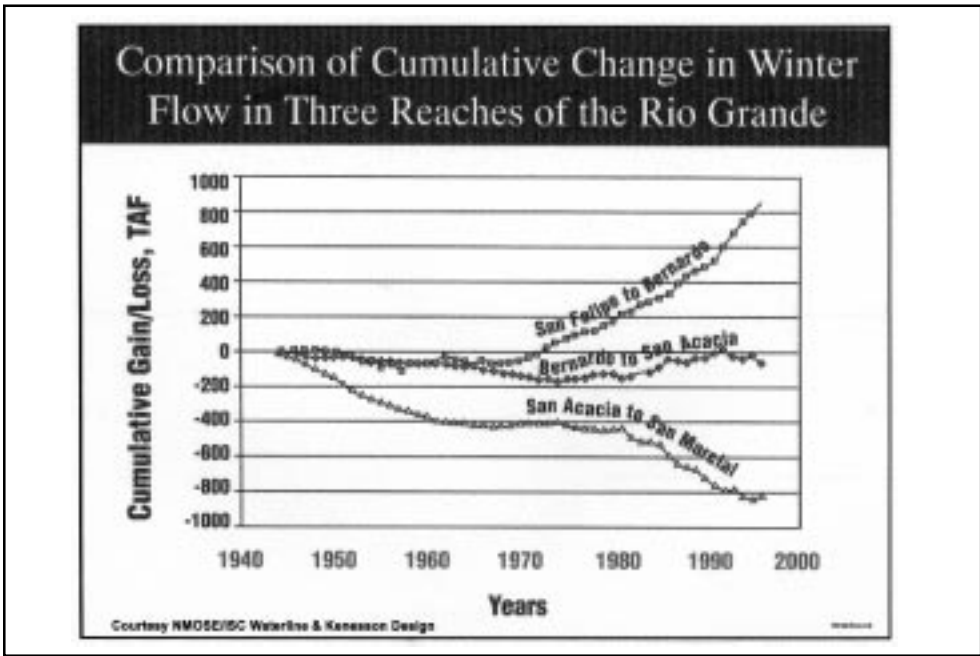


Figure 18. Comparison of cumulative change in winter flow in three reaches of the Rio Grande

It is worth remembering that water quantity isn't the only issue. Media coverage to the contrary, I don't view the Rio Grande as a "toxic sewer." One significant man-made problem is salinity build-up, mostly from irrigation return flow (Figure 19). The result is marginal quality water in the El Paso/Juarez area, especially in winter when the supply is not potable. This is a major consideration in the interstate negotiations over providing water to El Paso.

Finally, I'll close with a short list of what seems to be the biggest of the many, many issues that relate to surface water in the Rio Grande basin. Everyone here knows about these, so this is just a reminder:

- the possible need to provide instream flows for the Rio Grande silvery minnow;

- growing water demands in Albuquerque, Las Cruces, El Paso and Juarez, all of which are likely to be met in large part by surface water,
- Indian claims, which could easily account for 50% of the basin supply,
- and an expectation for all of these reasons—we could see a future in which the operations of reservoirs and water projects are quite different from today.

If changes in operations don't solve the problem, we look to the Compact. The Compact is always taken as a fact of life. This may not be so in the future, given all the pressures on the supply.

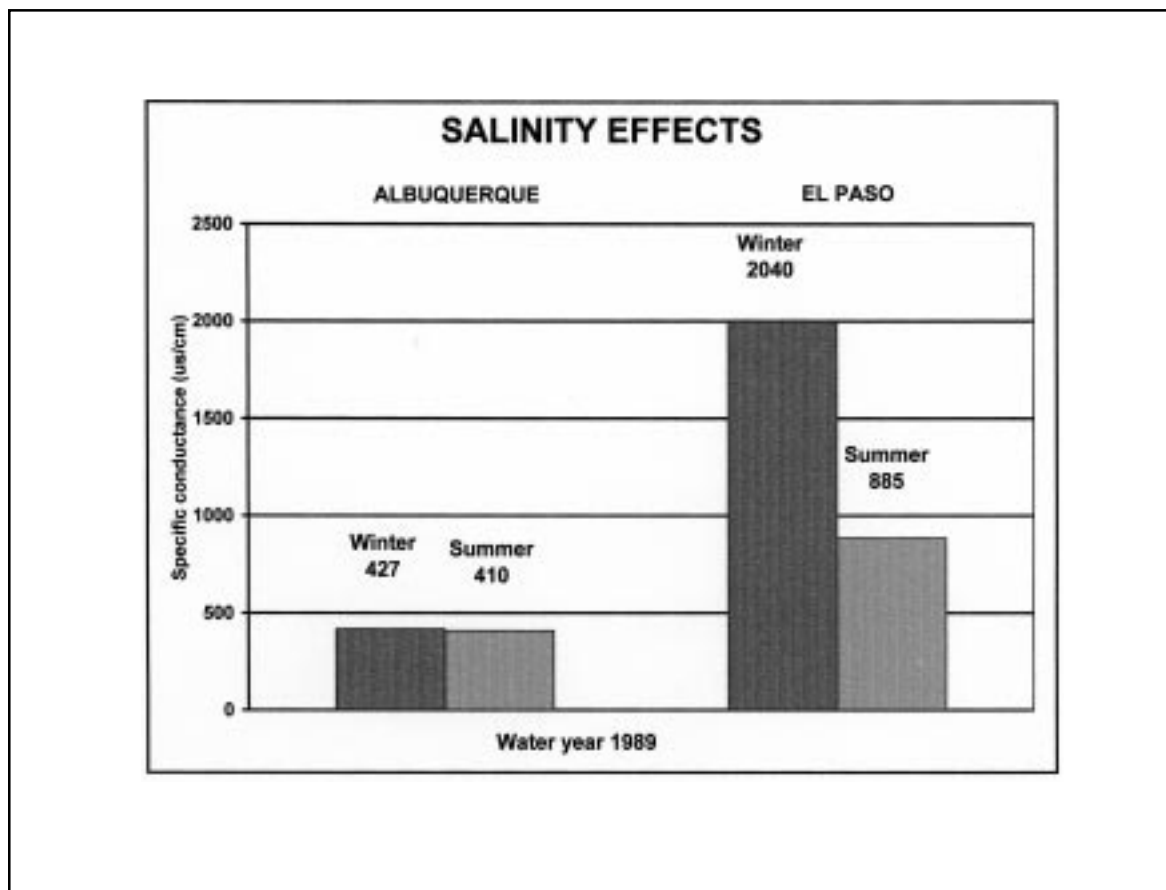


Figure 19. Salinity effect for Albuquerque and El Paso in 1989