How Science Can Provide Pathways to Solutions—The Technical Toolbox

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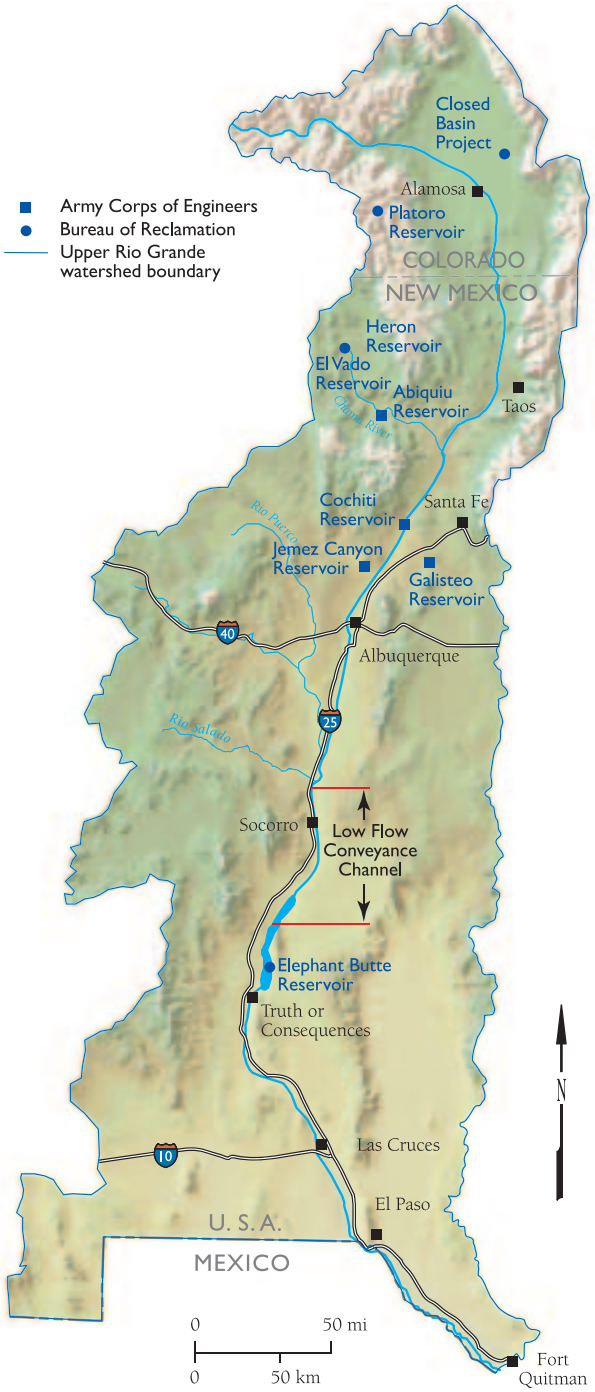
Policy makers and decision makers often rely upon scientists to provide answers to some of the most pressing problems they face. Scientists have a number of tools at their disposal to do this, including the whole array of technical tools we call "models." Models are generally complex computer programs that deal with real data in an effort to simulate the behavior of natural systems, taking into account an array of variables, from basic physical data—the length and shape of a stream bed, for instance—to complex and often unpredictable variables like rainfall, climate, and future water use. All of this is done in an effort to predict and gage the hypothetical effects of various scenarios so we can understand the impacts of the decisions we make, and chart a course for a future we wish to see.

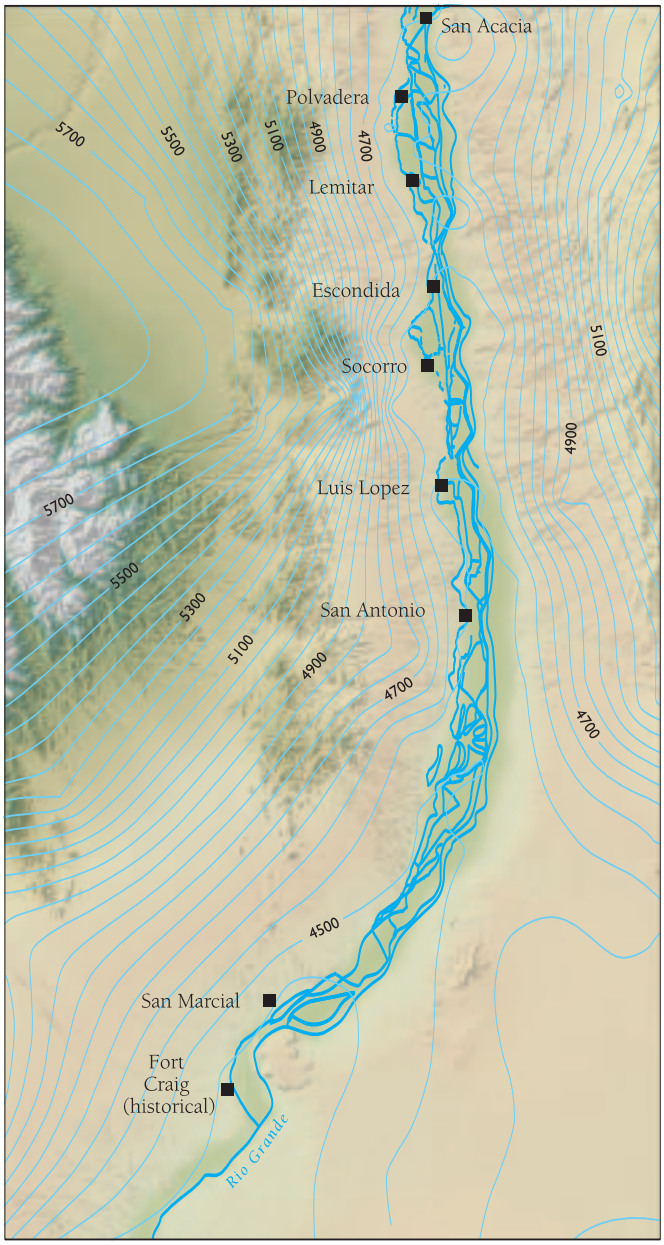
To address water supply issues in the San Acacia reach, hydrologists and water resource planners use regional models that address the broader Upper Rio Grande watershed in combination with models that look specifically at hydrology in the San Acacia reach. These dynamic modeling tools help us understand the workings of the natural hydrologic system, the riparian ecosystem, and the human impacts on water supply in this region. Understanding these complex relationships, and trying to predict how they will interact in the future, is the objective of modeling. This paper offers a look at some of the more significant efforts at developing and using hydrologic models and other technical tools applicable to the San Acacia reach.

HYDROLOGIC MODELING—THE UPPER RIO GRANDE WATER OPERATIONS MODEL

The basic tool for water supply planning in the Middle Rio Grande is the Upper Rio Grande Water Operations Model, or URGWOM. This is a multi-agency water operations model designed to help manage the accounting and operational decision making of many agencies. It is currently used on the Rio Grande throughout New Mexico to simulate water storage and delivery operations, to model flood control operations, and to provide a basis for long-range planning from thousands of pieces of information on water use, climate, evaporative losses at reservoirs, seepage to



Map of the Upper Rio Grande Basin, the area where water operations can be simulated in the Upper Rio Grande Water Operations Model (URGWOM).



Map of simulated water table, using linked surface water and ground water model for Socorro and San Marcial Basins between San Acacia and Elephant Butte Reservoir. To understand the general water movement in the shallow aquifer, monitoring wells in the study area were used to develop a water table map. In general, ground water moves from east to west to the center of the basin, where it discharges to the surface water. The water table map also indicates a strong north-south hydraulic gradient.

ground water, snowmelt runoff, and other hydrologic variables. It provided forty years of flow and storage projections for the Upper Rio Grande Water Operations Review and Draft Environmental Impact Statement, which evaluated alternatives for future water management.

URGWOM was developed by the U.S. Army Corps of Engineers and U.S. Bureau of Reclamation, with significant participation by the U.S. Geological Survey and the state of New Mexico. It continues to be refined and improved, and our ability to use it for planning purposes in conjunction with other modeling tools is expanding. To model actions involving changes in how federal agencies operate the reservoirs on the Rio Grande and requiring changes in legislative authority, we would have to revise our current model. The Interstate Stream Commission is leading work by the URGWOM tech team that will allow the model to simulate the interaction between the shallow and the deep water aquifers. This revision will allow the model to depict more accurately how water is routed between Cochiti and Elephant Butte.

THE MIDDLE RIO GRAND WATER SUPPLY STUDY

The Middle Rio Grande Water Supply Study, Phase 3, conducted by S.S. Papadopulos & Associates in 2004, evaluated the regional water supply. The conjunctive ground water–surface water supply available to the Middle Rio Grande region, under the constraints of the Rio Grande Compact, is characterized under a range of conditions. The study evaluates the probability of compliance with the Rio Grande Compact, assuming projected demand through year 2040. The study relied on demand projections as developed in the Jemez y Sangre, Middle Rio Grande, and Socorro–Sierra regional water plans, and assumes implementation of management actions suggested by the plans. The study concluded that the Middle Rio Grande region would likely have a severe water deficit in 2040 without implementing the water plans, and that even with full implementation (a highly optimistic future scenario) there would remain a projected deficit.

SAN ACACIA SURFACE WATER/GROUND WATER MODEL

The San Acacia Surface Water/Ground Water Model was created to improve our understanding of the complex interactions between the surface and subsurface hydrologic systems in the Socorro and San Marcial basins. Developed by the Interstate Stream Commission, the model simulates the Rio Grande channel, the Low Flow Conveyance Channel (LFCC), the main irrigation canals and drains, and the alluvial and Santa Fe Group aquifers in the reach from San

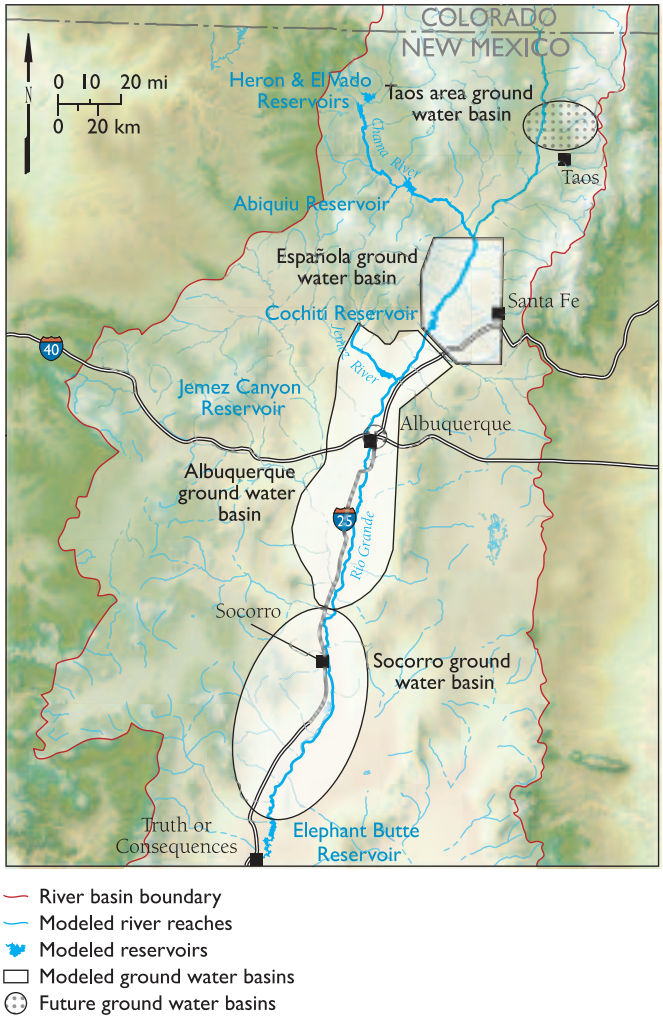
Acacia to Elephant Butte. The purpose of the model is to evaluate potential system-wide depletions that may result from various actions, including operation of the LFCC, implementation of habitat restoration projects, and modifications (both natural and man-made) of the river channel. A recent update uses a high-resolution telescopic model that focuses on the riparian area from the river west to the LFCC to predict the effects of habitat restoration between Highway 380 and San Acacia on water supply.

COOPERATIVE MODELING IN THE MIDDLE RIO GRANDE

In the late 1990s regional water-planning efforts in the Middle Rio Grande were initiated by the Middle Rio Grande Water Assembly and the Mid Region Council of Governments. Sandia National Laboratories was contracted to develop a decision support tool to conceptualize how water is used in the region, to understand the complexities of the system, and to recognize tradeoffs and consequences with different conservation approaches. Although the planning was done above the San Acacia reach, the model looks at flows into Elephant Butte for the purposes of meeting the obligations of the Rio Grande Compact with Texas. The model represents complex interactions and feedback between physical and social systems. Sandia National Lab included components such as surface water, ground water, population, and demands from urban use, agriculture, evaporation, and environmental uses.

The model was created in a collaborative fashion, with members of the planning groups giving input to the modeling team. The Utton Center at the University of New Mexico provided facilitation to the model development team, acting as an impartial party to manage the meetings and foster communication. Because of the number and variety of participants, facilitation was needed to organize input and bring closure to the discussion of issues. The simulation results gave the planning group a preferred scenario that was used as the platform for finishing the regional water plan. Local governments in the region, including the cities of Albuquerque, Rio Rancho, and other municipalities, adopted the plan as the "guidance document" for their own planning efforts. Implementation of the plan, as with the Socorro–Sierra and the other regional plans mandated by the state of New Mexico, will require significant action on the part of many entities in the region.

Building on the success of the Middle Rio Grande



Integrated Hydrologic Modeling, an interactive planning tool for the Upper Rio Grande.

Water Assembly collaboration, Sandia National Laboratory is currently working with the URGWOM team to develop a complementary system dynamics model, based on the original Middle Rio Grande planning model. Integration of both models will improve management of water resources in the Rio Grande basin because of the ability to model the interaction between surface and ground water. Decision makers can use the model to understand the impacts of reservoir operations on the river and ground water systems.

In the San Acacia reach, there are many different modeling efforts underway that ultimately will be included in a unified water operations model for the Rio Grande. Watershed models are being developed by New Mexico Tech; the Rio Salado will be the first. A mortality model for the Rio Grande silvery minnow was built to try and understand how water quality affects

What Is Modeling?

In general terms, a model is a simplified representation of a complex real system. Because it is very expensive and time consuming to test the effects of management changes on a real hydrologic system, we take a shortcut and develop a model of each aspect of the system that we need to understand. Each model must be complex enough to include all the phenomena and structures that are important to us, but not so complex as to be mathematically insolvable.

The structure of a model is developed using basic information about the system we are simulating—for example, the length and width of the streambed for surface water models, and the nature of the rocks that make up the aquifer system for ground water models. The system is divided up into grid cells or nodes, each of which represents a small chunk of the system.

Input to a ground water or surface water model includes the inflow of water (aquifer recharge in the case of a ground water model, and flow from upstream and from tributaries to a surface water model), as well as diversion of water from the system. A model uses basic equations that govern the flow and conservation of water (like Darcy's Law) to keep track of this water and move it along at the proper velocity, from cell to cell or node to node, and determine its fate.

A ground water model calculates what the water levels in the aquifers will be, and how much ground water will discharge into adjacent streams A surface water model calculates how much river water makes it downstream, how fast it gets there, and in the case of complex, rule-based models, how much is diverted from reservoirs for irrigation, how much is released from the reservoir into the stream bed, and how much remains in reservoir storage.

—Excerpted from an article by Peggy Barroll et al. on hydraulic modeling, which appeared in our 2003 Decision-Makers Field Guide, *Water Resources of the Lower Pecos Region, New Mexico*.

silvery minnow populations. In addition, data from the Interstate Stream Commission's San Acacia Surface Water/Ground Water Model will also be included. Because actions taken upstream affect water flows in the San Acacia reach, integrating water operations with Sandia's model will provide decision makers with a comprehensive set of tools that can help decipher the relationships between physical and social systems on the river between San Acacia and Caballo Reservoir.

SOCORRO–SIERRA REGIONAL WATER PLAN

The Socorro Soil and Water Conservation District (SWCD) is a government subdivision of the State of New Mexico very active at helping to direct funding and education from a variety of sources to those at the local level within the San Acacia reach. The SWCD was designated as the fiscal agent for writing the Socorro–Sierra Regional Water Plan. (The San Acacia reach lies within this planning region.) The Interstate Stream Commission accepted the regional plan in 2004 as the guiding document for planning efforts in Socorro and Sierra Counties. Prepared by Daniel B. Stephens & Associates, in cooperation with a wide variety of professionals and interested citizens, the plan contains a wealth of information on the region's projected demand for water, assesses ground water and surface water supplies, and evaluates alternative future scenarios for balancing supply and demand. There is still much work to be done to implement the three regional plans between Otowi and Elephant Butte and to reconcile their recommendations. There are conflicts among them, particularly concerning the transfer of water rights from agriculture to urban uses.

EVAPOTRANSPIRATION MODELING

Evapotranspiration is one of the most significant depletions on the river; therefore, tools to model evapotranspiration are critical. The ET Toolbox, a modeling tool developed by the U.S. Bureau of Reclamation, is the evapotranspiration model for the Middle Rio Grande. The primary purpose of the ET Toolbox is to estimate daily rainfall and water depletions (both agricultural and riparian) and open water evaporation within specific reaches. For operational and management purposes, the ET Toolbox provides products by river reach and by Middle Rio Grande Conservancy District (MRGCD) division to show various consumptive use requirements. These daily values can be used by URGWOM.

A high density evapotranspiration network, with real-time state-of-the-art instrumentation and modeling integrated with real-time remote imagery, is being developed as a collaborative project between the University of New Mexico, New Mexico State University, and New Mexico Tech in a project known as EPSCoR. The hydrology component of EPSCoR will result in coupling and extending models for climate and hydrologic predictions and increasing the connectivity between ground-based and satellite-based data. The main objective is to extend and integrate a net-

work of telemetered instruments that provide ground-based measurements of evapotranspiration in different ecosystems (riparian, upland, and agricultural). The primary product will be high frequency, high resolution evapotranspiration maps for the Rio Grande watershed between Cochiti Reservoir and the Mesilla Valley. Data products will be prepared and distributed via the Internet in a form accessible to researchers, managers, and water users.

DECISION SUPPORT SYSTEM FOR THE SOCORRO DIVISION

The Middle Rio Grande Endangered Species Act Collaborative Program is a multi-agency group of stakeholders trying to address in a cooperative manner science, habitat, and water supply issues for endangered species. Together with the Interstate Stream Commission they funded development of an effective rotational water delivery system for the Belen Division of the MRGCD in FY 2003. In FY 2004 the decision support tool was extended to the Socorro Division. Through work accomplished by Colorado State University and S. S. Papadopulos & Associates, a scheduled, rotational water delivery system for irrigators was designed. This replaced the continuous, on-demand delivery of the past. The rotational delivery system has resulted in significant reductions in water diversion in the Belen and Socorro Divisions of the MRGCD. There is a need to improve the model and its data sets, including validation of assumed values of irrigation efficiency, soil moisture depletion, and the extent of conveyance losses in delivery channels. The assumptions need to be compared to field conditions, and the return flow functions need improvement.

The MRGCD has actively embraced the rotational delivery system. The new operational system, combined with other improvements such as new flow meters on all diversions and delivery canals, automated water control gates on diversion dams and canals, limited lining of canals, and other improvements to the water conveyance system, has allowed the MRGCD to reduce depletions by 47 percent since 1996. In spite of severe drought conditions that have drastically reduced upstream storage of water during this time period, MRGCD has been able to provide an adequate supply of water to farmers throughout the district. This has also helped the MRGCD and other water managers keep enough water in the Rio Grande to protect the endangered silvery minnow and southwestern willow flycatcher and thus avoid threatened legal impediments.

GEOGRAPHIC INFORMATION SYSTEM AND REMOTE SENSING DATA

Operating on the University of New Mexico campus in Albuquerque, the Earth Data Analysis Center (EDAC) houses an extensive repository of Geographic Information System (GIS) data for New Mexico. The data can be downloaded by anyone and viewed with either standard commercial software or open source software. The clearinghouse includes data on general boundaries, roads, cities, topography, climate, geology, soils, elevation, water resources, aerial photographs, remote sensing, and population.

Because these data cover the entire state of New Mexico, specific information regarding the San Acacia reach can be extracted. Besides the statewide coverage, there are some datasets that are specific to the San Acacia reach, such as detailed land use inventories, trends, and vegetation maps. These data are constantly updated and represent the best collection of publicly available GIS data that can be used by decision makers in the San Acacia reach.

In 2003 NASA funded a center at the University of New Mexico devoted to acquiring real-time remote sensing data. The Center for Rapid Environmental Assessment and Terrain Evaluation (CREATE) uses existing satellites and a new ground station to acquire and process data in a very short amount of time. In addition, the data are available at much higher resolution than other remote sensing products. These data can be used in decision support systems to help understand evapotranspiration rates, for snowpack analysis, fire condition, vegetation growth, and landscape changes. In the San Acacia reach, the CREATE group has been supporting the evapotranspiration work being conducted as part of the EPSCoR program.

ECOSYSTEM RESEARCH

Located in the San Acacia reach, the Sevilleta National Wildlife Refuge's Long Term Ecological Research Center (LTER) has been conducting research on how climate change can impact ecosystems. Sevilleta is unique in that many biotic zones intersect within the refuge; the area can thus provide sensitive indicators for environmental response to climate change. Recent research projects have looked at the impact of climate change on vegetation, the response of vegetation to prescribed burns and cattle grazing, and evaporation and transpiration in uplands and riparian areas near the Rio Grande.

Sevilleta houses a large "spatial database" for both

GIS and remote sensing data that have been collected as part of the research conducted at the LTER. Some of the data are from publicly available sites and clipped into the LTER boundaries. All of the research conducted at Sevilleta is within the San Acacia reach, although some projects have locations both inside and outside Sevilleta, such as the evapotranspiration research conducted by EPSCoR.

The San Acacia reach has many sophisticated tools and models available to provide guidance on our water future: water for future human use, water for agriculture, water to meet the terms of the Rio Grande Compact and a treaty with Mexico, and water for the ecosystem. Models and studies are continually being refined, updated, and improved as better data are obtained—but the basic tools are in place. The extreme variability of water supply on a year-to-year basis, and the inherent difficulty in predicting variability in the future, make "certainty" a challenging target.

Models and planning tools can provide information to help policy makers make the most informed decisions. The hardest work remains in the arena of public policy. Obtaining the legal mechanisms to administer water rights above San Acacia is essential to achieving long-term sustainability in the San Acacia reach. It is critical that the three regional plans in the areas that affect the water supply in the San Acacia reach be consistent in both recommendations and implementation. Allowing scientists to use the models and propose options to managers and policy makers without being unduly constrained by political issues is the best hope for arriving at sustainable solutions.

Suggested Reading

For a hands-on look at one hydrologic model, the Sandia National Laboratories Middle Rio Grande Cooperative Model (2005), go to http://nmh2o.sandia.gov/ExTrainSD/SDWelcome.asp

The Socorro Soil and Water Conservation District Regional Water Plan is available at http://www.socorroswcd.com Click on the link that says Regional Water Plan for information on projected water supply and demand in the region.

For more information about the basin and the San Acacia reach hydrology, visit the U.S. Army Corps of Engineers at http://www.spa.usace.army.mil/urgwom

For detailed information about the Middle Rio Grande water supply and demand issues, have a look at the S. S. Papadopulos & Associates' Middle Rio Grande Water Supply Study, Phase 3, available at http://www.ose.state.nm.us/isc_planning_mrgwss.html