Integrated Groundwater and Surface-Water Modeling of the Pecos River Basin, New Mexico: Tools and Techniques

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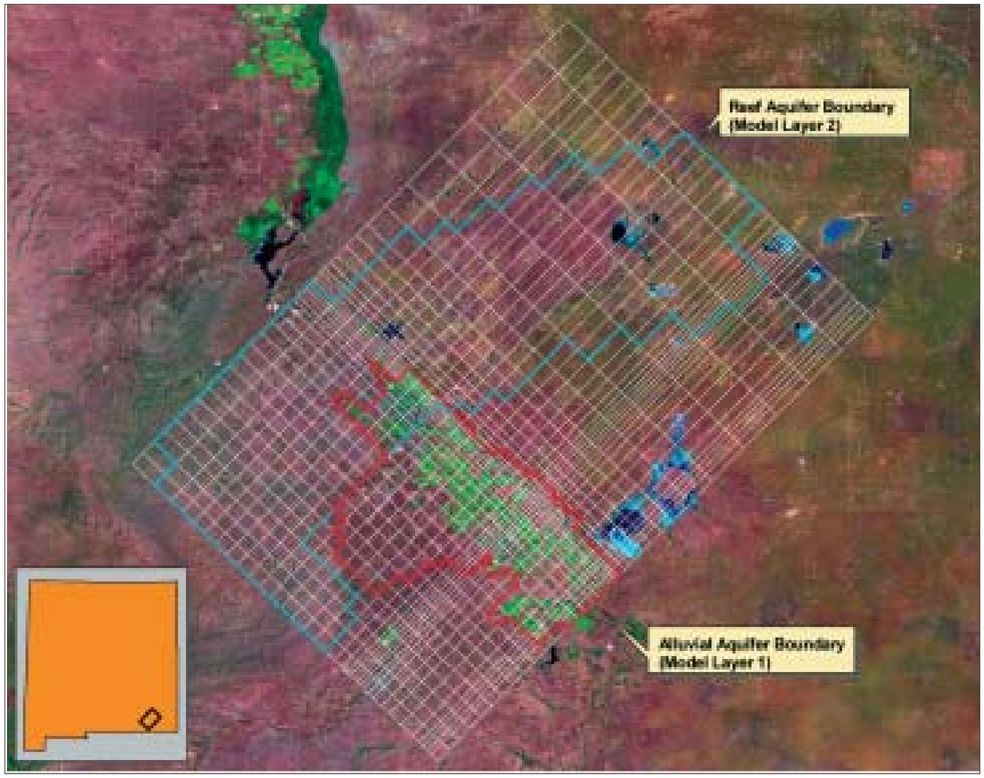
The State of New Mexico has been working with consultants and the U.S. Bureau of Reclamation to develop a Decision Support System (DSS) to evaluate management options for Pecos River water operations. Pecos River water must supply many competing needs including New Mexico irrigation, the Endangered Species Act, and New Mexico's interstate compact obligations to Texas.

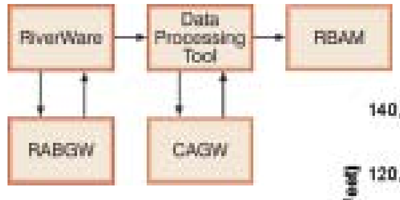
Technical evaluation of Pecos River management options is complicated by the interrelation between surface water and groundwater use. Groundwater pumping in the Roswell Basin intercepts base inflow to



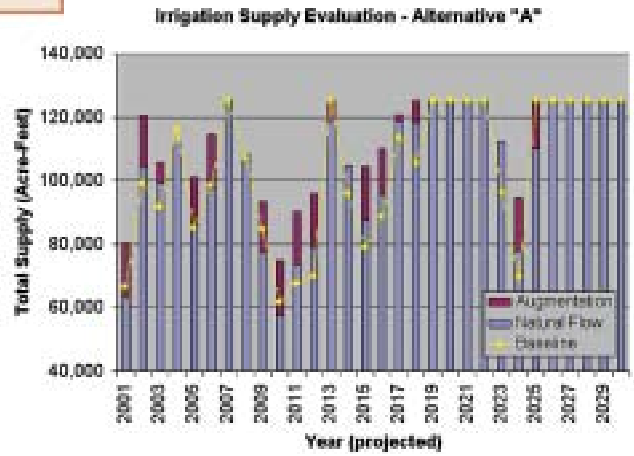
Location and model grid for Carlsbad Area Groundwater Model the Pecos River. Carlsbad area groundwater pumping supplements surface water irrigation supplies, and significantly impacts return flows to the river. These return flows form a major component of flows reaching the state line and are critical to New Mexico's compliance with the Pecos River Compact. To simulate these and other processes, a suite of models was developed that simulate surface water and groundwater hydrology from Santa Rosa Dam to the Texas border:

- RiverWare surface water model
- Carlsbad Area Groundwater Model (CAGW)
- Roswell Artesian Basin Groundwater Model (RABGW)
- Red Bluff Accounting Model (RBAM)
- Data Processing Tool (DPT)

The RiverWare model simulates daily Pecos River hydrology and reservoir operations from Santa Rosa to Avalon Dam, the primary diversion point for the Carlsbad Irrigation District. The RiverWare model provides a rule-based approach that allows for simulation of



operational policy of reservoirs and evaluation of different management alternatives. The effects of changes in groundwater use in the adjacent Roswell Basin can be calculated using the RABGW, and input into the RiverWare model as changes in base inflow.



Projected surface water supply for irrigation under a management alternative that includes augmentaion pumping and land retirement. Surface water supply under baseline (no action) scenario is also shown for comparison.

The interaction of groundwater and surface water in the Carlsbad area is represented by CAGW, which simulates groundwater heads and flow in the Capitan Reef and overlying alluvial aquifer in the Pecos River Basin from Lake Avalon to the Malaga Bend. CAGW incorporates surface water diversions generated by RiverWare with groundwater diversions, and irrigation return flows to predict base inflows to the Pecos River. The base inflow output from CAGW and the surface water releases from RiverWare are combined with reach-specific data and are run through a spreadsheet-based routing model, RBAM, which calculates the monthly flows at the New Mexico-Texas state line. Input and output from CAGW, RiverWare and RBAM are managed by a custom interface called the DPT, which has been developed using Visual Basic for Excel. The DPT manipulates, formats and archives input and output data, allowing the user to save and track multiple scenarios for future reference.

The DSS is operational, and is being used to evaluate water resource management schemes related to the needs of Pecos River endangered species, settlement of Water Rights Adjudication issues, and New Mexico's compliance with the Pecos River Compact.

This approach to building a DSS is flexible enough that it could be applied to other areas – assuming that an area-specific groundwater and surface water model had been developed – and is readily expandable to incorporate other modeling tools as needed.

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Groundwater on the Plateau

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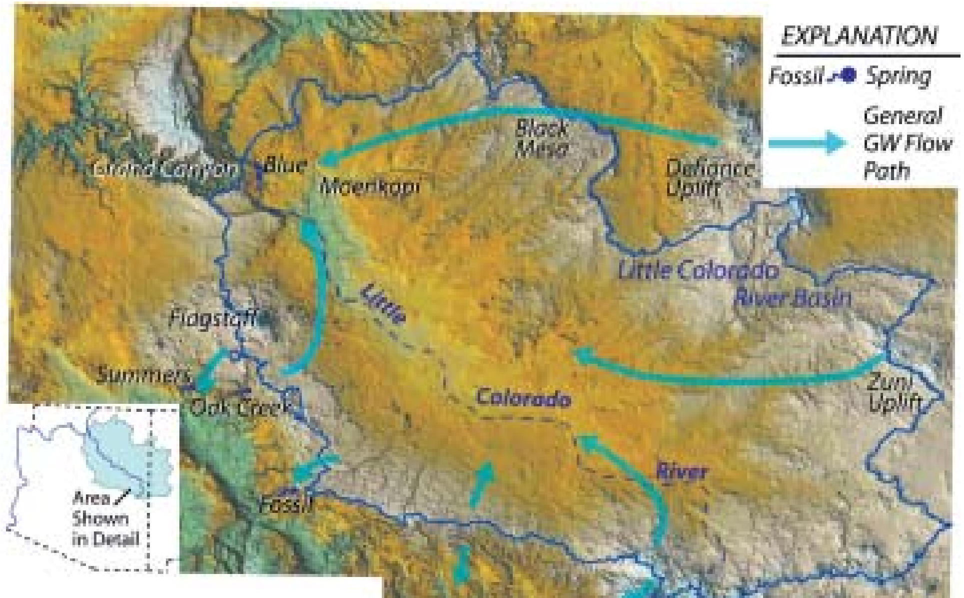
The C Aquifer underlies more than 27,000 square miles of the Little Colorado River (LCR) Basin in northeastern Arizona and northwestern New Mexico. The aquifer is estimated to store between 400 million and 1 billion acre-feet of water. The cities of Flagstaff, Winslow, Holbrook; many smaller communities; industry; and agriculture depend on the reliability and quality of water in this huge aquifer. With groundwater pumping exceeding 140,000 acre feet per year and growing 3 to 4 percent annually, the C aquifer is the most important and most depended-on resource in the LCR Basin.

Not surprisingly, the C aquifer is also a critical component of Arizona's attempt to adjudicate water rights in the Basin, now well into its third decade of debate. To help resolve some of the adjudication issues, a group of interested parties, including Indian tribes, the federal government, and the private sector, collaborated to make available much of the hydrologic data on the C aquifer. The U.S. Geological Survey and Hydro Geo Chem summarized the results in a new report describing the regional hydrogeology and water budget of this groundwater resource.



Study area location

The C Aquifer system (named for the prominent water-bearing rock, the Coconino Sandstone) also includes the Permian Kaibab Limestone, the De Chelly and Glorieta Sandstones, and the upper portions of the Supai Group. The rocks outcrop along the southern basin boundaries and along the Defiance and Zuni Uplifts, and form a bowl shaped structural depression beneath Black Mesa, where they are buried under as much as 6,000 feet of younger rocks. Structural divides along the Zuni and Defiance Uplifts create a westerly flow direction, while groundwater mounding along the Mogollon Rim creates flow both to the north and south, towards the Verde River. West of Flagstaff and north to the Grand Canyon the aquifer thins to extinction because of drainage into the underlying Redwall-Muav Limestone aquifer. The aquifer extends beyond the LCR northward into Utah's Blanding Basin and southeasterly into west-central New Mexico.

Water Budget

In contrast to basin and range alluvial aquifers, specific and limited C Aquifer discharge points can be measured. That is, the C Aquifer is a remarkably well-defined system in most areas. Even so, the water budget, based on a summation of all known discharges, should be considered a minimum value of aquifer flow. The C aquifer is recharged along its southern flanks from Flagstaff to the White Mountains, and along the Zuni and Defiance Uplifts. Groundwater diverges from these recharge areas, and most flows westerly to discharge points along the LCR and within the Grand Canyon. Annually, about 20,000 to 30,000 acre-feet discharges to the upper LCR or its tributaries between St. Johns and Winslow, but the single largest point of discharge, more than 160,000 acre-feet, is to Blue Springs, in the LCR gorge a few miles from its confluence with the Colorado River.

See Plateau, page 35

The Vidler Recharge Facility: Monitoring Results and Future Plans

Part 3 of 3

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Vidler Recharge Facility (VRF), in the Harquahala Valley 90 miles west of the Phoenix metropolitan area, was designed and permitted to store 100,000 acre-feet of water annually for 20 years. In 1998, the pilot facility operated for three months, recharging a total of 483 acre-feet of water. The pilot facility was discussed in the May/June 2002 issue of *Southwest Hydrology*. In 2000, operation of the full-scale facility began; the design of that facility was discussed in the July/August 2002 issue of *Southwest Hydrology*. During both pilot- and full-scale operation, a variety of techniques have been used to monitor recharge and changes in soil moisture at and adjacent to the facility.

Pilot-Scale Monitoring

Changes in vadose zone moisture conditions resulting from pilot-scale operation were monitored in three neutron logging wells. These wells were located north and south of the pilot-scale VRF and between the two pilot recharge basins. Data were collected with a combination gamma ray neutron probe. During the pilot-scale operations, only well NL-2, located between the basins, showed a significant change in soil moisture content. Increases in soil moisture content were observed from approximately 5 feet below land surface (bls) to about 90 feet bls and from 255 to 280 feet bls.

Two surface resistivity arrays were also used to monitor the effects of the pilot-scale operation. The results of the survey indicated that resistivity changed almost immediately with the initiation of recharge, and reflected an increase in soil moisture content at similar depths as those observed by the neutron logging in well NL-2. In addition, the resistivity data showed that the two vadose zone recharge wells that were located in Basin B had a significant impact on the soil moisture content at 200 feet bls, with a smaller increase observed at 320 feet bls.

Although the vadose zone monitoring indicated that water was being recharged during the pilot-scale facility operations, groundwater monitor wells indicated that the water had not yet reached the aquifer, approximately 440 feet bls.

Full-Scale Monitoring

The resistivity surveys and wells NL-1 and NL-2 were abandoned due to well problems and construction of the full-scale facility; only well NL-3 was retained as a vadose zone monitoring point, and data continued to be collected from that well. In the chart on p. 35, an increase in soil moisture content is indicated by a shift downward, towards fewer API units. This downward shift is exemplified by the March 19, 2001 data, showing an increase in soil moisture from land surface to approximately 70 feet bls and from 200 to

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