# COLLABORATIVE: RIVER INTERACTION & OBSERVATION (RIO) LABORATORY NETWORK -A LABORATORY NETWORK TO INVESTIGATE THE RIO GRANDE

Bruce M. Thomson and Julie Coonrod
Department of Civil Engineering
University of New Mexico

Enrique Vivoni
Department of Hydrology
New Mexico Tech

## INTRODUCTION

Management of natural resources in arid environments represents a major challenge because of the vulnerability of natural systems to very small changes in the environment. Management strategies are usually based on the quantity and quality of air and water resources, but must also consider other impacts including ecology, economy, social and political issues; all of the considerations normally incorporated in an environmental impact statement. The impacts most often are the result of increasing population in the region, but there is also increasing recognition they may also be caused by changes in regional or global climates.

The Upper Rio Grande Basin is an excellent example of an environmental system that is experiencing the conflicts of increasing demands for water, rapidly changing cultural and economic conditions, the presence of threatened and endangered species, and scarce water resources. This basin, which extends from Colorado to west Texas and Chihuahua, MX (Figure 1), is connected by the thread of the Rio Grande. The basin encompasses major variations in local climates. For example, four major biomes (Chihuahua Desert, Conifer Woodland, Great Basin, and Great Plains) are represented and converge at the Sevilleta LTER site, an attribute of great value for environmental research.

Another feature that is unique in the basin is the large concentration of education, research and natural resources management agencies and activities (Table 1). These include four research universities, two national laboratories, and major offices of five federal resource management agencies. In addition, state and local interests are represented. An unusual group of stakeholders are Native Americans, represented by 21 tribes or pueblos. Their presence adds complexity because they have sovereignty or state status for many federal environmental protection programs.

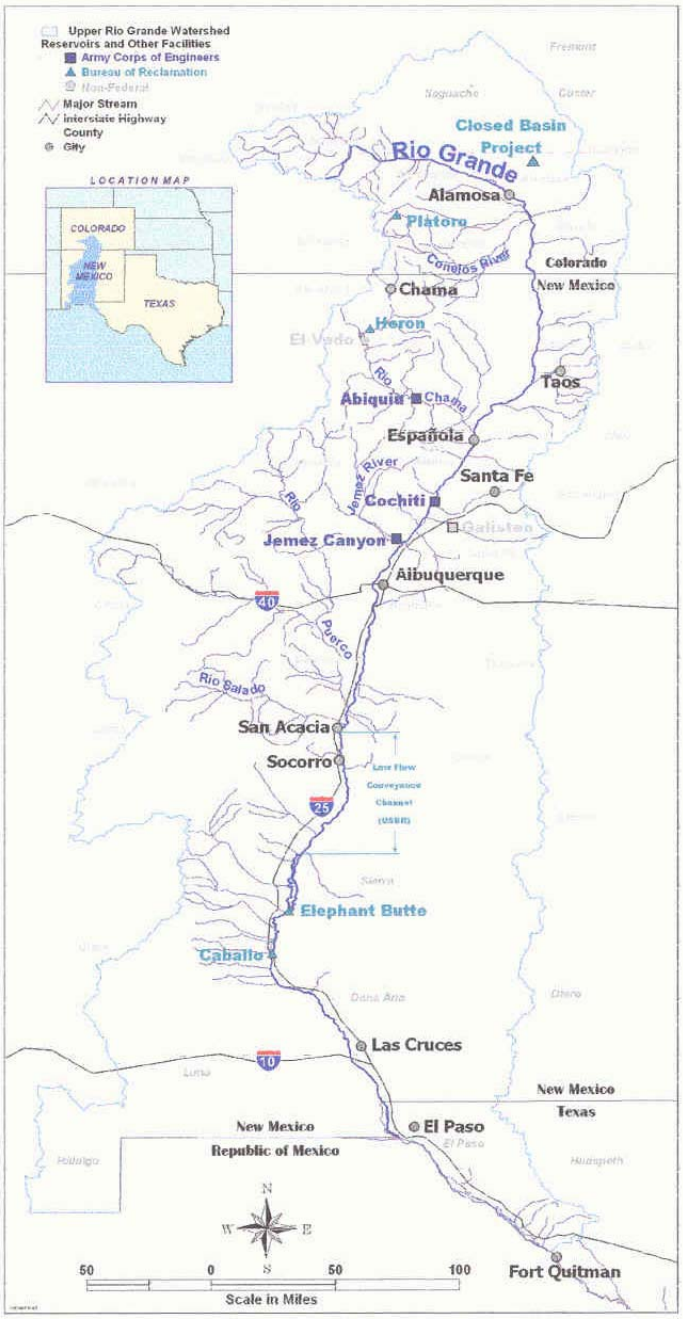
TABLE 1. IMPORTANT EDUCATION, RESOURCE INVESTIGATION AND RESOURCE MANAGEMENT ORGANIZATIONS OR AGENCIES ON THE UPPER RIO GRANDE IN NEW MEXICO.

| **Research Universities** | **Major Local Agencies** | **State Agencies** |
|---|---|---|
| University of New Mexico | City of Albuquerque Public Works, Open Space, Biopark | Office of the State Engineer & the Interstate Stream Commission |
| New Mexico Tech | City of Las Cruces | New Mexico Environment Department |
| New Mexico State University | Mid. Rio Grande Cons. District | |
| University of Texas at El Paso | Elephant Butte Irrigation District | |
| | Albuquerque Metro. Arroyo Flood Control Authority | |
| **Federal Agencies** | **Other Organizations** | |
| Bureau of Reclamation | Sandia National Laboratories | |
| U.S. Army Corps of Engineers | Los Alamos Natl. Laboratory | |
| U.S. Fish & Wildlife Service | Southwestern Indian Polytechnic Institute (SIPI) | |
| U.S. Geological Survey | Native American Pueblos or Tribes | |
| U.S. Forest Service | | |

It is proposed to establish a distributed laboratory network to monitor the resources of the Upper Rio Grande Basin called the River Interaction & Observation (RIO) Laboratory Network. The emphasis of this network will be on applications associated with water resources because water is the common currency across all political and cultural boundaries and thereby gives the region its identity. Water issues necessarily involve both surface and ground waters as the basin is managed according to the principles of conjunctive use. However, other important resources present in the basin are impacted by man's activities; these include air, sensitive ecosystems, and energy and mineral resources.

Major recent events greatly affect water Resources management in the river including recent completion of a NM statewide water management plan, a new major diversion to provide drinking water for the City of Albuquerque, federal court rulings regarding water supply for endangered species, a new drinking water standard for arsenic (a common constituent in basin waters), river and bosque restoration programs, implementation of stream standards by Native American Pueblos, and potential under delivery of water according to provisions in the Rio Grande Compact. These issues ate further complicated by the uncertainty associated with long-term precipitation patterns, as the southwestern US appears to enter a drought cycle after experiencing the wettest decade in the past century.

The current management structure for the Upper Rio Grande has evolved through a combination of congressional action (the Rio Grande Compact), interstate law suits, Native American water rights, and over a century of research by federal, state, and local governments, private corporations, development interests, and research foundations.




**Upper Rio Grande Basin**
**Water Operations Review and EIS**

Figure 1. Map of the Upper Rio Grande (courtesy of U.S. Army Corps of Engineers).

The objectives of this project include the following:

- Establish a field laboratory that will emphasize sensor development and application to environmental management water system safety, and impacts of urbanization of river water quality.
- Establish a network of linked satellite field laboratories to support investigations of surface water – ground water interactions, spatial and temporal water quality variations, seasonal and long-term climate changes, and provide input for water resources management models.
- Develop methods of managing and processing large amounts of environmental data to detect phenomenon of significance to water resources management in the basin.
- Establish a framework for collaboration of the state, local and federal water resources management investigations throughout the basin.

## RIVER INTERACTION & OBSERVATION (RIO) LABORATORY NETWORK

The environmental challenges associated with resource management in the upper Rio Grande basin are extraordinary and must be addressed using, tools and information from a wide range of technical and social science disciplines. Due to this complexity there is rapidly increasing integration of and reliance upon models in basin management. In the Rio Grande Basin the major emphasis has been on management of water resources and has included development of the water operations models, systems models, and ground water models. These models require very large amounts of data for calibration and prediction. Further, they only represent approximations of the physical and biological systems.

The proposed RIO Laboratory Network is an assemblage of field monitoring stations linked to a central laboratory facility that would supervise data collection and processing. It is proposed that the central laboratory facility would be co-located with the new diversion and intake structure under development for the City of Albuquerque's drinking water plant. This diversion will consist of an inflatable dam, a fish passageway, intake structure and lift station. The City of Albuquerque has reviewed this proposal and given preliminary support to the concept of a field laboratory near the diversion. This location has a number of unique attributes that make it ideal for a field laboratory to study the Rio Grande:

- It will be the first diversion on the main stem of the Rio Grande for drinking water and the first new diversion since completion of Cochiti Dam.
- It will include the first fish passageway on the river to support restoration of the Rio Grande Silvery Minnow.
- The diversion is approximately 1 km downstream from a large storm water discharge channel that provides drainage for most of the urban development in Albuquerque.
- Instrumental measurements from sensor equipment installed at the field laboratory can be correlated to laboratory analyses conducted to support operation of the drinking water treatment plant.
- Operation of the inflatable dam will have a major effect on surface water – ground water interactions as well as the ecology of the bosque.
- The diversion structure, inlet and associated lift station are all located on public land.
- A comprehensive Environmental Impact Statement has been prepared for this site that could be updated and adapted to facilitate development of the field lab.
- The location of the diversion, in the Rio Grande State Park near downtown Albuquerque, will make the field laboratory well suited for supporting K-12 and public education programs.

Potential locations for satellite field laboratories include other major diversions on the river, state and national wildlife refuges, and the Sevilleta LTER. The purpose of the satellite laboratories is to collect information that reflect spatial variability along the watershed as well as temporal changes. Data collected from these sites could be transmitted to the central facility through a number of methods including manual downloading of data loggers, use of cell phone systems, radio or microwave telemetry, or possibly use of satellite communications.

Brief examples of the types of research projects that would be appropriate for the RIO Laboratory Network are discussed below.

### SENSOR DEVELOPMENT AND APPLICATION TO WATER TREATMENT & RIVER MANAGEMENT

The City of Albuquerque's diversion and water treatment project will allow the City to switch from total dependence on diminishing ground water resources to surface water sources. There are a number of unique features associated with this project. Operation and performance of the treatment plant will depend on river water quality, hence frequent sampling and a water quality laboratory will be incorporated in the design. A field lab at the diversion point will allow testing and development of water quality sensors both for incorporation in the water treatment process and for monitoring river characteristics. Examples of sensors that might be useful in water treatment include the following:

- Measurement of sediment concentrations and characteristics.
- Detection of microbial quality, especially pathogenic organisms, a major urban storm water pollutant.

- Continuous detection of organic compounds (e.g., pesticides, herbicides, solvents, and pharmaceutically active compounds), inorganic compounds (e.g., arsenic), and radioactive constituents (a high profile class of contaminants in NM)

In addition to their application for water treatment, the RIO Laboratory Network will facilitate development of technologies for continuous monitoring of river sediment and water characteristics. Co-locating a field laboratory with the City of Albuquerque's diversion structure will provide a secure central location on the river at a point where it is highly instrumented for flow, velocity, sediment and water quality, as well as environmental characteristics.

## SURFACE WATER – GROUND WATER INTERACTIONS

Ground water is a very important resource in the Middle Rio Grande. Along the river, it serves as a principal supply for potable water for nearly all residents in the basin. The river interacts with the local and regional ground water in a complicated manner. Ground water recharge is primarily through infiltration from the river and from unlined irrigation ditches. The rate of infiltration as well as the depth to ground water are important factors in the type of vegetation that is established and thrives in the bosque. At the same time, evaporation from these soils can represent large depletions if there is a favorable hydraulic connection between the shallow ground water and the atmosphere. Field investigations of this interaction near the diversion structure and inflatable dam presents a unique opportunity for observing the phenomena under tightly controlled and well monitored circumstances.

Measurements of water content changes in the soil above the water table can show the magnitude and direction of the vertical flux of soil water. The water content can be measured with sensors placed at different depths at various locations in the unsaturated soil adjacent to the river. Ground water levels in wells adjacent to the river will indicate lateral gradients and the direction of local ground water movement. These measurements can also be used to deduce the influence of unlined irrigation conveyances on local ground water levels and movements.

## DATA MINING AND ANALYSIS

Continuous monitoring of an environmental system creates large data sets. Data mining and machine learning involve feature discovery and representation, and the generation of Bayesian networks to model the data. Similarly, image processing and data mining techniques developed for the early detection of pathogens and toxins in tissue samples can be applied to remote sensing data from airborne or satellite detectors. Features are extracted, discretized, and summarized, and a Bayesian network is built to model the classification problem. Examples of problems that might be amenable to these techniques are the following:

- Changes in river morphology with time
- Detecting changes in water characteristics that might impact treatment processes or viability of threatened aquatic organisms
- Detecting long term changes in watershed characteristics resulting from drought of climate change

## INVESTIGATIONS OF RIO GRANDE WATER QUALITY

Through a set of synoptic field sampling campaigns of the Rio Grande sponsored by the NSF SAHRA program, water quality measurements along the Upper Rio Grande have revealed interesting spatial and temporal variations of nutrient and solute concentrations (Phillips 2004). Chemical tracers show that local discharge of saline ground water is a major source of salinity, and that agricultural return flows have a comparatively small contribution to the chloride budget. This suggests that water quality improvements along the Rio Grande to meet federal drinking water regulations downstream may be achievable through interception of saline ground water or by changes in river management. In contrast to salinity, nutrients in the river come mainly from anthropogenic sources including agricultural return flows, urban storm water, and discharge of treated municipal wastewater.

Current field sampling efforts have revealed much information about river water quality. The measurements, however, are simple snapshots of the river water quality during brief two-week periods. The spatial and temporal variability of the river water quality is not known as there are no continuous water quality monitoring stations on the river. The RIO Laboratory Network will allow the continuous, spatially distributed sampling of water quality at linked satellite stations (e.g., Albuquerque, Belen, Soccorro, San Acacia, Las Cruces, El

Paso), each measuring several water quality parameters (e.g., total dissolved solids, dissolved oxygen, temperature, pH, etc.). Such a networked facility, will allow analysis of the impacts of diversions, wastewater discharge, hydrogeological brine sources, agricultural return flows, and biogeochemistry cycling on water quality.

## MOBILE FIELD DATA COLLECTION FOR WATER QUALITY STUDIES

Traditional studies of river and watershed characteristics depend on manual data collection. This method is labor-intensive, time-consuming and susceptible to recording and georeferencing errors. Recent advances in mobile computing and wireless communications allow collection, processing and transmitting data while in the field. Vivoni and Camilli (2003) have previously developed an integrated system for environmental and geolocation data acquisition that significantly streamlines the data collection process. The system consists of hardware and software that enable wireless, mobile, and Internet connection in the field. This system can be incorporated in the field lab network for the IT-enhanced collection of environmental data. This will give investigators the capability of computerized field measurements during intensive sampling campaigns and allow correlation with installed sensors.

## INTEGRATION OF IN-SITU MEASUREMENTS AND MODELING

Enhancements to traditional river water quality assessments can be realized by using geographical information systems (GIS) for processing images, field data collection and hydrologic and water quality (H/WQ) modeling. The processed data from the network of in-situ, continuous water quality and quantity stations, as well as measurements from the field campaigns, should be analyzed within a geographic context and related to potential sources of contamination (e.g., wastewater treatment facilities, agricultural discharge, geologic brine sources, flow diversion). Data collected from the field lab network can support hydrologic and water quality modeling needed for managing the river. A variety of approaches are available, ranging from detailed hydrodynamic and biogeochemical transport modeling to conceptual, system dynamics modeling of the river system. On-going efforts at UNM (HEC-RAS & FLO-2D surface water models, ET measurements and scaling), Sandia National Laboratory (dynamic water systems model), US Army Corps of Engineers (Upper Rio Grande Water Operations Model) and the US Geological Survey (ground water model) will be coordinated with data collected by the lab network.

## CONCLUSION

The extraordinary intellectual resources along the Upper Rio Grande which have been devoted toward understanding the physics, chemistry, biology, and political-social-economic interactions that have created the environment of the Rio Grande watershed. Of course, the central thread of this watershed is the river itself. A River Interaction and Observation (RIO) Laboratory Network is proposed that would facilitate collaboration among the scientific and resource management organizations within the basin.

The goal of the RIO Laboratory Network is to fully integrate the data gathered from the in-situ field stations with both hydrologic and water quality models. Processing the information and making it available to collaborating research organizations will facilitate its integration into their models. The integration of the modeling and field data collection within the RIO facility will allow improved river management to protect our unique and fragile environment.

## REFERENCES

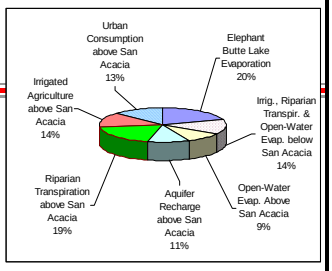
Phillips, F.M. (2004) Salt of the earth: What makes the Rio Grande go saline? in *New Mexico Academy of Science Centennial Volume)* edited by R. Nygren, New Mexico Academy of Science, Albuquerque, (forthcoming).

Thomson, B., Thompson, S. (1991). Rio Grande Laboratory/Consortium Concepts, The Rio Grande Basin – Global Climate Change Scenarios, NM Water Resources Research Report No. M24, Las Cruces, NM, pp. 33-36.

Vivoni, E.R., Camilli, R. (2003). Real-time streaming of environmental field data. *Computers and Geosciences. 29:*457-468.

## Introduction

- Major challenges on the upper Rio Grande
  - Technical – Physical, environmental (biological & chemical)
  - Social/Political/Legal
  - Complicating factors:
    - Population and economic growth
    - Uncertainties associated with long term climate variability & possible change

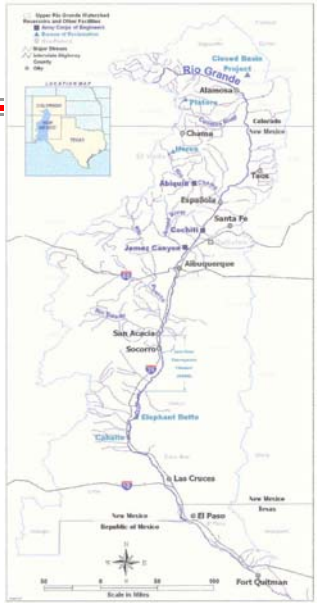



RIO Laboratory 2

## Many New Developments

- Completion of Basin & State Wide Water Plans
- Application by CABQ to withdraw water for potable use & approval of EIS
- Federal court rulings regarding water for endangered species
- River & bosque restoration plans
- Development of stream standards by Pueblos
- New drinking water standard for As
- NPDES permits & TMDLs for storm water
- Potential under delivery of water under Rio Grande Compact

## The Basin




RIO Laboratory 4

## Unique Attributes of Basin

- Boundary between US & Mexico
- Wide range of climate, environmental & hydrologic conditions
  - 4 major biomes
- Watershed is relatively isolated
- Extraordinary concentration of technical expertise
  - Research
  - Education
  - Resource management

RIO Laboratory 5

## Technical Expertise in Basin-1

- Universities
  - University of New Mexico
  - New Mexico Tech
  - New Mexico State University
  - University of Texas at El Paso
  - Southwestern Indian Polytechnic Institute
- National Laboratories
  - Sandia National Laboratories
  - Los Alamos National Laboratory

## Technical Expertise in Basin-2

- Federal Resource Management Agencies
  - US Geological Survey
  - US Army Corps of Engineers
  - US Bureau of Reclamation
  - US Fish & Wildlife Service
  - US Forest Service
- NM State Resource Management Agencies
  - Office of the State Engineer & Interstate Stream Commission
  - NM Environment Department
  - Others

## Technical Expertise in the Basin-3

- Local Water Management Agencies
  - Cities
    - Albuquerque - Public Works, Open Space, Biopark
    - Las Cruces
    - El Paso
    - Rio Rancho
  - Mid. Rio Grande Cons. District
  - Elephant Butte Irrig. District
  - Flood Control Authorities - AMAFCA, SCAFCA, etc.
- Pueblos & Tribes

## River Interaction & Observation (RIO) Laboratory

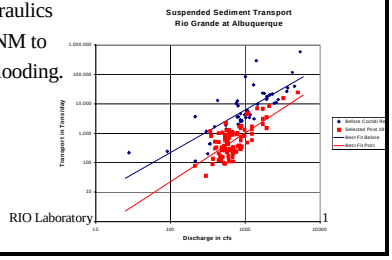
- A distributed field laboratory along length of upper Rio Grande
- Central field laboratory, possibly co-located with CABQ diversion structure. Attributes
  - Inflatable dam
  - Fish way
  - ~1 km downstream from North Diversion channel
  - Central location
  - Water quality monitoring for treatment plant
- Satellite monitoring stations along river, connected by telemetry

## Examples of Studies & Activities

- Measurement of flow & sediment transport
- Sensor development & water quality studies
- Impact of dam on bosque & ET studies
- Mobile field instrumentation
- K-12 and public education

## Flow & Sediment Transport Studies

- Difficulties of measuring flow in unstable sand bottom channels
  - Dam sill will establish a stable cross section
- Tougher still to measure sediment transport
  - Must know how sediment will affect dam operation
  - Effects on channel morphology
- Opportunity to study river hydraulics
  - HEC-RAS modeling by UNM to study effects of over bank flooding.




RIO Laboratory 1

## Sensor Development & Water Quality Studies

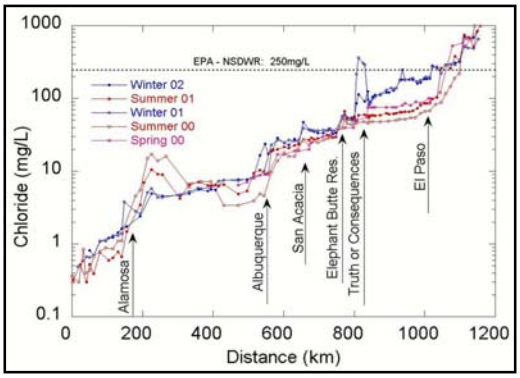
- Diversion of water for treatment & potable use will require knowledge of water quality
  - Data needed for plant operation
  - Establish river water quality monitoring program
  - Threat detection
- Potential sensor systems
  - Microbial characteristics, especially during storm events
  - Continuous detection of regulated/hazardous toxic constituents (inorganics, organics, radionuclides)
  - Detection of fish passage
- RIO lab can provide data for calibrating remote sensing systems

## Impact of Dam on Bosque & ET Studies

- Fluctuating water levels provide ideal opportunity to study surface water-ground water interactions
  - Investigate effects of elevated water levels on bosque restoration
- Investigations of open water & soil evaporation
  - UNM CE Field laboratory
- ET studies
  - Link, improve & expand existing tower sites (UNM Biology & CE Depts.)

## Mobile Field Data Collection

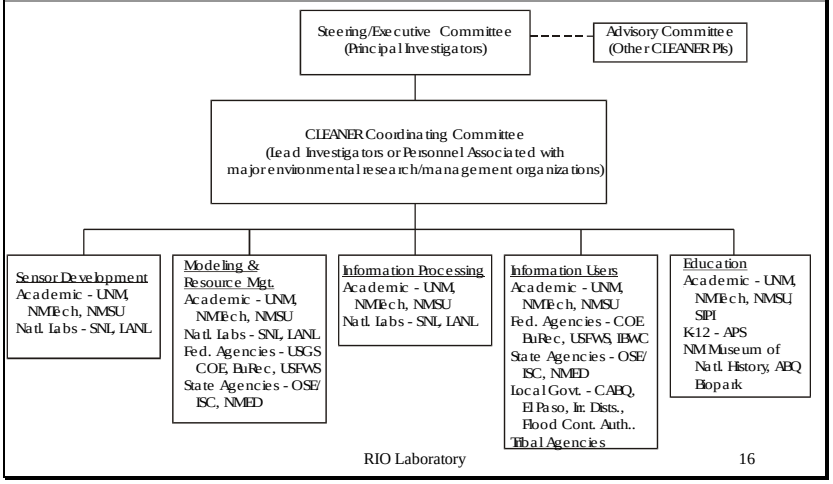
- Link field equipment to GPS to facilitate spatial & temporal data collection
- Establish & link remote sites to central facility




## Public Education

- Incorporate public education component into field laboratory
  - Interpretive displays
  - Facilitate K-12 science projects
- Web based data collection & display
  - River status - stage, flow & quality along length

## Proposed Project Organization-1




RIO Laboratory 16

## Proposed Organization of Project-2

- Six subcommittees
  - Sensor Development Subcommittee - Universities & labs
  - Modeling & Resource Management Subcommittee - State & federal agencies, Pueblos, universities & labs
  - Information Processing Subcommittee - Universities & labs
  - Information Users Subcommittee - State & federal agencies, Pueblos, local agencies, universities
  - Education Subcommittee - Universities, SIPI, museums, public schools

## Concluding Remarks

- Current status
- Rio Grande presents a unique opportunity for research on river hydrology & environment in arid climate
- RIO Laboratory would facilitate collaborative research between some of the most prominent research organizations in U.S.
  - Need to develop mechanisms for this collaboration
  - Need to develop facilities

## Current Collaborators

- UNM - John Stormont, Kerry Howe, Tim Ward, Steve Cabaniss, Laura Crossey, Michael Campana
- NM Tech - Jan Hendricks
- SNL - Pat Brady, Vince Tidwell, Ray Finlay
- Bureau of Reclamation - Drew Baird
- City of Albuquerque - John Stomp
- Corps of Engineers - Gail Stockton