

**Water Resources Research Institute  
Annual Technical Report  
FY 2008**

# Introduction

This program report provides the required information for projects funded with the 2008 base grant and mandatory non-federal matching funds. Please note that there may be some overlap in information with our 2007 report because data collection is based on a July-June fiscal year rather than the March-February USGS Grant Award period.

The New Mexico Water Resources Research Institute (NMWRRI) was established in 1963 by the New Mexico State University Board of Regents, becoming one of the first of the 54 state institutes approved nationwide under the authorization of the 1964 Water Resources Research Act. It is considered to be the statewide nucleus for coordinating water resources research. Using the expertise of researchers in a variety of disciplines at state-supported universities, the institute is able to respond to the critical water needs of New Mexico and the region. It operates under the general advice of a Program Development and Review Board, whose membership includes faculty representatives as well as state and federal agency personnel.

The mission of the NMWRRI is to develop and disseminate knowledge that will assist the state, region, and nation in solving water resources problems. Specifically, the institute encourages university faculty statewide to pursue critical areas of water resources research while providing training opportunities for students who will become our future water resources scientists, technicians, and managers. It provides an outlet for transferring research findings and other related information to keep water managers and the general public informed about new technology and research advances. In addition, the institute maintains a unique infrastructure that links it with many federal, state, regional, and local entities to provide expertise and specialized assistance.

The institute maintains a dynamic program to transfer technical information from the producer to the user and the public. Technical publications, newsletters, conferences, press announcements, and presentations keep practitioners aware of new technology and research advances. The NMWRRI homepage ([wrri.nmsu.edu](http://wrri.nmsu.edu)) provides on-line information about the institute, newsletters, technical report series, requests for proposals, upcoming conferences and symposia, links to related entities, and the research reference library.

New Mexico is one of the driest states in the nation, averaging no more than 20 inches of precipitation a year, varying from about 6.5 inches in the Four Corners area to more than 30 inches in the high mountains. The relative humidity is low, resulting in a high rate of evaporation. Summer rain accounts for almost half of the annual precipitation other than in the high mountains. Widely varied precipitation contributes as much to a water allocation problem as water scarcity itself. To compound the situation, New Mexico, like much of the West, continues to suffer from the worst drought in 100 years or longer. Water conservation measures continue to expand in municipalities throughout New Mexico to help ensure adequate public water supplies for residential and industrial use. Drought ordinances are in place in cities across the state, and county and municipal governments are working together to limit water use and reduce demand. The Drought Task Force, established in April 2002 by New Mexico's governor after declaring a state of emergency because of the drought, continues to monitor the situation.

During the past year, New Mexico continued to suffer from extreme quantity water-related conditions with parts of the state suffering from extreme drought. For the period from October 2008 to February 2009, precipitation was below normal for a statewide average of 78 percent. The state's northern mountains averaged about 108 percent of normal precipitation while the southern desert precipitation averaged only 32 percent of normal, and the southeastern plains reported 57 percent of normal. Daily streamflow conditions for the period were at or above average for the majority of the river basins in northwest and north central New Mexico. However, river basins in northeast and southern New Mexico have streamflow conditions that were below the historical average. Streamflow conditions in the Gila and lower Pecos River basins were all below

average.

Water problems in New Mexico, like in other western states, continue to revolve around three key issues: quality, quantity, and management. Because water resources are so limited, water quality and water resources management have taken on increasing importance. These concerns are interrelated and sufficiently complex so that the highest quality research is essential to solving them.

# Research Program Introduction

The primary objective of the New Mexico Water Resources Research Institute is to maintain a balanced program of research that addresses water issues and problems critical to New Mexico, the region, and the nation. In administering this program, the institute relies on financial support from state appropriations, federal and state agencies, and the USGS Water Resources Research Institute Annual Base Program.

To make the best use of limited resources, the institute has targeted four areas as high priority for funding: water conservation, planning and management; atmospheric, surface and groundwater relationships; water quality; and utilization of saline and other impaired waters. During the reporting period, three projects received funding from the 2008 Annual Base Program. These projects include two that fit into the water conservation, planning and management category: WRRRI Information Transfer Program and Estimating Water Use through Satellite Remote Sensing. One project was funded in the utilization of saline and other impaired waters category: Utilization of Saline and Other Impaired Waters for Turfgrass Irrigation. Two projects were supported with state funds: a water quality project, Land Application of Industrial Effluent on a Chihuahuan Desert Ecosystem: Impact on Soil Physical and Hydraulic Properties and a water planning and management project, Development of Geospatial Modeling Tools for Watershed-based Water Resources Management in New Mexico. The NMWRRRI also administered a USGS 104G award categorized in the atmospheric, surface and groundwater relationships category: Validation, Calibration and Improvement of Remote Sensing ET Algorithms in Mountainous Regions.

During the reporting period, the NMWRRRI administered a total of 45 projects dealing primarily with water quality and conservation issues. The total value of these projects was over \$1.7 million, including required cost sharing. Awards were made by various federal and state agencies and from the institute's annual state appropriations. Dollar amounts per project award ranged from \$2,325 to nearly \$396,600. During the reporting period, 32 projects were conducted at New Mexico State University, 6 at New Mexico Tech, 4 at the University of New Mexico, and 3 at New Mexico Highlands University. Faculty members were principal investigators on 35 projects and NMWRRRI staff managed 10 projects. The institute maintained frequent contact with its researchers through periodic progress updates, site visits, and expenditure tracking.

Research projects administered by the NMWRRRI utilized at least 87 students during the year including undergraduates, masters, Ph.D. candidates, and a Post-doctoral student in the disciplines of agricultural economics, biology, chemical engineering, chemistry, civil engineering, computer engineering, earth and environmental science, engineering technology, environmental engineering, environmental geology, general studies, geography, geology, health science, horticulture, hydrology and hydro-geology, mathematics, mechanical engineering, natural resource management, plant and environmental science, range science, soil science, water resources engineering.

Projects administered by the NM Water Resources Research Institute during the reporting period are listed below. Note that total award value is shown and includes both agency and cost sharing when appropriate, and includes multiyear funding.

Runoff Processes and the Evolution of Water Chemistry in the Saguache Creek Watershed of the Upper Rio Grande. WRRRI Student Research Grant 07 (Marty Frisbee, New Mexico Tech) \$0 (reporting only)

Multi-disciplinary Analysis of a New Mexico Cold Water Tufa Spring Mound. WRRRI Student Research Grant 06 (Katrina Koski, New Mexico Tech) \$0 (reporting only)

Land Application of Wastewater Containing Arsenic: Impacts on the Sorption and Mobility of Arsenic in Soil. WRRRI Student Research Grant 07 (Sylvia Nemmers, New Mexico State University) \$2,325

Iron(II) Oxidation in New Mexico Waters: Experimental Development of a Molecular-Level Predictive Model. WRRRI Student Research Grant 07 (Andrea Higdon, New Mexico Tech) \$4,866

Uranium and Heavy Metals in Macroinvertebrates in the Santa Fe River on the Cochiti Reservation. WRRRI Student Research Grant 06 (Carlos R. Herrera, New Mexico Highlands University) \$4,899

Assessment of a Novel Source-Tracking Protocol for Evaluating the Significance of Municipal Wastewater Sources on the Microbial Contaminant Levels of Discharged Wastewaters. WRRRI Student Research Grant 09 (Jesus Sigala, New Mexico State University) \$4,920

The Dependency of Anomalous Transport Behavior on Flow Path Orientation. WRRRI Student Research Grant 09 (Nicholas B Engdahl, University of New Mexico) \$4,952

Effects of Copper Sulfate Treatment on Benthic Macroinvertebrates in Peterson Reservoir Sediments. WRRRI Student Research Grant 09 (Daryl Williams, New Mexico Highlands University) \$4,953

Removal of Arsenic from Aqueous Solution Using Activated Carbon Prepared from Pecan Shells. WRRRI Student Research Grant 09 (Ranganath Potluri, New Mexico State University) \$4,990

Evaluation of Multi-stage Solar-powered Desalination System. WRRRI Student Research Grant 09 (Akash Mummaneni, New Mexico State University) \$4,991

Bioassessment of Arsenic Contamination of the Gallinas River Using Benthic Macroinvertebrates. WRRRI Student Research Grant 07 (Bildad Eta Eyong, New Mexico Highlands University) \$4,992

Designing a Combined Piezometric and Gravity Monitoring Network in Lower Rio Grande Basin. WRRRI Student Research Grant 09 (B. V. N. P. Kambhammettu, New Mexico State University) \$5,000

Residence Time Distribution in Dynamically Changing Hydrologic Systems. WRRRI Student Research Grant 09 (Jesus D. Gomez, New Mexico Tech) \$5,000

From Stormwater Management to Stormwater Integration: The Use of Low Impact Development Techniques in the Albuquerque Region. WRRRI Student Research Grant 09 (KT LaBadie, University of New Mexico) \$5,000

Aqueous Geochemistry of the Springs and Wells of the Sevilleta National Wildlife Refuge: Evaluating Hydrochemical Pathways and Microbiology. WRRRI Student Research Grant 09 (Amy J. Williams, University of New Mexico) \$5,000

Composite Membrane for Membrane Distillation Desalination Process. WRRRI Student Research Grant 09 (Sai Reddy Pinappu, New Mexico State University) \$5,000

Investigation of Improved Operational Streamflow Forecasting in the Rio Grande Basin. WRRRI Student Research Grant 09 (Shalamu Abudu, New Mexico State University) \$5,000

Uranium Abatement in Water. WRRRI Student Research Grant 09 (Nicholas G. Beltran, New Mexico State University) \$5,000

New Mexico Water Rights Prices Database Development. WRRRI Student Research Grant 07 (Shawn Landfair, New Mexico State University) \$5,000

Investigating Potential Salt Contamination of Aquifers from Irrigated Landscapes. WRI Student Research Grant 07 (Elena Sevostianova, New Mexico State University) \$5,000

Estimating Evaporation from Elephant Butte Reservoir with the Monin Obukhov Similarity Theory Using Simple Instrumentation. WRI Student Research Grant 07 (Jimmy Moreno, New Mexico State University) \$5,000

Drinking Water Purification for U.S.A.-Mexico Border Region. WRI Student Research Grant 07 (Arely Torres, New Mexico State University) \$5,000

Carbon Nanotube-Based Biosensor for Pathogens Concentration and Detection. WRI Student Research Grant 07 (Dipendu Saha, New Mexico State University) \$5,000

The Effects of Acequias and Riparian Evapotranspiration on the Rio Grande Flow Levels. WRI Student Research Grant 07 (Ciara Cusack, New Mexico State University) \$5,000

Feasibility Study of Wastewater Purification by Low Temperature Distillation Method. WRI Student Research Grant 07 (Veera Gnaneswar Gude, New Mexico State University) \$5,000

The Effects of Eutrophication on the Structure and Function of Stream Biofilms. WRI Student Research Grant 06 (David J. VanHorn, University of New Mexico) \$5,000

Development of a Fine-scale GIS for Modeling Monsoon Season Flash Flood Events in the Lower Rio Grande of New Mexico. WRI Student Research Grant 08 (Sylvia Nemmers, New Mexico State University) \$5,000

Water Information Websites for the New Mexico/Chihuahua Border Region Phase I. SCERP \$24,999

Land Application of Industrial Effluent on a Chihuahuan Desert Ecosystem. Rio Grande Basin Initiative. \$29,240

Sustainable Recovery of Potable Water from Saline Waters. New Mexico state appropriations \$19,960; 104B program \$10,000

New Mexico Pesticide Management Plan 2007-2008. Memorandum of Agreement with the New Mexico Department of Agriculture \$30,000

WRI Information Transfer Program. 104B program \$32,335

Development of Geospatial Modeling Tools for Watershed-based Water Resources Management in New Mexico. New Mexico state appropriations \$49,789; 104B program \$10,000

Estimating Water Use through Satellite Remote Sensing. New Mexico state appropriations \$20,000; 104B \$40,000

Salinity Management Program and Rio Grande Project Salinity Assessment. Texas A&M University, \$63,036

Water Information Websites Phase II. SCERP \$66,523

Validation, Calibration and Improvement of Remote Sensing ET Algorithms in Mountainous Regions. USGS 104G \$74,795

Transboundary Assessment Act Mesilla Basin Workplan. USGS \$82,000

Utilization of Saline and Other Impaired Waters for Turfgrass Irrigation. New Mexico state appropriations \$60,000; 104B program \$30,000

Grand Unified Groundwater Model Development for the Lower Rio Grande. Lower Rio Grande Water Users Association \$108,545

Gila Settlement Act Planning. New Mexico Interstate Stream Commission \$109,000

Continued Development of a RiverWare Model of the Rio Grande Flow and Coordinated Database. Texas A&M University \$162,602

A Joint Investigation of Evapotranspiration Depletion of Treated and Non-Treated Saltcedar at the Caballo Dam, New Mexico. U.S. Bureau of Reclamation \$170,608

Monitoring and Forecasting Climate, Water and Land Use for Food Production in Afghanistan. USGS \$396,599

# Validation, Calibration, and Improvement of Remote Sensing ET Algorithms in Mountainous Regions

## Basic Information

<b>Title:</b>	Validation, Calibration, and Improvement of Remote Sensing ET Algorithms in Mountainous Regions
<b>Project Number:</b>	2006NM63G
<b>Start Date:</b>	9/1/2006
<b>End Date:</b>	8/31/2009
<b>Funding Source:</b>	104G
<b>Congressional District:</b>	Second
<b>Research Category:</b>	Climate and Hydrologic Processes
<b>Focus Category:</b>	Hydrology, Water Quantity, Models
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Jan M.H. Hendrickx, Jan Kleissl

## Publication

- Hendrickx, J.M.H., J. Kleissl, J.D. Gomez-Velez, S.-h Hong, J.R. Fabrega-Duque, D. Vega, H.A. Moreno-Ramirez, and F.L. Ogden. 2007. Scintillometer networks for calibration and validation of energy balance and soil moisture remote sensing algorithms. Proc International Society for Optical Engineering (SPIE). 6565:65650W.
- Gomez, J.D., J. Kleissl, J.M.H. Hendrickx, and O.K. Hartogensis. 2008. Large aperture scintillometers for hydrology. Water Res. Res. submitted.
- Hong, S.-h., J. Kleissl, J.M.H. Hendrickx, R.G. Allen, W.G.M. Bastiaanssen, R.L. Scott, and A.L. Steinwand. 2008. Validation of SEBAL for mapping sensible and latent heat fluxes in arid riparian areas from remotely sensed optical imagery. Water Res. Res. In preparation.
- Kleissl, J., S.-h. Hong, and J.M.H. Hendrickx. 2008. New Mexico scintillometer network in support of remote sensing, and hydrologic and meteorological models. Bulletin American Meteorological Society. In press.
- Kleissl, J., J. Gomez, S.-H. Hong, J.M.H. Hendrickx, T. Rahn, and W.L. Defoor. 2008. Large aperture scintillometer intercomparison study. Boundary Layer Meteorol. 128:133-150, DOI 10.1007/s10546-008-9274-1.
- Gomez, J.D., J. Kleissl, J.M.H. Hendrickx, and O.K. Hartogensis. 2009. Large aperture scintillometers for hydrology. Water Res. Res.: resubmitted.
- Hendrickx, J.M.H., J. Kleissl, J.D. Gómez-Vélez, S.-h. Hong, J.R. Fábrega-Duque, D. Vega, H.A. Moreno-Ramírez, and F.L. Ogden. 2007. Scintillometer networks for calibration and validation of energy balance and soil moisture remote sensing algorithms. Proc. International Society for Optical Engineering, SPIE 6565:65650W.
- Hong, S.-h., J. Kleissl, J.M.H. Hendrickx, R.G. Allen, W.G.M. Bastiaanssen, R.L. Scott, and A.L. Steinwand. 2009. Validation of SEBAL for mapping sensible and latent heat fluxes in arid riparian areas from remotely sensed optical imagery. Water Res. Res. submitted.
- Kleissl, J., S.-h. Hong, and J.M.H. Hendrickx. 2009. New Mexico scintillometer network in support of remote sensing, and hydrologic and meteorological models. Bulletin American Meteorological Society: 90:207-218.

10. Kleissl, J., J. Gomez, S.-H. Hong, J.M.H. Hendrickx, T. Rahn, and W.L. Defoor. 2008b. Large aperture scintillometer intercomparison study. *Boundary Layer Meteorol.* 128:133–150, DOI 10.1007/s10546-008-9274-1.

## Problem and Research Objectives

Accounting of key reservoirs and fluxes associated with the global water cycle, including their spatial and temporal variability, are crucial goals of water resource managers. Advancements in satellite optical remote sensing have resulted in the development of several operational remote sensing evapotranspiration (ET) algorithms. While these algorithms typically give accurate ET predictions over flat terrain, significant difficulties have been encountered in mountainous regions which are characterized by heterogeneous soil and topography and high elevation changes. However, mountain runoff represents more than 90% of the total runoff in the semi-arid basins of the Rio Grande, Oranje, Colorado, and Rio Negro rivers. Thus improving ET estimates in the mountains is crucial for determining the regional water balance in the southwestern U.S. and in many mountainous regions worldwide.

## Methodology

Most remote sensing algorithms obtain ET as the residual of the energy balance after measuring and/or modeling net radiation, ground heat flux, and sensible heat flux  $H$ . Among these fluxes,  $H$  is the most complex to estimate and its value is associated with the greatest uncertainty. We will use novel measurement techniques, such as scintillometers, together with spatially dense meteorological measurements and archived ETA numerical weather model data to measure  $H$  and determine how it is related to temperature lapse rate, wind speed, water vapor deficit, and boundary layer height. Two protected sites with idealized topographical shape will be considered in the field study: the Magdalena Ridge and the Valles Caldera National Park in New Mexico. First, the measured  $H$  will be used to validate estimates derived from the Surface Energy Balance over Land (SEBAL) algorithm applied on data from synchronous ASTER and MODIS satellite overpasses. Second, techniques for calibration of the SEBAL algorithm in near-real time using surface measurements of  $H$  will be developed. Third, parameterizations in the SEBAL algorithm for mountain lapse rates, wind speeds, and surface roughnesses will be critically reviewed and improved by considering meteorological measurements and archived numerical weather model data. Through this work we will make a lasting contribution to ET estimation from SEBAL and other remote sensing algorithms for current and future satellite missions.

## Principal Findings

The support of this USGS/NMWRRI project together with support of other sponsors has allowed us to investigate and develop procedures for the validation and calibration of remote sensing ET algorithms in mountainous regions in New Mexico. Our research work on ET algorithms started well over eight years ago. However, due to the extremely complex nature of combining the physics of momentum, mass, and energy transport in the atmospheric boundary layer with the radiation physics of remote sensing imagery, it took over five years to prepare our first publications. The USGS/NMWRRI support is critical to complement our progress to date and to develop new knowledge to expand our remote sensing algorithms to more challenging conditions.

For the validation of SEBALNM we have used the new technology of scintillometry. Since no other research group had established a network of six scintillometers over an area of 315,000 km<sup>2</sup> we have spent considerable effort to test the performance of scintillometers under the mountainous conditions of New Mexico.

We performed first two field studies with six large aperture scintillometers (LASs) using horizontal and slant paths. The accuracy of this novel and increasingly popular technique for measuring sensible heat fluxes was quantified by comparing measurements from different instruments over nearly identical

transects. Random errors in LAS measurements were small, since correlation coefficients between adjacent measurements were greater than 0.995. However, for an ideal set-up differences in linear regression slopes of up to 21% were observed with typical inter-instrument differences of 6%. Differences of 10% are typical in more realistic measurement scenarios over homogeneous natural vegetation and different transect heights and locations. Inaccuracies in the optics, which affect the effective aperture diameter, are the most likely explanation for the observed differences (Kleissl et al., 2008b). The quantification of the instrument error of large aperture Kipp & Zonen scintillometers is critical information for all hydrologists using scintillometer worldwide. These results are relevant for Objective One.

We also established in New Mexico a first-of-its-kind network of seven Large Aperture Scintillometer (LAS) sites to measure sensible heat fluxes over irrigated fields, riparian areas, deserts, lava flows, and mountain highlands. Wireless networking infrastructure and auxiliary meteorological measurements facilitate real-time data assimilation. LAS measurements are advantageous in that they vastly exceed the footprint size of commonly used ground measurements of sensible and latent heat fluxes ( $\sim 100 \text{ m}^2$ ), matching the pixel-size of satellite images or grid cells of hydrologic and meteorological models ( $\sim 0.1\text{-}5 \text{ km}^2$ ). Consequently, the LAS measurements can be used to validate, calibrate, and force hydrologic, remote sensing, and weather forecast models. We have published initial results for: (1) variability and error of sensible heat flux measurements by scintillometers over heterogeneous terrain and (2) the validation of the Surface Energy Balance Algorithm for Land (SEBAL) applied to MODIS satellite imagery (Hendrickx et al., 2007; Kleissl et al., 2008a). The findings from this study are relevant for Objectives One and Two.

In another recently submitted publication we present our experiences with the emerging method of scintillometry for hydrologic studies include the use of SEBALNM. Large aperture scintillometers are employed to derive the sensible heat flux over irrigated fields, riparian areas, deserts, lava flows, and mountain highlands in New Mexico. The theory and technical aspects of the setup, operation, and analysis of LAS data are discussed. The advantages of a larger flux footprint, compared with other measurement techniques for the sensible heat flux, are explained, particularly in the context of the calibration and validation of remote sensing surface energy balance algorithms, and hydrologic and meteorological models. The scintillometer transects were used to explore this measurement technique as a potentially useful tool in hydrological applications. Evapotranspiration rates for hydrologic applications can be obtained at scales of the pixel-size of satellite images or grid cells of hydrologic and meteorological models ( $0.1\text{-}10 \text{ km}^2$ ) (Gomez et al., 2008). The findings from this study are relevant for Objectives One and Two.

Finally, in another recent publication we discuss why scintillometer measurements cannot be used directly for the calibration and validation of SEBALNM since the sensible heat flux determined by SEBALNM absorbs biases caused by its assumptions and atmospheric conditions (Hong et al., 2008). This was somewhat of a surprise to us and is very relevant for practitioners worldwide; it is relevant for Objective Two.

We have already taken many measurements relevant for Objective Three such as air temperature and humidity measurements along elevation gradients and scintillometer measurements over snow in the Valles Caldera. These measurements are being analyzed. Since a new PhD student withdrew from the project in the fall semester of 2007, this work has been delayed and, therefore, we requested a no-cost extension of one year.

Much progress has been made with the development of methods to derive ET in mountainous regions using SEBAL and METRIC. Hendrick's group is now involved with three projects that involve mountain ET: ET mapping in the Salt Basin for the Interstate Stream Commission, ET mapping in the Sacramento Mountains for the Bureau of Geologie, and ET mapping in the Green River Basin of Wyoming for the Wyoming State Engineer's Office. We have derived and are testing new approaches to estimate the lapse rate in the mountains as well as reference ET as a function of elevation, slope, and aspect. Without this project we never could have done this.

# Award No. 08HQAG0146 Monitoring and Forecasting Climate, Water and Land Use for Food Production in Afghanistan

## Basic Information

<b>Title:</b>	Award No. 08HQAG0146 Monitoring and Forecasting Climate, Water and Land Use for Food Production in Afghanistan
<b>Project Number:</b>	2008NM114S
<b>Start Date:</b>	9/22/2008
<b>End Date:</b>	9/21/2013
<b>Funding Source:</b>	Supplemental
<b>Congressional District:</b>	
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	

## Publication

## Problem and Research Objectives

This is in the first year of a cooperative agreement to NMSU in support of the Afghanistan Water, Agriculture and Technology Transfer Program. These activities will focus on the application and development of techniques for monitoring the physical variables governing crop growth, such as the timing and amount of precipitation, evapotranspiration and temperature, along with human-related factors such as cropped area, agricultural inputs, and economic indicators.

## Status of Project

Funding under Agromet has supported the following activities:

Installation of 113 weather observation sites: 1) all of the 113 observation sites are recording daily rain and snow; 2) 80 out of 113 sites are reporting in addition to rain and snow on crops (wheat, rice, barley and maize) and pasture and grazing twice a month (fortnightly forms) including crop condition (all the weather adverse factors, shortage of inputs, weed, pests and diseases infestations) and crop phenological stages (including land preparation) in addition to areas planted (% of the total by agricultural zone), planting and harvesting dates in addition to the expected yields during the agricultural year and final obtained yields after the harvesting; and 3) out of 113 sites, 21 sites are complete agrometeorological stations (three observations daily), with 19 classical stations recording 7 weather parameters and 5 automatic stations that can report on up to 20 weather parameters at daily step.

The Agromet Project built an Agrometeorological Database Management system.

Training activities: all the observers and other Specialists coming from different organizations including NGOs and four Afghan Ministries on Agrometeorological techniques and tools. Up to 196 persons were trained by Agromet Project in Agrometeorology methods and tools even in computer use in addition to instruments principle/concepts and observation techniques (physical and biological sides).

Agromet now has almost 120 persons on staff to manage including three National counterparts (one from MAAH and two from Meteorological Department).

Agromet established a preliminary (with the available short time series data) the "Crop (Wheat) Yield Forecasting Agrometeorological Model" (statistics basis) to be able to forecast the wheat production three months before the harvesting. More data are needed to develop more accurate crop performance index for wheat and other major crops in Afghanistan.

Agromet has prepared regular Monthly Agromet Bulletins.

Agromet currently has prepared and disseminated 19 Extension Technical Manuals and Training Courses Material (largest one: "Dari Training Manual": 249 pages)

Network of users and providers: Agromet Project is working closely with USGS (Data and products) related to FEWS-NET (Famine Early Warning System Network) and several other partners including FAO, WFP, ICARDA, and DACAAR.

Agromet is providing all the needed information related to the climate impact on agriculture and water supplies in a timely manner.

Recently, Agromet began providing a weekly special agrometeorological report to the Afghan Cabinet.

# Award No. 08HQAG0117 Transboundary Aquifer Assessment Program

## Basic Information

<b>Title:</b>	Award No. 08HQAG0117 Transboundary Aquifer Assessment Program
<b>Project Number:</b>	2008NM115S
<b>Start Date:</b>	4/1/2008
<b>End Date:</b>	3/31/2013
<b>Funding Source:</b>	Supplemental
<b>Congressional District:</b>	
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	

## Publication

1. Hawley, John W. and Alfredo Granados-Olivas, 2008, Progress Report on Development of an Annotated Bibliography for Transboundary Aquifer Systems of the Mesilla Basin-Paso del Norte Area, New Mexico, Texas (USA), and Chihuahua (MEX), poster presented at the 2008 New Mexico Water Research Symposium, Socorro, NM, August 2008, Symposium Program and Abstracts.

## Problem and Research Objectives

Rapid population growth in the United States-Mexico border region over the last decade has placed major strains on limited water supplies in the region; water quantity and quality issues are likely to be the determining and limiting factors affecting future economic development, population growth, and human health in the border region; increasing use of groundwater resources in the border region by municipal and other water users has raised serious questions concerning the long-term availability of the water supply. Cooperation between the United States and Mexico in assessing and understanding transboundary aquifers is necessary for the successful management of shared groundwater resources by state and local authorities in the United States and appropriate authorities in Mexico, including management that avoids conflict between the United States and Mexico. While there have been some studies of binational groundwater resources along the United States-Mexico border, additional data and analyses are needed to develop an accurate understanding of the long-term availability of useable water supplies from transboundary aquifers.

The objectives of the Transboundary Aquifer Assessment Program is to collect and evaluate new and existing data to develop high-quality, comprehensive groundwater quantity and quality information and groundwater flow models for the Mesilla Basin aquifer in New Mexico, Texas, and Mexico.

## Methodology

Review all previously developed groundwater flow models. Using field studies to develop any additional data that are needed to define aquifer characteristics to the extent necessary to enable the development of groundwater flow models. Evaluate all available data and publications relevant to the aquifer and produce a binational bibliography. Create a geographic information system database to characterize the spatial and temporal aspects of the aquifer. Expand existing agreements, as appropriate, between the authorities in the United States and Mexico, to (1) conduct joint scientific investigations; (2) archive and share relevant data; and (3) carry out any other activities consistent with the program. Establish a basin steering committee of local stakeholders to provide review and feedback on tasks and products.

## Principal Findings

A bibliography of previous studies that was compiled in 2004 was updated and reviewed by the USGS, New Mexico, and Texas team. The basin hydrogeologic framework model that was produced in 2004 was reviewed and updated with recent data and information. Expansion of this model into Mexico was proposed and is pending once an agreement has been finalized for conducting joint investigations and sharing of data. The basin groundwater flow models that have been developed in the last 20 years were reviewed and evaluated for their possible use. This evaluation also needs involvement of the Mexican authorities for selecting a model for expansion into Mexico.

# Utilization of Saline and Other Impaired Waters for Turfgrass Irrigation (Leinauer)

## Basic Information

<b>Title:</b>	Utilization of Saline and Other Impaired Waters for Turfgrass Irrigation (Leinauer)
<b>Project Number:</b>	2008NM89B
<b>Start Date:</b>	3/1/2008
<b>End Date:</b>	2/28/2009
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	2
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Irrigation, Conservation, Water Use
<b>Descriptors:</b>	None
<b>Principal Investigators:</b>	Bernhard Leinauer, Ryan Goss

## Publication

1. Ritsema, C., L. W. Dekker, K. Oostindie, D. Moore, and B. Leinauer. 2008. A Practical Field Method for Determining Soil Water Repellency and Critical Soil Water Content. In: Soil Science: Step-by-step Field Analyses. S. D. Logsdon et al. (Editors). Soil Science Society of America.
2. Leinauer, B., V. Gibeault, L. Lauriault, R. Autio, S. Cockerham, R. Kirksey, and S. Ries. 2008. Establishment and Subsequent Spring Survival of Low Maintenance Turfgrasses in Transition Zone Climates. Proceedings of the 1st ETS (European Turfgrass Society) Conference - 19th-20th May, 2008: 113 - 114.
3. Leinauer, B. and S. Cockerham (eds.). Turfgrass Water Conservation. Cooperative Extension University of California, Division of Agriculture and Natural Resources. In press.
4. Leinauer, B., and R. Green. Water Management Technologies. In B. Leinauer and S. Cockerham (eds.) Turfgrass Water Conservation. Cooperative Extension University of California Division of Agriculture and Natural Resources. In press.
5. Serena, M., B. Leinauer, M. Schiavon, and S. Macolino. Planting Date and Water Quality Effects on the Establishment of 2 Warm-Season Grasses under Sub-Surface Drip and Sprinkler Irrigation. 2008 ASA-CSSA-SSSA Annual Meeting Abstracts [CD-ROM computer file].
6. Leinauer, B., and E. Sevostianova. Turf Quality of Minimally Irrigated Warm and Cool Season Grasses. 2008 ASA-CSSA-SSSA Annual Meeting Abstracts [CD-ROM computer file].
7. Sevostianova, E., B. Leinauer, M. Shukla, and B. Maier. Accuracy of Moisture Sensors in Saline Soils. 2008 ASA-CSSA-SSSA Annual Meeting Abstracts [CD-ROM computer file].
8. Leinauer, B., M. Serena, and M. Schiavon. Perennial ryegrass heat and drought tolerance. 2008 Research Report submitted to Pure-Seed Testing.
9. Leinauer, B., M. Serena, T. Barrick. Investigating Seed Coating and Moisture Effects on Turfgrass Germination and Establishment. 2008 Research Report submitted to Barenbrug Inc.
10. Leinauer, B., M. Serena, and M. Schiavon. 2008 Bermudagrass Performance in the Southwest. 2008 Research Report submitted to Pennington/Seeds West and Pure-Seed Testing.
11. Leinauer, B., M. Serena, and M. Schiavon. 2008 Seashore Paspalum Performance in the Southwest. 2008 Research Report submitted to Scotts Co. and Turf Ecosystems, LLC.
12. Leinauer, B., M. Serena, and M. Schiavon. Comparing spring and summer establishment of bermudagrass seed and sod under two irrigation systems using saline water. 2008 Report submitted to the Lawn Institute, The Scotts Co., Seeds West Inc., Pure Seed Testing Inc., Rio Grande Basin

- Initiative, and The Toro Co.
13. Leinauer, B., M. Serena, and M. Schiavon. Comparing spring and summer establishment of bermudagrass and seashore paspalum under two irrigation systems using saline water. 2008 Report submitted to The Scotts Co., Seeds West Inc., Pure Seed Testing Inc., Rio Grande Basin Initiative, and The Toro Co.

## Problem and Research Objectives

**Problem:** Due to rapid population growth and urban development in the United States, current water allocations coupled with expected future demands might soon exceed the supply required to satisfy present per-capita water-use rates. In addition, urban development has also led to the proliferation of recreational areas such as golf courses and athletic fields and irrigation of these areas accounts for a large percentage of total urban water use. This study will assess information on the feasibility of using saline water for the irrigation of cool and warm season grasses in the desert southwest (USDA climate zone 8a). The study will also determine if adequate quality turfgrass can be achieved using subsurface drip irrigation. The combination of 1) irrigation through microsystems, 2) the use of turfgrasses that are adapted to the climatic and soil conditions in the desert southwest, and 3) the use of saline water could reduce the amount of potable water used for turf irrigation and increase the efficiency of irrigation systems in turf areas.

### Objectives:

1. To study the long-term effects of water quality and type of irrigation on turf quality of several warm and cool season grasses in the arid southwest.
2. To study the long-term effects of three salinity levels and two irrigation systems on changes in soil chemical properties at several depths in the turfgrass root zone.

### Methodology

The study, which began in 2005, is being conducted at the NMSU University Golf Course. From 2005 to 2007 the test area included two irrigation types (sprinkler and subsurface drip) as the main block factor; three water quality levels (potable, saline ground water, and a 50/50 mix of both sources) as the split-block factor, and four warm season grasses (bermudagrass, inland saltgrass, seashore paspalum, and zoysiagrass) as the split-split factor. All treatments were replicated three times. The 6' by 6' test plots were evaluated for overall turfgrass color and quality, drought stress, and soil chemical properties. In January of 2008 subsurface drip irrigation had to be terminated because the well used to deliver saline water could no longer provide amounts necessary to water both drip and sprinkler irrigated plots.

### Principal Findings

1. Similar to results obtained in 2007, warm season grasses such as bermudagrass, seashore paspalum, and inland saltgrass remained unaffected by salt accumulation in the rootzone, and plots showed excellent turfgrass quality during the summer of 2008.
2. Salinity (based on electrical conductivity) in rootzones irrigated with potable water was measured at 0.9 dS/m at depths of 10 to 20 cm and 40 to 50 cm in June and at 0.5 dS/m in November. Under saline irrigation electrical conductivity reached 5.6 dS/m and 3.4 dS/m at depths of 10 to 20 cm and 40 to 50 cm respectively in June and 3.0 and 2.1 dS/m in November. Sodium Adsorption Ratio (SAR) reached 11.6 and 10.9 at depths of 10 to 20 cm and 40 to 50 cm respectively in June and 11.2 and 9.1 in November. Preliminary results suggest that downward salt movement occurs to depths of 50 cm when saline water is used for irrigation.
3. Turf plots will be treated with saline water until the end of 2009. Warm season grasses will be evaluated for turf quality, and soil chemical changes in the rootzone will be recorded and documented.

# Estimating Water Use through Satellite Remote Sensing (Bleiweiss)

## Basic Information

<b>Title:</b>	Estimating Water Use through Satellite Remote Sensing (Bleiweiss)
<b>Project Number:</b>	2008NM90B
<b>Start Date:</b>	3/1/2008
<b>End Date:</b>	2/28/2009
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	2
<b>Research Category:</b>	Climate and Hydrologic Processes
<b>Focus Category:</b>	Conservation, Management and Planning, Water Use
<b>Descriptors:</b>	None
<b>Principal Investigators:</b>	Max P. Bleiweiss, Zohrab Samani, Rhonda Skaggs

## Publication

1. Samani, Z., A. Bawazir, M. Bleiweiss, R. Skaggs, and T. Schmugge. Using ASTER Satellite Data to Calculate Riparian ET in the Middle Rio Grande, New Mexico. A refereed journal article accepted for publication in the International Journal of Remote Sensing.
2. Skaggs, R., Z. Samani, A. Bawazir, and M. Bleiweiss. Yield Response to Water in Irrigated New Mexico Pecan Production: Measurements and Policy Implications. in Urbanization of Irrigated Land and Water Transfers. Robert S. Gooch and Susan S. Anderson "eds.". Denver, CO: U.S. Committee on Irrigation and Drainage, 469-480. ISBN: 978-1-887903-25-7.
3. Piñon, Aldo. Evaluating Pecan Water Use in the Mesilla Valley, New Mexico Using Remote Sensing. M.S. Thesis, NMSU Department of Civil Engineering, April 2008.
4. Kirksey, Brad. Measurement Of Water Use (Evapotranspiration) By Alfalfa As Managed By Farmers In Dona Ana County, New Mexico. M.S. Thesis, NMSU Department of Civil Engineering, May 2009.
5. Lopez, Eric. Title to be announced. M.S. Thesis, NMSU Department of Civil Engineering, May 2009.

## Problem and Research Objectives

A recent evaluation of the water budget at Lower Rio Grande has shown that 56% of water is unaccounted for (Magallanez and Samani, 2001). The 56% likely includes domestic water use, riparian vegetation use, supplementary farm irrigation pumping and off-season runoff. In order to better account for the various uses of water and sources of beneficial and non-beneficial use, and ultimately to optimize the use of water resources, a realistic evaluation of the amount and spatial and temporal variation of ET is needed.

For the purpose of the effort, the primary goal is to use the spatial and temporal variation of ET information to assess and map economic return from agricultural activities. Once ET is determined, then biomass can be calculated and linked to crop yield. This could provide an excellent opportunity to evaluate the impact of various parameters such as crop type, field size, soil, etc. on the economic return from irrigated agriculture.

## Methodology

Recent innovations in satellite technology have made it possible to process satellite data to estimate evapotranspiration (ET) with high spatial and temporal resolution. This technology (so named REEM), utilizes remote sensing parameters (land surface temperature (LST), normalized difference vegetation index (NDVI), and short wave albedo along with climate station data to arrive at an estimate of ET. These ET maps will be processed by overlaying agricultural field boundaries (initially, pecan orchards) to arrive at a field by field estimate of total ET. This is then linked to biomass and crop yield for a determination of economic return. Crop coefficients for alfalfa and other crops were also determined.

## Principal Findings

The main objective of the study was to evaluate the water use of the population of pecan orchards in the Valley and to relate pecan ET to the fractional vegetation cover (fc) in order to create crop consumptive models for the study area. An analysis of GIS vector files, ET maps created with two satellite-based remote sensing models, weather data and measured ET was undertaken to study the spatial variation and distribution of ET among the pecan orchards from the Mesilla Valley, New Mexico. A linear model was developed to estimate orchard values of fractional cover (fc) from the normalized vegetation index (NDVI) calculated from remotely sensed data. A pecan model was created for the Valley to estimate the water use of open-canopy orchards that uses midseason NDVI calculated from a single satellite image (as indication of fc) and crop coefficients for unstressed closed-canopy orchards. The results from this study indicated that (a) the annual ET in pecans depicted a high spatial and temporal variation within the orchards of the region, which increased during the midseason to reflect differences in agricultural management practices (irrigation, planting arrangements, etc.), size and age of trees, and the fc; and (b) the annual water use in pecans was linearly related to the fc in a field basis. These findings were different than those found for crops with canopies and growth patterns that are different from pecans, but similar to results reported for similar trees. The main conclusions drawn from this study are the following:

1. Seventy six percent of all the pecan orchards were smaller than 10 acres constituting the 19% of the total area, while the remaining 24% were orchards greater than 10 acres which accounted for the 81% of the total pecan acreage;

2. As modeled by the Landsat model, the orchards greater than 10 acres had a weighted average ET of 1,018 mm/year while the smaller than 10 ac. used 852 mm/year; ASTER yielded a weighted average of 991 mm and 800 mm for the orchards larger and smaller than 10 ac. respectively during 2002;
3. Two main problems affected the accuracy of seasonal ET estimation in the two models (ASTER and Landsat): (a) the missing of portions of annual ET caused by lack of satellite data or a large separation between the dates of satellite imagery in several periods of the year; and (b) the effect of thermal contamination on the computed orchard averages of annual ET; the Landsat model was less affected by these problems due to a larger number of images and higher TIR resolution;
4. Larger orchards (>10 ac.) tended to have larger water consumptions during the year since these were more commercially-oriented than small orchards using higher technology and improved irrigation practices (Skaggs and Samani, 2003);
5. A higher variation (standard deviation) among the crop coefficients of pecans was found during the midseason (April to September) caused by differences in irrigation practices, tree age and size, densities and fractional cover values;
6. The seasonal accumulated ET in at least in a group of pixels in one location agreed well with previous measured ET values from literature, and was more accurate for the Landsat model;
7. The values of  $f_c$  estimated with supervised classification of DOQQs for the orchards, were within the range of measured values, with an absolute difference of 0.07 and average error of 14%;
8. The NDVI was significantly correlated to  $f_c$  values in a field basis ( $R^2 = 0.63$ ); NDVI was found best to predict  $f_c$  compared to other VIs;
9. The NDVI calculated from a single satellite image for the midseason (June 16th) was strongly correlated to pecan annual ET ( $R^2 = 0.73$ ); this relation was used as a model to predict pecan annual water use and adjust  $K_c$  of open-canopy orchard to  $K_c$  of closed-canopy orchards;
10. Monthly crop coefficients predicted from the pecan model compared well with monthly crop coefficients estimated with the remote sensing model (REEM) with a SEE of 0.053 and regression coefficient ( $R^2$ ) of 0.93
11. Yield-ET functions have been developed, using the REEM generated ET estimates and yield data provided by key informants. This research is providing estimates of field-level gross economic returns from consumptive water use by pecans.

Additional work has focused on the determination of  $K_c$  for crops other than pecans and alfalfa (this work was leveraged with funds from the Office of the State Engineer) and preparation for implementation of the findings into the daily operations of the Elephant Butte Irrigation District for more efficient irrigation practices.

# Information Transfer Program Introduction

The New Mexico Water Resources Research Institute maintains an active program to transfer technical information from the producer to the user and the public. Technical publications, newsletters, conferences, symposia, press announcements, and presentations keep practitioners aware of new technology and research advances. The WRRRI homepage ([wrrri.nmsu.edu](http://wrrri.nmsu.edu)) provides online information about the institute's newsletters, technical report series, requests for proposals, upcoming conferences and symposia, and the research reference library. All 53 past annual water conference proceedings have full-text viewing via the institute's homepage. Other federal and state servers, such as the U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, USGS, and National Weather Service are linked to the WRRRI homepage.

# Geographic Information System for Water Resources Research Planning

## Basic Information

<b>Title:</b>	Geographic Information System for Water Resources Research Planning
<b>Project Number:</b>	2002NM1B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2009
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Second
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Management and Planning, Conservation, Water Quality
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Bobby J. Creel

## Publication

1. Creel, B.J., J.W. Hawley, J.F. Kennedy, and A. Granados-Olivas. 2006. Groundwater resources of the New Mexico-Texas-Chihuahua border region. *New Mexico Journal of Science*. 46:11-29.
2. Granados-Olivas, A., C. Brown, J. Greenlee, B. Creel, J.W. Hawley, J.F. Kennedy, O. Dena-Ornelas, and B. Hurd. 2006. Geographic information systems at the Paso del Norte region: The academic accomplishments and challenges for a transboundary water resources GIS cooperation. *New Mexico Journal of Science*. 46:45-56.
3. Kennedy, J.F., R.P. Langford, and J.W. Hawley. 2006. Using GIS and Remote Sensing to Reconstruct Late Quaternary and Early Holocene Paleo-Hydrography Using Climate Data and Modern Topography: An example from the Southwestern US. *Computers and Geosciences*. In press.
4. Kennedy, J.F., R.P. Langford, and J.W. Hawley. 2006. Estimating a Water-Balance Equation for a Playa in the Tularosa Basin of Southern New Mexico. *Computers and Geosciences*. In press.
5. King, J.P., J.W. Hawley, J.W. Hernandez, J.F. Kennedy, and E.L. Martinez. 2006. Study of Potential Water Salvage on the Tucumcari Project, Arch Hurley Conservancy District: Phase I. A pre-appraisal-level study of the potential amount of water that may be saved, and the costs of alternative methods of reducing carriage losses from district canals. *New Mexico Water Resources Research Institute Technical Completion Report 335*, with plates and appendices on CD ROM, New Mexico State University, Las Cruces, New Mexico.
6. Ortiz, Marquita. 2007. The Impacts of Land Use Change on Water Resources and Traditional Acequia Culture in Northcentral New Mexico. Master's thesis, Department of Geography, New Mexico State University, Las Cruces, NM.
7. Alfredo Granados-Olivas, Erick Sanchez-Flores, Antonio De la Mora-Covarrubias, Servio Tulio De la Cruz, Gerardo Reyes-Macías, Francisco Llera-Pacheco, Javier Chavez, Bobby Creel, and Christopher Brown, 2008, Roadmap of Geospatial Education in Mexico, ASPRS 2008 Annual Conference Portland, Oregon, April 28-May 2, 2008.
8. Glaze, Susanna, Bobby J. Creel, Casey Gomez and Royce Stevens, 2008, Rio Grande Basin Initiative Interactive Mapping for New Mexico, In Proceedings of the 2008 AWRA Spring Specialty Conference, San Mateo, CA, March 17-19, 2008.
9. Zhuping Sheng, Christopher Brown, Bobby Creel, Raghavan Srinivasan, Ari Michelsen, and Michael P. Fahy, 2008, Installation of River and Drain Instrumentation Stations to Monitor Flow and Water Quality and Internet Data Sharing, *New Mexico Water Resources Research Institute Technical*

Completion Report 344 and Texas Water Resources Institute Technical Report 320, August 2008, 38 p.

10. Hawley, J.W. and Kernodle, J.M., 2008, Early contributions to arid-zone hydrogeology in the eastern Basin and Range region Historical Note: *Ground Water*, 46(3), 510-516.
11. Eastoe C.J., Hibbs, B.J., Granados-Olivas, A., Hogan, J.F., Hawley, J., and Hutchison, W.R., 2008, Isotopes in the Hueco Bolson Aquifer, Texas (USA) and Chihuahua (Mexico): Local and general implications for recharge sources in alluvial basins, *Hydrogeology Jour.*, 16(4), 737-747.
12. Sandor, J.A., Hawley, J. W., Schiowitz, R.H., and Gersper, P.L., 2008, Soil-geomorphic setting and change in prehistoric agricultural terraces in the Mimbres area, New Mexico, *New Mexico Geological Society Guidebook* 59, 167-175.
13. Hawley, J.W., and Granados-Olivas, A., 2008, Progress report on development of an annotated bibliography for transboundary aquifer systems of Mesilla Basin-Paso del Norte area, New Mexico, Texas, and Chihuahua: 2008 New Mexico Water Research Symposium (N.M. Tech-8/12/2008), N.M. Water Resources Research Institute, NMSU, Symposium Program and Abstracts, p. E-14.
14. Hawley, J.W., and Kennedy, J.F., 2008, Digital hydrogeologic models of basin-fill aquifer systems in the southwestern New Mexico border region A powerful tool for binational water-resources management: American Institute of Professional Geologists 45th Annual Meeting AIPG-AHS-3rd IPGC Symposium, Flagstaff, AZ, Program-Poster Abstract, p. 48.
15. Monger, H. C., Gile, L.H., Hawley, J.W., and Grossman, R.B., 2008, The Desert Project An analysis of arid land soil-geomorphic processes, in Topical Session T17. Integration of soils and geomorphology in deserts: A tribute to the 50 years of soils research of Dan Yaalon: Geological Society of America/Soil Science Society of America-Joint Meeting, *GSA Abstract with Programs*, 40(6).

## Problem and Research Objectives

The New Mexico Water Resources Research Institute has become the focal point for geographic information system (GIS) data and information concerning water resources in New Mexico. It combines database management with digital mapping into spatial-tabular data models. These models are powerful tools for representing and manipulating earth-science information.

As use of geographic information systems has grown and presented new opportunities, it also has raised a number of new issues and problems. Of increasing concern is the management of a growing collection of spatial data sets and applications programs. These data sets and programs are very expensive to produce but relatively easy to share, so there is a great incentive to avoid duplicating production efforts. The trend clearly is toward managing these elements in distributed spatial libraries.

The primary objective of the project is to increase availability and accessibility of water resource information to support water resource planning and management in the state. The first task provides spatial data library accessibility. This task maintains arrangements and establishes those necessary to provide access to spatial data maintained by other agencies and organizations. The second task, spatial data development, evaluates needs, establishes priorities, and undertakes development of spatial data that is otherwise unavailable. These efforts will be coordinated with cooperating agencies and organizations to ensure no duplication of effort and to establish guidelines for coverages and priorities. The principal investigators maintain, update as necessary, and make the data available to cooperating agencies and organizations through both formal and informal arrangements to facilitate water resource planning activities.

## Methodology

A number of cooperative data sharing agreements have been entered into with state, federal, and local agencies and organizations to facilitate access and to develop spatial data. Others will be pursued as necessary. Research funded by the NMWRRI in many cases results in the development of data that can be represented in a spatial form and thus can contribute to the state data pool. Projects that have such a potential are adjusted as necessary to meet this secondary purpose.

The NMWRRI maintains a GIS laboratory consisting of computer workstations; data storage devices; input/output devices (color plotter, digitizer, etc.); software for mapping and analysis (ARC/Info); database development and visualization; and network systems. The laboratory is connected via fiber to the New Mexico State University computer network and thereby to the Internet. The NMWRRI also maintains an Internet web server site through which both spatial and tabular water resource data can be provided.

## Principal Findings

Various research activities are supported by the system for water resources planning in the state. The New Mexico Interstate Stream Commission provides grants to regional groups to support water resources planning. NMWRRI continues to be utilized by the NM Interstate Stream Commission to provide GIS mapping products for use in their plans and in public outreach. NMWRRI has helped many regional groups with GIS mapping products for use in their plans and in public outreach efforts.

Additionally, support has been given to the New Mexico/Texas Water Commission and various public entities of southern New Mexico for their planning activities. GIS mapping support is also provided to the Lower Rio Grande Water Users Organization.

This sophisticated mapping and geo-spatial database management system, originally designed to support WRRI-funded research activities, is now being used for external research grants (e.g., Creation of a Digital Hydrogeologic Framework Model of the Mesilla Basin and Southern Jornada del Muerto Basin; creation of maps for the purpose of water planning funded by the New Mexico Interstate Stream Commission; and pesticide management planning in the state funded by the New Mexico Department of Agriculture) by water resources management and planning agencies in the state. A research grant resulted in the creation of a regional geographic information system to support water planning in the Paso del Norte borderland area of the southwestern United States.

This is an ongoing project with new data continually being added to the database and assistance being given to produce specific GIS products upon request. Continued funding is anticipated from annual state appropriations as well as pending agency awards.

# Information Transfer Program

## Basic Information

<b>Title:</b>	Information Transfer Program
<b>Project Number:</b>	2002NM3B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2009
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Second
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Education, None, None
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Cathy T. Ortega Klett, Bobby J. Creel

## Publication

1. Tillery, S., Z. Sheng, J.P. King, B. Creel, C. Brown, A. Michelsen, R. Srinivasan, and A. Granados. 2006. The Development of a Coordinated Database for Water Resources and Flow Model in the Paso del Norte Watershed. New Mexico Water Resources Research Institute, Technical Completion Report No. 337, New Mexico State University, Las Cruces, New Mexico.
2. King, J.P., J.W. Hawley, J.W. Hernandez, J.F. Kennedy, and E.L. Martinez. 2006. Study of Potential Water Salvage on the Tucumcari Project Arch Hurley Conservancy District: Phase I. A pre-appraisal-level study of the potential amount of saved-water and the costs of alternative methods of reducing carriage losses from district canals. New Mexico Water Resources Research Institute, Technical Completion Report No. 335, with plates and appendices on CD ROM, New Mexico State University, Las Cruces, New Mexico.
3. Bawazir, A.S., J.P. King, S. Kidambi, B. Tanzy, F. Nibling, N.H. Troxel Stowe, and M.J. Fahl. 2006. A Joint Investigation of Evapotranspiration Depletion of Treated and Non-Treated Saltcedar at the Elephant Butte Delta, New Mexico. New Mexico Water Resources Research Institute, Technical Completion Report No. 328, New Mexico State University, Las Cruces, New Mexico.
4. Ortega Klett, C.T. 2006. Proceedings of the 50th Annual New Mexico Water Conference, New Mexico Water: Past, Present, and Future or Guns, Lawyers, and Money. New Mexico Water Resources Research Institute, Conference Proceedings Report No. 339, New Mexico State University, Las Cruces, New Mexico.
5. Ortega Klett, C.T. 2006. Proceedings of the 51st Annual New Mexico Water Conference, Water Quality for the 21st Century. New Mexico Water Resources Research Institute, Conference Proceedings Report No. 340, New Mexico State University, Las Cruces, New Mexico.
6. Sheng, Z., C. Brown, B. Creel, R. Srinivasan, A. Michelsen, and M.P. Fahy. 2008. Installation of River and Drain Instrumentation Stations to Monitor Flow and Water Quality and Internet Data Sharing. New Mexico Water Resources Research Institute, Technical Completion Report No. 344, New Mexico State University, Las Cruces, New Mexico. 47 pp. (co-published as Texas Water Resources Institute Technical Report No. 320)
7. Aragón, C.A. and E.R. Vivoni. 2008. Development and Testing of a Semi-Distributed Watershed Model: Case Studies Exploring the Impact of Climate Variability and Change in the Rio Salado. New Mexico Water Resources Research Institute, Technical Completion Report No. 345, New Mexico State University, Las Cruces, New Mexico. 155 pp.
8. Aldrich, G.A., J. Chermak, and J.A. Thacher. 2008. Water Quality and Land Use: Implications for

- Regulation and Urban Planning. New Mexico Water Resources Research Institute, Technical Completion Report No. 346, New Mexico State University, Las Cruces, New Mexico. 70 pp.
9. Ortega Klett, C.T. 2009. Proceedings of the 53rd Annual New Mexico Water Conference, Surface Water Opportunities in New Mexico. New Mexico Water Resources Research Institute, Conference Proceedings Report No. 347, New Mexico State University, Las Cruces, New Mexico. 134 pp.
  10. Lucas, R.W., T.T. Baker, M.K. Wood, C.D. Allison, and D.M. VanLeeuwen. 2008. Response of Streambanks to Different Intensities and Seasons of Cattle Grazing in Two Montane Riparian Areas in Western New Mexico. New Mexico Water Resources Research Institute, Miscellaneous Report No. 29, New Mexico State University, Las Cruces, New Mexico. 28 pp.
  11. Wood, Karl, 2008, El Agua es Vida or Water is Life, Society of Range Management, 30(5), 6-10.

**Statement of Critical Water Problem:**

The New Mexico Water Resources Research Institute's Information Transfer Program is designed to bring the results of its research projects to the public and to educate New Mexicans on the critical water issues of the state, region, and nation. Different sectors of the public are targeted for each of its activities.

**Statement of Results and Benefits:**

The program goal is to provide people with water information appropriate to their level of training and interest. Information transfer activities are funded primarily from non-federal sources. Responsibilities for different segments of the program have been assigned to various professional and support staff at the institute.

**Nature, Scope, and Objectives:**

The primary methods for information transfer are conferences, publications, audio/visual presentations, and available information on the institute's website. For the past 53 years, the NMWRRI has sponsored the Annual New Mexico Water Conference focusing on a topic of importance to the New Mexico water community. The annual conference is held in different locations around the state, usually in the fall. Most of the conference participants are water resources practitioners working for state, federal, or local agencies, although some members of the general public and of academia also attend. Average attendance ranges between 200 and 350 people, depending on the location and topic of the conference.

Publications include technical completion reports resulting from NMWRRI-sponsored projects, special in-house publications, and conference proceedings. The institute has published more than 375 technical and miscellaneous reports. The peer reviewed technical completion reports are directed toward water professionals working in disciplines related to the research projects. All technical reports are now available via the NMWRRI website in full text. Those interested in a particular report are able to print off the Internet instead of ordering a hard copy of the report. WRI water conference proceedings for the past 53 years are also available online in full text.

A quarterly newsletter, *The Divining Rod*, focuses on research and current water issues. It is emailed to approximately 1,600 readers and hard copies are sent to about 300 readers. The newsletter is available on the WRI homepage.

A reference room, housed at the institute, contains over 11,000 documents and is used frequently by faculty, students, and others. A complete catalog of holdings can be searched through the NMWRRI homepage on the Internet, along with an extensive water resources and information system database.

The institute director and associate director are invited frequently to speak at local, regional, and national conferences and workshops in addition to serving on a number of committees that focus on water resources.

**Accomplishments:**

The 53<sup>rd</sup> Annual New Mexico Water Conference was held in late October in Albuquerque, New Mexico. The conference was entitled, "Surface Water Opportunities in New Mexico." The conference was attended by about 160 participants. A full proceedings of the conference was produced and is available on the WRRI website. All conference participants received a copy on CD.

The NMWRRI coordinated the 2008 Water Research Symposium held on the campus of New Mexico Tech, in Socorro, New Mexico. The one-day "2008 New Mexico Water Research Symposium" was co-sponsored by Sandia National Laboratories, Los Alamos National Laboratory, New Mexico's three state universities, the Office of the State Engineer, New Mexico Interstate Stream Commission, and the AWRA-New Mexico section. Twenty-seven oral presentations were given and 35 posters displayed. Over 127 participants including 45 students from throughout New Mexico, Arizona, and west Texas attended. Nine students gave oral presentations and 26 students presented posters.

In January, the WRRI joined New Mexico State University's International Relations Institute to sponsor a day-and-a-half conference entitled, "Transboundary Water Crises: Learning from Our Neighbors in the Rio Grande (Bravo) and River Jordan Watersheds." A prominent group of speakers from across the U.S., Mexico, and the Middle East discussed the many similarities of the two river basins including their semi-arid landscapes, large human populations, international boundaries, and their use by various cultures. Both watersheds are associated with political tensions and controversies. The conference drew 215 participants including faculty and students from a wide range of academic disciplines. Several media organizations covered the conference including an hour-long interview with several of the conference speakers broadcast in Spanish.

The WRRI co-sponsored the Fall 2008 and Spring 2009 New Mexico State University Water Lecture Series, a monthly seminar with attendance averaging about 100.

The institute's publications for the period included three technical reports: "Water Quality and Land Use: Implications for Regulation and Urban Planning"; "Development and Testing of a Semi-Distributed Watershed Model: Case Studies Exploring the Impact of Climate Variability and Change in the Rio Salado"; and "Installation of River and Drain Instrumentation Stations to Monitor Flow and Water Quality and Internet Data Sharing." The WRRI also published one miscellaneous report, "Response of Streambanks to Different Intensities and Seasons of Cattle Grazing in Two Montane Riparian Areas in Western New Mexico." The 53<sup>rd</sup> Annual New Mexico Water Conference proceedings was produced in hardcopy and on CD. NMWRRI technical completion reports are available at no charge while supplies last. A copy charge is assessed if the report is out of print or has been reprinted.

The institute's publications link on its website averages over 450 webpage hits each month. It averages 320 online requests for publications from its technical and miscellaneous report series and 97 hits per month of its proceedings series each month. Because of the ability to view and print all institute publications online, the WRRI is

averaging only a few requests for hard copies of specific publications each month via the postal mail or visits to the institute. Requests online have more than quadrupled in the past three years.

The institute's quarterly newsletter, *The Divining Rod*, is an eight- to sixteen-page newsletter that focuses on research projects administered by the NMWRRI and on current water issues in New Mexico. It provides information on upcoming conferences, seminars, and workshops; describes new grants and newly released publications; and provides general information on new developments in water resources research and management. Each issue is available on the NMWRRI's homepage. Hard copies of the newsletter are distributed to approximately 300 readers and about 1,600 readers receive it via email. To become more cost-effective and to save resources, the institute recently moved to distributing the newsletter primarily via email. During the reporting period, the institute published one 8-page issue and two 12-page issues of *The Divining Rod*. The newsletter received an average of 114 hits per month online during the reporting period.

Online usage of the WRRI's reference room averages 400 requests per month. During the reporting period, approximately 25 publications were checked out of the library.

The institute's director and assistant director participate in local, state, and national conferences and workshops and speak before many groups. For example, during the reporting period, Director Karl Wood was the plenary speaker before an audience of 250 at the International Rangeland/Grassland Congress in Hohhot Inner Mongolia. His talk was entitled, "Rangeland Management and Hydrology with Special Emphasis on Livestock and Wild Ungulate Use." The director also moderated several panels at local meetings and updated state legislators on desalination research in New Mexico. The associate director presented numerous technical presentations in conjunction with the Rio Grande Basin Initiative and the U.S. Transboundary Aquifer Assessment Program. These presentations were given jointly with students, agency staff, and international faculty members.

The institute director is an active member of the National Institute of Water Resources. The NMWRRI staff also regularly provides expertise for solving specific problems and general concerns. They play a central role in planning for the water future of the region by cooperating with a host of water resources entities throughout the state and region, particularly in the Paso del Norte area.

The Information Transfer Program is an ongoing program with no particular timelines.

# USGS Summer Intern Program

None.

<b>Student Support</b>					
<b>Category</b>	<b>Section 104 Base Grant</b>	<b>Section 104 NCGP Award</b>	<b>NIWR-USGS Internship</b>	<b>Supplemental Awards</b>	<b>Total</b>
<b>Undergraduate</b>	3	3	0	8	14
<b>Masters</b>	9	0	0	5	14
<b>Ph.D.</b>	6	1	0	1	8
<b>Post-Doc.</b>	0	1	0	0	1
<b>Total</b>	18	5	0	14	37

## Notable Awards and Achievements

New Mexico State University researcher Nirmala Khandan was featured among "28 Best & Brightest Ideas" in the Genius Issue of Esquire Magazine, December 2008 for his New Mexico WRRI sponsored project, "Sustainable Recovery of Potable Water from Saline Waters." The low-cost, low-energy desalination process has also featured in several local news articles and has a U.S. and international patents pending.

Elena Sevostianova, Ph.D. student working with New Mexico State University researcher Bernd Leinauer, was awarded first price at the National Agronomy Meeting in Houston, Texas for her poster presentation "Accuracy of Moisture Sensors in Saline Soils." The presentation was co-authored by B. Leinauer, M. Shukla, and B. Maier. NMSU's Department for Communications and Marketing Services issued a press release that was published by numerous newspapers in the State.

Amy Williams, University of New Mexico master's student in the department of Earth & Planetary Sciences, received the American Geophysical Union, Hydrology Section Outstanding Student Paper Award for the 2008 AGU Fall Meeting. Her research is entitled, "Aqueous Geochemistry of the Springs and Wells of the Sevilleta National Wildlife Refuge: Evaluating Hydrochemical Pathways and Microbiology."

Carlos Herrera, New Mexico Highlands University master's student in the department of Natural Resources Management received the Best Poster award at the 2008 New Mexico Water Research Symposium held at New Mexico Tech in Socorro, New Mexico on August 12, 2008. His poster was entitled, "Uranium and Heavy Metals in Macroinvertebrates in the Santa Fe Rivers on the Cochiti Reservation." Carlos's family and representatives from Cochiti Pueblo's environment department helped in the sample collection and lab preparation and were vital in counting invertebrates as well as classifying them to species level.

## Publications from Prior Years

1. 2000NM10B ("Soil Moisture-Rainfall Feedbacks in New Mexico") - Articles in Refereed Scientific Journals - Montandon, L.M., Small, E.E., 2008, The impact of soil reflectance on the quantification of the green vegetation fraction from NDVI, *Remote Sensing of Environment*, 112, 1835-1845.
2. 2000NM7G ("Institutional Adjustments for Coping with Prolonged and Severe Drought in the Rio Grande Basin") - Conference Proceedings - Ward, Frank A., Pulido-Velazquez, Manuel, 2008, Water conservation in irrigation can increase water use, *Proceedings of the National Academy of Sciences of the United States of America*, 105(47), 18215-18220.
3. 2000NM7G ("Institutional Adjustments for Coping with Prolonged and Severe Drought in the Rio Grande Basin") - Articles in Refereed Scientific Journals - Ward, Frank A., Kealy, Mary Jo, Guy, Gary, Manning, Leah M., 2008, Efficient Conservation Measures in Irrigated Agriculture to Sustain Urban and Environmental Water Demands, *Review of Agricultural Economics*, 30(3), 425-434.
4. 2000NM7G ("Institutional Adjustments for Coping with Prolonged and Severe Drought in the Rio Grande Basin") - Articles in Refereed Scientific Journals - Ward, Frank A., Pulido-Velazquez, Manuel, 2008, Efficiency, equity, and sustainability in a water quantity-quality optimization model in the Rio Grande basin, *Ecological Economics*, 66(1), 23-37.
5. 2000NM7G ("Institutional Adjustments for Coping with Prolonged and Severe Drought in the Rio Grande Basin") - Other Publications - Ward, Frank A., 2009, Economics in integrated water management, *Environmental Modelling & Software*, 24(8), 948-958.
6. 2000NM7G ("Institutional Adjustments for Coping with Prolonged and Severe Drought in the Rio Grande Basin") - Articles in Refereed Scientific Journals - Ward, Frank A., Pulido-Velazquez, Manuel, 2009, Incentive pricing and cost recovery at the basin scale, *Journal of Environmental Management*, 90(1), 293-313.
7. 1999NM102B ("Detection of Groundwater through Ultra-Sensitive Magnetic Measurements with Ultra-short Pulse Lasers") - Articles in Refereed Scientific Journals - Smith, David D., Chang, Hongrok, Arissian, L., Diels, J.C., 2008, Dispersion-enhanced laser gyroscope, *Physical Review A - Atomic, Molecular, and Optical Physics*, 78(5).
8. 2006NM41B ("Mitigation of Membrane Biofouling by Harnessing Bacterial Cannibalism (Huang)") - Articles in Refereed Scientific Journals - Igor V. Magedov, Alexander Kornienko, Madhuri Manpadi, Marcia A. Ogasawara, Adriana S. Dhawan, Snezna Rogelj, Severine Van slambrouck, Wim F.A. Steelant, Nikolai M. Evdokimov, Pavel Y. Ugliinskii, Eerik M. Elias, Erica J. Knee, Paul Tongwa, Mikhail Yu. Antipin, 2008, Structural Simplification of Bioactive Natural Products with Multicomponent Synthesis. 2. Antiproliferative and Antitubulin Activities of Pyrano[3,2-c]pyridones and Pyrano[3,2-c]quinolones, *Journal of Medicinal Chemistry*, 51(8), 2561-2570.
9. 2006NM60G ("Impacts of Land Use Change on Water Resources, Water Quality, and Acequia Culture in Northern New Mexico/Southern Colorado") - Articles in Refereed Scientific Journals - Grimsrud, Kristine M., Chermak, Janie M., Hansen, Jason, Thacher, Jennifer A., Krause, Kate, Grimsrud, Kristine M., 2008, A two-agent dynamic model with an invasive weed diffusion externality: An application to Yellow Starthistle (*Centaurea solstitialis* L.) in New Mexico, *Journal of Environmental Management*, 89(4), 322-335.
10. 2006NM60G ("Impacts of Land Use Change on Water Resources, Water Quality, and Acequia Culture in Northern New Mexico/Southern Colorado") - Water Resources Research Institute Reports - Aldrich, Gwendolyn A., Janie M. Chermak, and Jennifer A. Thacher, 2008, Water quality and land use implications for regulation and urban planning. Las Cruces, N.M.: New Mexico Water Resources Research Institute, Technical Report No. 346, New Mexico State University.
11. 2006NM44B ("Development of Geospatial Modeling Tools for Watershed-based Water Resources Management in New Mexico (Vivoni)") - Articles in Refereed Scientific Journals - Forman, Barton A., Vivoni, Enrique R., Margulis, Steven A., 2008, Evaluation of ensemble-based distributed hydrologic model response with disaggregated precipitation products, *Water Resources Research*,

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12. 2006NM44B ("Development of Geospatial Modeling Tools for Watershed-based Water Resources Management in New Mexico (Vivoni)") - Articles in Refereed Scientific Journals - Vivoni, Enrique R., Hernan A Moreno, Mascaro, Giuseppe, Rodriguez, Julio C., Watts, Christopher J., Garatuza-Payan, Jaime, Scott, Russell L., 2008, Observed relation between evapotranspiration and soil moisture in the North American monsoon region, *Geophysical Research Letters*, 35(22).
  13. 2006NM44B ("Development of Geospatial Modeling Tools for Watershed-based Water Resources Management in New Mexico (Vivoni)") - Articles in Refereed Scientific Journals - Dominguez, Francina, Kumar, Praveen, Vivoni, Enrique R., 2008, Precipitation recycling variability and ecoclimatological stability - A study using NARR data. Part II: North American monsoon region, *Journal of Climate*, 21(20) 5187-5203.
  14. 2006NM44B ("Development of Geospatial Modeling Tools for Watershed-based Water Resources Management in New Mexico (Vivoni)") - Articles in Refereed Scientific Journals - Mascaro, Giuseppe, Deidda, Roberto, Vivoni, Enrique R., Mascaro, Giuseppe, 2008, A New Verification Method to Ensure Consistent Ensemble Forecasts through Calibrated Precipitation Downscaling Models, *Monthly Weather Review*, 136(9), 3374-3391.
  15. 2006NM44B ("Development of Geospatial Modeling Tools for Watershed-based Water Resources Management in New Mexico (Vivoni)") - Articles in Refereed Scientific Journals - Istanbuloglu, Erkan, Yetemen, Omer, Vivoni, Enrique R., Gutierrez-Jurado, Hugo A., Bras, Rafael L., 2008, Eco-geomorphic implications of hillslope aspect: Inferences from analysis of landscape morphology in central New Mexico; *Geophysical Research Letters*, 35(14).
  16. 2006NM44B ("Development of Geospatial Modeling Tools for Watershed-based Water Resources Management in New Mexico (Vivoni)") - Articles in Refereed Scientific Journals - Mendez-Barroso, Luis A., Garatuza-Payan, Jaime, Vivoni, Enrique R., Mendez-Barroso, Luis A., 2008, Quantifying water stress on wheat using remote sensing in the Yaqui Valley, Sonora, Mexico, *Agricultural Water Management*, 95(6), 725-736.
  17. 2006NM44B ("Development of Geospatial Modeling Tools for Watershed-based Water Resources Management in New Mexico (Vivoni)") - Articles in Refereed Scientific Journals - Noto, Leonardo V., Ivanov, Valeriy Y., Bras, Rafael L., Vivoni, Enrique R., Noto, Leonardo V., 2008, Effects of initialization on response of a fully-distributed hydrologic model, *Journal of Hydrology*, 352(1/2), 107-125.
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  19. 2006NM44B ("Development of Geospatial Modeling Tools for Watershed-based Water Resources Management in New Mexico (Vivoni)") - Water Resources Research Institute Reports - Aragoïn, Carlos A., and Enrique R. Vivoni. 2008. Development and testing of a semi-distributed watershed model case studies exploring the impact of climate variability and change in the Rio Salado. Technical Report No. 345; New Mexico Water Resources Research Institute, New Mexico State University.
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  21. 2006NM38B ("A Physically-based Parsimonious Approach for Spatial Disaggregation and Recovery of NEXRAD Precipitation Data in Mountainous Terrains (Wilson)") - Articles in Refereed Scientific Journals - Bayani Cardenas, M., Wilson, John L., Haggerty, Roy, Bayani Cardenas, M., 2008, Residence time of bedform-driven hyporheic exchange, *Advances in Water Resources*, 31(10),

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  25. 2006NM51B ("Sustainable Recovery of Potable Water from Saline Waters (Khandan)") - Articles in Refereed Scientific Journals - Gude, V. and Khandan, N., 2009, Desalination at low temperatures and low pressures, Desalination, 244, 239-247.
  26. 2006NM51B ("Sustainable Recovery of Potable Water from Saline Waters (Khandan)") - Articles in Refereed Scientific Journals - Gude, V. and Khandan, N., 2009, Sustainable desalination using solar energy, Submitted to Environ. Sci. & Technol.
  27. 2007NM102B ("Geographic Information System for Water Resources Research Planning") - Conference Proceedings - Glaze, Susanna, Bobby J. Creel, Casey Gomez and Royce Stevens, 2008, Rio Grande Basin Initiative Interactive Mapping for New Mexico, In Proceedings of the 2008 AWRA Spring Specialty Conference, San Mateo, CA, March 17-19, 2008.
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  29. 2007NM102B ("Geographic Information System for Water Resources Research Planning") - Water Resources Research Institute Reports - Zhuping Sheng, Christopher Brown, Bobby Creel, Raghavan Srinivasan, Ari Michelsen, and Michael P. Fahy, 2008, Installation of River and Drain Instrumentation Stations to Monitor Flow and Water Quality and Internet Data Sharing, New Mexico Water Resources Research Institute Technical Completion Report 344 and Texas Water Resources Institute Technical Report 320, August 2008, 38 p.