COOPERATIVE MODELING:
COMMUNITY-BASED WATER RESOURCES MANAGEMENT FOR THE RIO GRANDE

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ABSTRACT

The watersheds in which we live are composed of a complex set of natural and social systems that interact over a range of spatial and temporal scales. These systems are continually evolving in response to changing climatic patterns, land use practices, and the increasing intervention of humans. Sustainable management of watersheds and their water resources benefits from the development and application of models that offer a comprehensive and integrated view of these complex systems and the demands placed upon them. The utility of these models is greatly enhanced if they are developed in a participatory process that incorporates the views and knowledge of decision-makers, resource managers, special interest groups, and the public. System dynamics provides a unique mathematical framework for integrating the natural and social processes important to watershed management and for providing an interactive interface for engaging the public. We have employed system dynamics modeling to assist in community-based water planning for a three-county region in north-central NM. The planning region is centered on the Middle Rio Grande (MRG) Basin and includes the greater Albuquerque metropolitan area. Model development included close collaboration between the Middle Rio Grande Water Assembly, the Mid-Region Council of Governments, the Utton Transboundary Resources Center at the UNM School of Law, numerous regional agencies and experts, and SNL. The challenge in the MRG Basin, which is common to other arid/semi-arid environments, is to balance a highly variable water supply among the demands posed by urban development, irrigated agriculture, river/reservoir evaporation, and riparian/in-stream uses. Both a description of the model and the planning process are given along with results and perspectives drawn from both.

The demand for water worldwide has more than tripled since 1950 and is projected to double again by 2035 (Postel, 1997). As many as 2.4 to 3.4 billion people may be living in water-scarce or water-stressed conditions by 2025 (Engelman et al., 2000), with the most susceptible populations living in arid environments. So far the growing demand has been met largely by improving and expanding storage capacity, and by mining fossil groundwater resources. However, both solutions have physical limits. Bringing future demand in line with available supplies will require increasingly efficient water management practices and greater conservation of water resources. The development of well-conceived, short-term, and long-term regional water management plans that include input from a broad array of stakeholders is one approach for working toward these goals.

Developing management plans that are both scientifically sound and publicly acceptable, however, is fraught with difficulty. Water management solutions are complicated by the interplay (including cause and effect relationships, feedback loops, and time delays) of hydrological, ecological, social, and economic systems. Further, the urgency of water resources management issues around the world is drawing stakeholders with diverse technical and non-technical backgrounds into the management process, adding another set of players at the planning table.

Models built to tease apart and quantify the dynamics and the interplay of complex systems have long been a tool for scientists and water managers, but their operation, application, and utility can be obscure to the general public. An open and participatory planning process can help build confidence and acceptance in such models (Louks et al., 1985). Several examples of models used in regional water planning exist (e.g., Ford, 1996; Simonovic and Fahmy, 1999; Stave, 2003). However, there are few instances in which models have been created and implemented with direct public involvement (Wallace et al., 1988; Palmer et al., 1993).

The Middle Rio Grande (MRG) Basin in north-central New Mexico (Figure 1) is a prime test bed for the development of a process and a tool that addresses the issues named above. Growing human population coupled with a current multi-year drought in this already semi-arid region have made water resources management a critical issue reaching across social, political, economic, and professional boundaries. The main regional challenge is balancing a limited supply of water, subject to wide seasonal and annual variation, with the disparate demands posed by urban development, riparian and in-stream uses, and irrigated agriculture.

In this paper we describe a project aimed at building and applying a community-based, water resources planning model for a three-county region along the Rio Grande. The model is developed within the framework of system dynamics (Sterman, 2000; Forrester, 1990) for the purposes of (1) quantitatively exploring alternative water management strategies in terms of costs and water savings; (2) educating the public on the complexity of the regional water system; and (3) engaging the public in the decision process. Specifically, the model provides a means of screening alternative water management strategies and gauging public/political acceptance of the measures, while other more sophisticated modeling will be required to fully evaluate and design the leading alternatives.

The planning process will evolve as new data and new understanding of the system are both developed and as consequences unfold from historic and current management decisions. The model, periodically updated to include new data and understanding, can be a focal point in the ongoing process of resource management.

Unique aspects of this work are (1) model development included the direct cooperation and involvement of the public; and (2) the model was subsequently used by the public along with local governments to develop a 50-year water plan for the region. The goal of the planning process was to balance regional consumption with projected supply in a publicly and politically acceptable manner. At the time of this writing, the model is fully engaged in the regional water planning process.

This project represents collaboration between the Middle Rio Grande Water Assembly (MRGWA), the Mid-Region Council of Governments (MRCOG), the Utton Transboundary Resources Center at the University of New Mexico School of Law, and Sandia National Laboratories (SNL). Regional experts from city, county, state, and federal water management agencies, and from private consulting firms, contributed to the model development. SNL provided funding for this project through its New Mexico Small Business Assistance Program (NMSBA), which in turn is funded via a tax credit program administered by the New Mexico State Legislature. The NMSBA helps provide small New Mexico businesses with various kinds of technical tools and applications offered by SNL, but which are not available through the commercial public sector.

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Cooperative modeling project objectives

- **Objective 1: Provide unbiased tool for quantitative consideration and comparison of water management alternatives and scenarios**
- **Objective 2: Provide tool for engaging policy makers, stakeholders and public in decision process**
- **Objective 3: Provide a tool to help educate the community about the interconnectedness and complexity of our regional water system**

Cooperative Modeling in the Middle Rio Grande Basin

- **Uses PC-based, dynamic simulation modeling to mine and interpret data**
- **Uses "system dynamics" to link hydrology, ecology, economics**
  - **Probabilistic projections**
  - **Time lags**
  - **Feedback loops**
- **Draws upon regional expertise across all fields in regular, ongoing "cooperative modeling" meetings**
  - **City, county, state & federal water managers**
  - **Lawyers**
  - **Economists**
  - **Agriculturalists**
  - **Hydrologists**
  - **Environmentalists**
- **Provides a tool for evaluating tradeoffs, evaluating alternative management strategies, and projecting consequences**
- **Informs policy makers and the public**

"Dynamic simulation modeling" and "system dynamics" refers to a modeling approach developed at MIT for application to business topics, such as the interactions between labor availability, inventories, production times, and so on. This approach assumes that complex systems are in fact made up of multiple interacting subsystems, all of which are dynamic, or change in time. The system dynamics approach has been increasingly used for modeling hydrological and ecological dynamics.

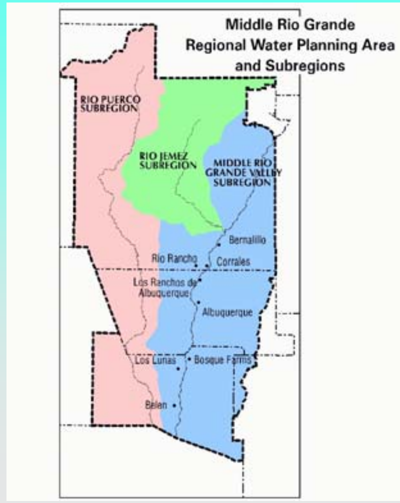
MRG cooperative modeling collaboration

- **MRGWA Cooperative Modeling Team**
- **Mid Region Council of Governments (MRCOG)**
- **Middle Rio Grande Conservancy District**
- **Interstate Stream Commission**
- **Office of the State Engineer**
- **U.S. Geological Survey**
- **S.S. Papadopulos & Associates**
- **U.S. Bureau of Reclamation**
- **U.S. Army Corps of Engineers**
- **City of Albuquerque Water Planning Dept., and Openspace**
- **CH2MHill Engineering**
- **City of Rio Rancho**
- **UNM Departments of Biology, Civil Engineering**
- **MRGWA constituency groups and working teams**

All of these organizations participated in different ways in the model development process. Some were closely involved and some were very loosely involved. SNL modelers and the MRGWA Cooperative Modeling Team met bi-weekly for over a year and then monthly for about another half a year to develop the model. Data for the model came from several of the organizations listed here, including the Middle Rio Grande Conservancy District, Office of the State Engineer, USGS, S.S. Papadopulos & Assoc., U.S. Bureau of Reclamation, Army Corps of Engineers, City of Albuquerque, City of Rio Rancho, and UNM. Many of these same organizations reviewed the model operation and output related to their data, and their area of expertise.

Middle Rio Grande Region Model

- Model boundaries extend from Otowi to Elephant Butte (i.e., MRG planning region)
- Model employs an annual time step
- Key model components:
  - Surface water budget
  - Groundwater budget
  - Rio Grande leakage
  - Ag, riparian and open water ET
  - Population growth
  - Municipal, industrial, environmental and Ag demand
  - Limited economics



Establishing the boundary conditions and key assumptions is critical for using any model. In this model the spatial boundaries of the model are defined by the three-county region including Bernalillo, Sandoval and Valencia Counties. However, some data from above and below the three-county region were required in order to meet regional planning needs. Almost all water planning strategy options are available for only the three-county region.

Spatial aggregation of the model over the three-county region means that all dynamics – such as surface water inflows, or agricultural evapoptranspiration, or urban consumption, are all summed. In other words, dynamics for the northeast side of Bernalillo county cannot be broken out from dynamics for the entire three-county region.

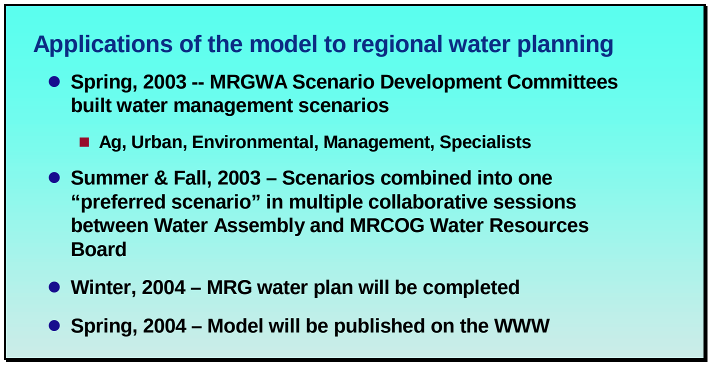
Similarly, the model is temporally agreggated at the scale of one year, meaning that spring or winter dynamics cannot be broken out from dynamics spanning the entire year.

Data and model structure

- Data are drawn from:
  - U.S. Geological Survey
  - U.S. Bureau of Reclamation
  - Cities of Albuquerque and Rio Rancho
- Model is calibrated to:
  - USGS Modflow groundwater model
  - Bureau of Reclamation ET Toolbox
- Structure is derived from work with regional experts

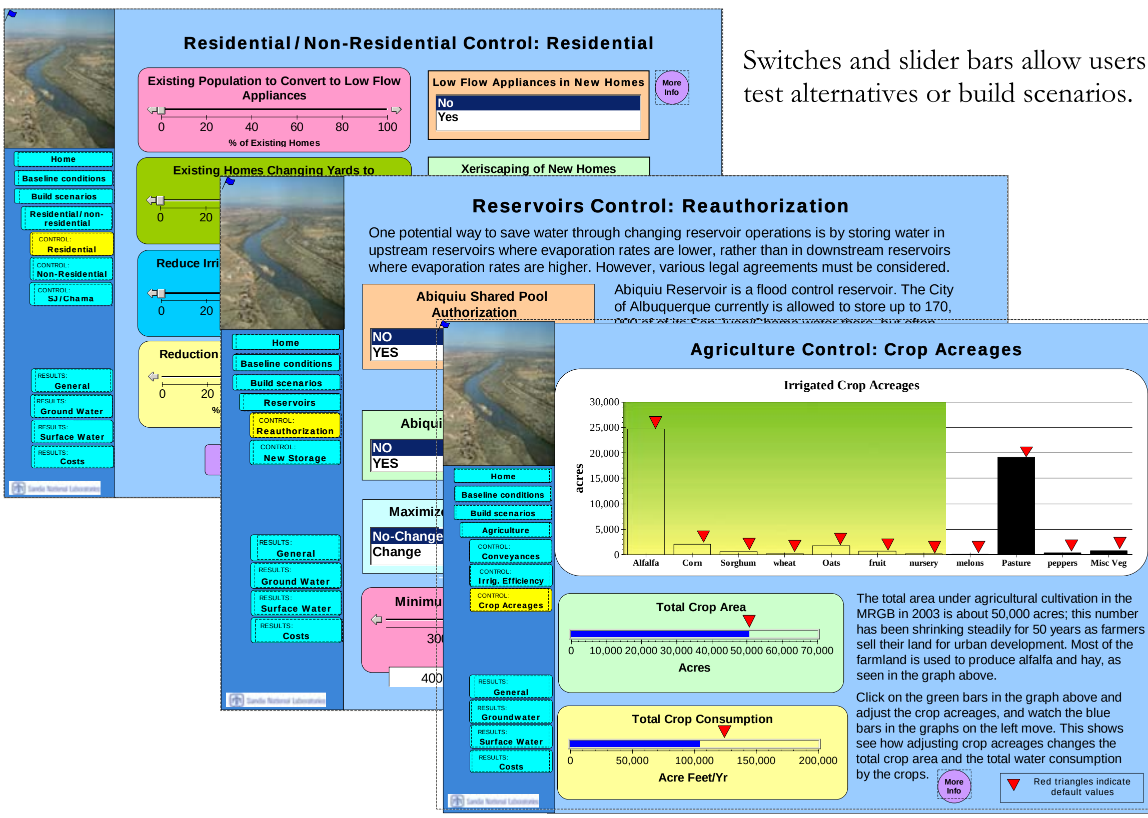
All data in the model came from the public record. No data used in the model were generated by SNL.

Calibration of the model was done as follows: Model results for the historic period 1950-1998 were compared to actual data from the same historic period. Variation or "error" identified weaknesses in the model, and were reduced by making modifications. These modifications sometimes involved finding new data or modifying model structure. Currently the model matches historic data within an error range of approximately 10 percent.



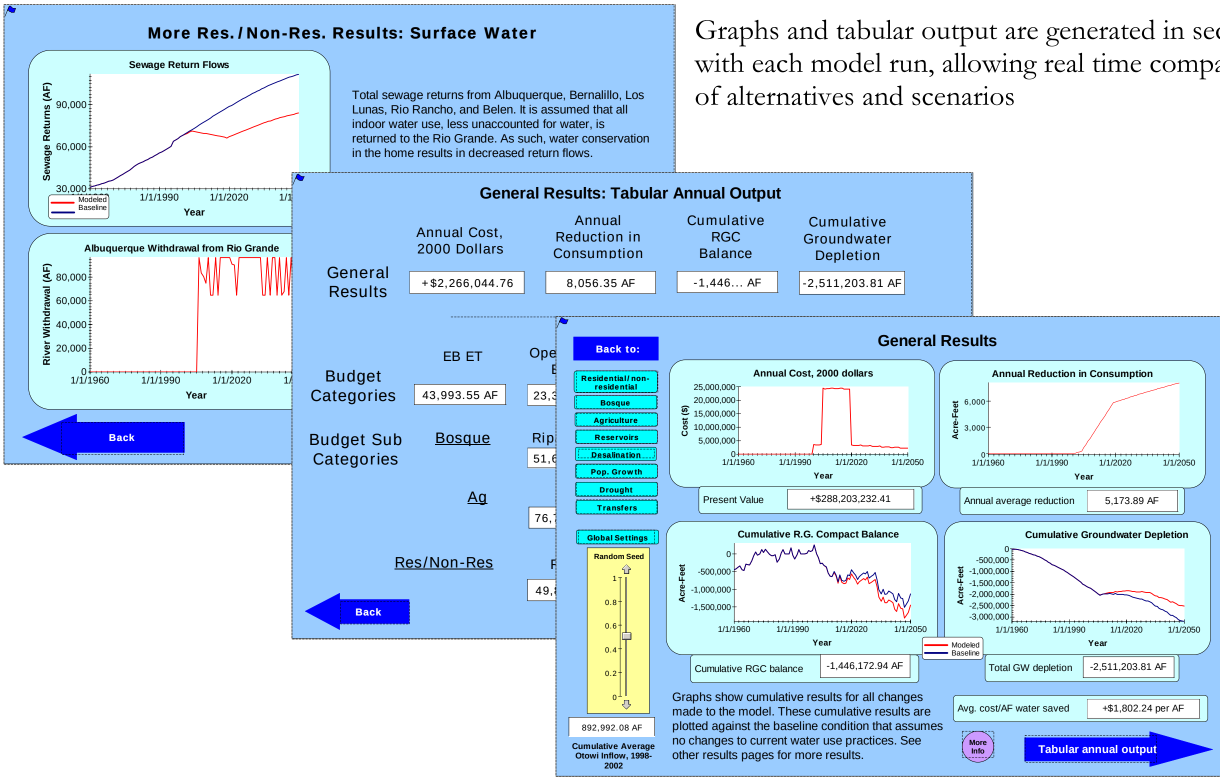
The model contains 66 slider bars or buttons that affect about a dozen sets of water management alternatives, ranging from urban and agricultural conservation, reservoir operations, and changes to human population. A water management “scenario” is comprised of a whole set of slider bar and button settings representing changes across many different kinds of alternatives. In 2003 the Water Assembly and the MRCOG used the model to develop their single “preferred scenario,” or the scenario which they felt best met the future needs of the community.

Examples of model interface “control” pages



Switches and slider bars allow users to test alternatives or build scenarios.

Examples of model interface “output” pages



Graphs and tabular output are generated in seconds with each model run, allowing real time comparison of alternatives and scenarios

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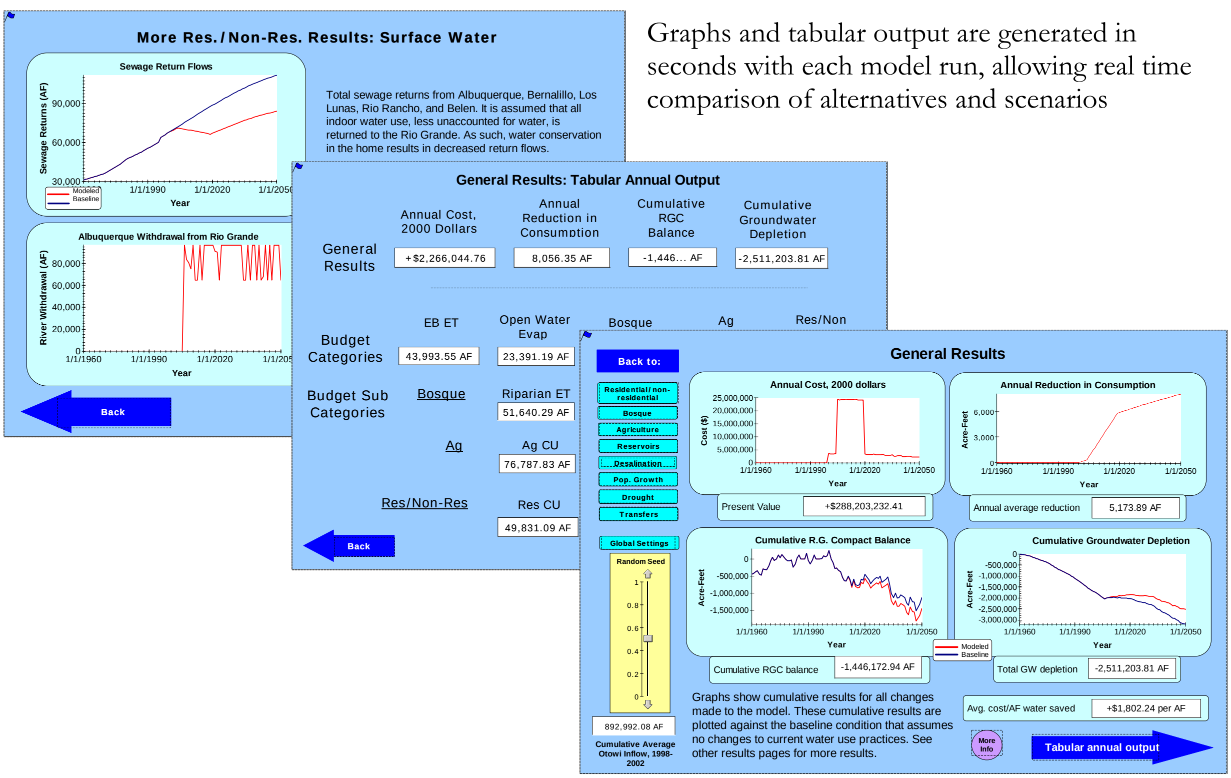

Graphs and tabular output are generated in seconds with each model run, allowing real time comparison of alternatives and scenarios