Water Resources Research Institute

Annual Technical Report

FY 2000

Introduction

This program report provides the required information for projects funded with the Year 2000 base grant and mandatory non-federal matching funds, as well as continuing projects from the Year 1999 program and a project awarded through the 1996 Regional Competitive Grant Program for which New Mexico was the lead institute. Please note that there may be some overlap in information with our 1999 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 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 NMWRRI welcomed new director, Dr. M. Karl Wood in June 2000. Dr. Wood replaced Dr. Tom Bahr who retired after serving as the institute's director for 21 years. Dr. Wood has a long history of outstanding research in water-related issues in New Mexico and the Southwest, particularly in the field of watershed management. He also has administrative experience and a proven ability to work with faculty and the water resource managers and users who are served by the NMWRRI. Dr. Wood plans to emphasize social and economic priorities as well as the physical ones of water conservation and quality, reaching beyond the state borders to a region that includes northern Mexico. Greater demands for and shortages of municipal water at local, state and regional locations will require more in depth answers. Water managers will need more information to live with the increasing government regulations. He would also like to see the institute's role in education and training expanded beyond undergraduate and graduate participation to include kindergarten through high school levels to increase exposure to the field of water resources.

Research Program

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 as well as federal and state agencies, and the USGS State Water Research Institute Program (WRIP). To make the best use of limited resources, the institute has targeted four areas as high priority for funding: water conservation, planning and management; surface-groundwater relationships; water quality; and utilization of saline and other impaired waters. Projects funded in the Year 2000 WRIP included "Ultrafiltration Based Detection of Viruses and Cryptosporidium Oocysts from Environmental Water Samples," and "Genetic Techniques for the Verification and Monitoring of Dahaloethane Biodegradation in New Mexico Aquifers," both of which focused on important water quality issues, and "Information Management Program and Geographic Information Systems for Water Resources Research Planning"which focused on conservation, management and planning.

A project completed in this reporting period entitled "Institutional Adjustments for Coping with Prolonged and Severe Drought in the Rio Grande Basin," that received funding through the 1996 Regional Competitive Grant Program, hopes to impact the conservation, planning and management of water resources in the western United States.

During the reporting period, the NMWRRI administered a total of 26 projects dealing primarily with water quality and conservation issues. The total value of these projects was more than $2 million, including required cost sharing. Awards were made by various federal and state agencies, as well as from the institute’s annual state appropriations. Dollar amounts per project award ranged from under $1k to more than $880k. Research on seven projects was conducted at other universities in the state, while NMSU faculty members were principal investigators on nine projects and NMWRRI staff managed ten projects. The institute maintained frequent contact with its researchers through periodic progress updates, site visits and expenditure tracking.

Research projects utilized at least 30 students during the year including 13 undergraduates, 14 master’s candidates, and 3 Ph.D. candidates.

Projects administered by the NM Water Resources Research Institute during the reporting period that were funded from sources other than the Year 2000 USGS State Water Resources Institute Program are listed below. Note that award value includes both agency and cost sharing where appropriate.

Mapping Services - Regional Water Plan Task Orders #3, #4, #5, #6 and #7. Professional Services Agreement with the NM Interstate Stream Commission, $20,000

New Mexico Pesticide Management Plan. Memorandum of Agreement through the New Mexico Department of Agriculture - US Environmental Protection Agency funding, $70,000

Riparian Evapotranspiration Study of the Middle Rio Grande. US Bureau of Reclamation, NMWRRI and New Mexico State University, $776,145

Sources of Salinity in Rio Grande and Mesilla Basin Aquifers. Joint Powers Agreement with the NM Interstate Stream Commission, $150,000

Evaporation Estimation at Elephant Butte Reservoir - Office of the State Engineer, $64,010

Evaporation Study of Dona Ana County - US Environmental Protection Agency through the Lower Rio Grande Water Users Organization, $45,000

Organizational Review of Transfers of Surface Water from Irrigation to Domestic Use - US Environmental Protection Agency through the Lower Rio Grande Water Users Organization, $39,400

Water Resources Training Program, US Bureau of Indian Affairs, $45,392

Creating a Single Map: Combining Databases to Form a Single Regional GIS System (with University of Texas at El Paso and Universidad Autonoma de Ciudad Juarez faculty) - The William and Flora Hewlett Foundation, $75,000

Hyperfiltration-Induced Precipitation of Sodium Chloride - USGS 1999 WRIP Base Grant, $51,135

Soil Moisture-Rainfall Feedbacks in New Mexico - USGS 1999 WRIP Cost Sharing, $34,429

Detection of Groundwater through Ultra-Sensitive Magnetic Measurements with Ultra-short Pulse Lasers, USGS 1999 WRIP Cost Sharing, $36,741

Impact of Heterogeneous Consumer Response on Water Conservation Goals, USGS 1999 WRIP Cost Sharing, $22,034

Arsenic and Arsenic Species in the Rio Grande, and the Effect of Irrigated Lands, NMWRRI State Appropriations funding, $24,680

A Flash Flood Prediction Model for Rural and Urban Basins, NMWRRI State Appropriations funding, $24,753

Water Valuation Proposal Development, Texas A&M, Texas Agricultural Experiment Station, El Paso, $37,584

Monitoring Network of the Groundwater Flow System in the Mesilla Basin, New Mexico State University, $12,300

Basic Information

Title:	Genetic Techniques for the Verification and Monitoring of Dihaloethane Biodegradation in New Mexico Aquifers
Project Number:	B-03
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Water Quality, None, None
Descriptors:	biodgradation, carcinogen, xenobiotic
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Rebecca Reiss

Publication

Problem and Research Objectives

Fresh water supplies throughout the world are threatened by the release of the dihaloethanes 1,2-dibromoethane (EDB) and 1,2-dichloroethane (EDDC). These compounds are used for industrial, petrochemical, food-industry and agricultural applications. Dihaloethanes are carcinogens known to form adducts with glutathione, which can bind to DNA. Mutations introduced during the replication of adduct-bound DNA can cause cancer. In addition, dihaloethanes are cytotoxic and have been linked with a variety of acute health effects, including damage to the liver, stomach, and adrenal cortex along with significant reproductive system toxicity, particularly to the testes.

According to the EPA's toxic release inventory database, approximately 2,670 pounds of EDB and 433,000 pounds of EDC were released onto land and into water between 1987 and 1993 in America. In New Mexico, approximately 175 locations have or have had EDB or EDC contaminated soil and groundwater, our primary drinking water source. The primary source of EDB and EDC contamination in New Mexico is associated with petroleum refining industries and fuel dispensing systems.

This research project has two objectives: 1) determine the route of the gene (*dhlA*) in aquifers, and 2) determine which microbes may harbor the *dhlA* gene. The hypothesis is that the gene is present at very low levels until selection pressure is increased. Dihaloethanes can provide a rich carbon source for those microbes that harbor the genes to metabolize theses compounds, so there is a strong selective advantage for those microbes that contain the *dhlA* gene in contaminated environments. Since the preliminary experiments involved isolating total DNA from water and sediment samples as a template for PCR, we do not know which microbes harbor this gene, or whether it is chromosomal or extrachromosomal. The hypothesis is that the gene will be found in a variety of naturally occurring microbes due to their ability to transfer genetic information laterally.

Methodology

The first step for Objective 1 was to design a DNA isolation procedure that eliminates all inhibitors of DNA *Taq* polymerase. This enzyme amplifies DNA in the process of polymerase chain reaction (PCR). Modifications to the previously developed DNA isolation protocol include a microfiltration step. Next the conditions to amplify the *dhlA* gene were established using DNA from *Xanthobacter autotrophicus* strain GJ10 as a positive control. A nested PCR strategy was designed in which two consecutive rounds of PCR are performed.

The method suggested to meet the second objective was to clone and sequence the 16SrRNA gene from all the microbes in the aquifer. A different approach is being developed to determine the microbial community of each aquifer. Rather than cloning and sequencing each individual 16S amplification produce, the 16S region is labeled with flourescent primers, digested with restriction enzymes and electrophoresed on the Prism 310 Genetic Analyzer. The data are compared to the ribosomal database to determine the species.

Principal Findings and Significance

Preliminary results demonstrate that microorganisms with the *dhlA* gene are present in several EDB and EDC contaminated aquifers in New Mexico. The polymerase chain reaction (PCR)

method was employed to detect the *dhlA* gene in crude DNA extracted from groundwater samples. Verification, optimization and refinement of this technique will provide a reliable method for detecting and tracking the *dhlA* gene in aquifer systems. Once developed, groundwater and soil samples can be quickly tested for the presence of the gene. This will facilitate the determination of the route of the gene within the aquifers, to track the progress of groundwater remediation plans such as natural attenuation or active bioremediation.

A procedure to isolate DNA and protein from aquifer samples was established. The existence of enzyme activity that breaks down EDC was confirmed. Senior and graduate level students assisted with optimizing the amplification of the 16S RNA gene from cultured samples using flourescently labeled primers, designing of the restriction digestion procedures, and establishing the conditions for capillary electrophoresis.

To expedite the DNA sequencing that was necessary to confirm the identity of the PCR product, students assisted in setting up a sequencing reaction and worked with preparing basic sequence analysis.

The project will continue for a second year with similar objectives, but somewhat different methodology proposed. Because the enzyme activity has been detected, another set of primers will be designed based on the protein sequence of the conserved regions of the protein. These primers will be less specific and will amplify variants of *dhlA* that are missed by the other primers. Gene tracking will begin by testing samples from as many different regions as possible.

Using the process of end-labeled restriction fragment length polymorphisms, the microbial community in each aquifer will be determined. Species living in each aquifer will be compared to the presence of *dhlA* activity. If time permits, the most likely species to harbor the plasmid will be cultured using standard environmental microbiological techniques and tested for the presence of the *dhlA* gene using PCR.

Basic Information

Title:	Ultrafiltration Based Detection of Viruses and Cryptosporidium Oocysts from Environmental Water Samples.
Project Number:	B-02
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Water Quality, None, None
Descriptors:	ultrafiltration, microbial concentration, cryptosporidium
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Kevin H. Oshima

Publication

1. Oshima, Kevin. 2001. Efficient and Predictable Recovery of Viruses and Cryptosporidium Parvum Oocysts from Water by Ultrafiltration Systems. New Mexico Water Resources Research Institute Technical Completion Report No. 315. New Mexico State University. Las Cruces, NM. 55pp.
2. Winona, L. 2000. Optimization of a small and large-scale ultrafiltration system to concentrate viral particles from water. Master's Thesis, Department of Biology, College of Arts and Sciences, New Mexico State University, Las Cruces, NM.
3. Winona, L. May 2000. Optimization of a small and large-scale ultrafiltration system to concentrate viral particles from water, presented at the American Society for Microbiology Annual Meeting, Los Angeles, CA
4. Olszewski, J. and K.H. Oshima. 2000. Small scale tangential flow ultrafiltration of environmental waters. Proceedings of the Water Technology Conference, American Water Works Association. (in press)
5. Kuhn, R.C. and K.H. Oshima. Small scale hollow fiber ultrafiltration of Cryptosporidium parvum oocysts from water. (submitted)
6. Winona, L., A. Ommani, J. Olszewski, J. Nuzzo and K. Oshima. Characterization and optimization of ultrafiltration for concentrating viruses from environmental water from small volumes of water. Applied and Environmental Microbiology. (submitted)

Problem and Research Objectives
In terms of drinking water safety, very little is know about the extent of viral and parasitic contaminants in source (influent) and product (finished) drinking water and their relationship to disease. Critical to identifying and quantitating water-borne pathogens is the development and use of methods that reliably concentrate pathogens from drinking, surface and ground waters.

The U.S. Environmental Protection Agency (EPA) has mandated that large water utilities in the U.S. test their source and product water for viral pathogens from surface or groundwater systems. There is growing concern for the potential health risks associated with the presence of pathogens in surface, ground and drinking waters, however, little data were available to determine how significant the risks.

By the end of the funding period, the following objectives were to have been completed: 1) Complete optimization for the recovery of viruses (T1,PP7 and poliovirus) and *Cryptosporidium* oocysts from spiked environmental water samples using field scale ultrafiltration systems. 2) Optimization of processes downstream of the initial ultrafiltration step to allow for the concentration of the water sample to the final concentrate. 3) Complete optimization studies for integrating PCR assays for enterovirus and *Cryptosporidium* oocysts into the concentration and detection system. 4) Field testing for the detection of bacteriophage, enteroviruses and *Cryptosporidium* from tap, surface and ground water. 5) If time allows, begin initial tests to determine the sensitivity and reproducibility of other waterborne viruses in small scale testing.

Methodology
A prototype of the field scale ultrafiltration system has been developed and was used for this project. This system has a centrifugal pump and can easily be adjusted to accommodate either a field scale hollow fiber or a tangential flow ultrafiltration system.

For surface water samples, an initial prefiltration step has been developed to reduce fouling of the ultrafilter and remove large pieces of debris. Each experiment will be done in triplicate. Treatment of the phage sample with ether in the final concentrate may be used if microbial contamination interferes with the plaque assay.

Principal Findings and Significance
Virus Recovery
Results indicate that the recovery of the model viruses from small-scale (2L) samples produced similar results when expanded to a 100L field-scale system for both ultrafiltration systems. This suggests that it is appropriate to use small-scale experiments to predict performance from a large-scale system.

Both ultrafiltration systems appear to be reusable many times after sanitation. Both ultrafiltration systems were able to filter 100L of surface water (as high as 50NTU) in 2.5 hours with minimal prefiltration.

The most efficient recoveries were produced when the filters were blocked with 5% FBS or calf serum. After the filtration process 0.05 M glycine is added to the retentate and the retentate is

recirculated through the ultrafilter for 30 minutes for the hollow fiber and for the tangential ultrafilter. For surface water samples, after the retentate/eluent is recirculated, a fresh solution of 0.05 glycine is added to the filter module and agitated for 15 minutes and eluent is added to the retentate. Recoveries of 69-86% were obtained for the three model viruses from 100L of ground or surface water with the hollow fiber ultrafiltration system and 57-100% from the tangential flow system from 100L.

The hollow fiber ultrafiltration system appeared to provide slightly more consistent recoveries between the three viruses than the tangential flow ultrafilter, although both systems appear to be feasible for concentrating viruses from field-scale volumes.

Cryptosporidium Oocysts

Recoveries of *Cryptosporidium* oocysts appear to be efficient and similar in 2L and 10L hollow fiber ultrafiltration systems. In 10L of surface water, recoveries were from 54-88%. Filters can be sanitized between uses to remove oocysts by overnight incubation of the filter modules in 5% SDS at 37°C. Viruses and oocysts can be concentrated together in the hollow fiber ultrafiltration system, taking the place of what has been two separate processes.

Basic Information

Title:	Information Management Program and Geographic Information Systems for Water Resources Research Planning
Project Number:	B-04
Start Date:	3/1/2000
End Date:	2/28/2001
Research Category:	Engineering
Focus Category:	Conservation, Water Quantity, Water Quality
Descriptors:	geographic information systems, water resources information, data development
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Bobby J. Creel

Publication

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.

It also will evaluate needs, establish priorities and undertake development of spatial data that is otherwise unavailable. These efforts will be coordinated with cooperating agencies and organizations to assure no duplication of effort and establish guidelines for coverages and priorities

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 will provide spatial data library accessibility**.** This task will maintain arrangements and establish those necessary to provide access to spatial data maintained by other agencies and organizations. The second task, spatial data development, will evaluate needs, establish priorities and undertake development of spatial data that is otherwise unavailable. These efforts will be coordinated with cooperating agencies and organizations to assure no duplication of effort and establish guidelines for coverages and priorities. The principal investigator will 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, and visualization; as well as 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 and Significance

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 has been 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., sources of salinity in the Mesilla Valley and creation of maps for the purpose of water planning funded by the New Mexico interstate Stream Commission, and the New Mexico Department of Agriculture for pesticide management planning in the state) by water resources management and planning agencies in the state. A recent research grant resulted in the completion of two detailed reports on transboundary groundwater aquifers of southwest New Mexico, funded by EPA-Region 6. The system has widespread applicability for water rights administration and stream adjudications.

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.

Basic Information

Title:	Hyperfiltration-Induced Precipitation of Sodium Chloride
Project Number:	B-03
Start Date:	7/1/1999
End Date:	6/30/2000
Research Category:	Water Quality
Focus Category:	Treatment, Water Quality, None
Descriptors:	reverse osmosis, membrane, hyperfiltration
Lead Institute:	Water Resources Research Institute
Principal Investigators:	T. Michael Whitworth

Publication

1. Whitworth, T.M. and Chen Gu. 2001. Hyperfiltration-induced precipitation of sodium chloride. New Mexico Water Resources Research Institute Technical Completion Report No. 314. New Mexico State University, Las Cruces, NM. 35 pp.
2. Whitworth, T.M. and G. DeRosa. Experimental evidence for hyperfiltration-induced precipitation of heavy metals. Chemical Geology (submitted)

Problem and Research Objectives

Less than two percent of the world's water supply is fresh water suitable for drinking. The rest is too saline for human consumption. Especially in arid or semiarid areas, fresh water supplies are being used up faster than they can be naturally replaced. It is increasingly important that cost-effective methods be developed for use of saline or other impaired waters in order to ensure adequate future water supplies for the state of New Mexico, as well as the rest of the world.

Conventional reverse osmosis shows great promise of providing an economical method of purifying saline and other impaired waters. However, reverse osmosis is presently limited by a relatively large waste stream which, for some applications, can be as much as 80% of the total volume treated. High waste disposal costs rule out or severely limit the use of reverse osmosis for many applications.

The goal of this project was to reduce the reverse osmosis waste stream to a solid - a reduction in waste volume of up to four orders of magnitude - thus allowing all of the water input into the system to be purified.

Methodology

Two types of experiments were to be performed. The first set passed undersaturated NaCl solutions through montmorillonite clay membranes and focused on 1) measuring the non-equilibrium thermodynamic membrane coefficients of the clay membranes, 2) measuring precipitation rate constants, and 3) testing theoretical models. The second set of experiments focused on testing and refining the bench-scale, reverse-osmosis waste reduction system and collecting performance data to aid further design work to 1) scale up the system for commercial use, and 2) design an under-sink system for homeowner use.

Principal Findings and Significance

A series of seven experiments were completed where undersaturated NaCl solutions were passed through clay membranes. Most of these solutions were approximately 90% saturated. NaCl crystals were observed on the membranes for several experiments and X-ray dispersive scans during examination with the microprobe. While the experiments demonstrated the validity of the proposed process, development of commercial applications will take further work. Work is continuing on developing commercial applications at the Petroleum Recovery Research Center at New Mexico Tech. The project continuation has been funded by the National Petroleum Technology Office of the Department of Energy.

Basic Information

Title:	Institutional Adjustments for Coping with Prolonged and Severe Drought in the Rio Grande
Project Number:	G-01
Start Date:	9/1/1997
End Date:	2/28/2001
Research Category:	Climate and Hydrologic Processes
Focus Category:	Drought, Economics, Hydrology
Descriptors:	drought, model, water rights, water banking
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Frank A. Ward, Robert A. Young, Ronald D Lacewell, W. Marshall Frasier, John Ellis

Publication

1. Ward, FA, R Young, R Lacewell, JP King, M Frasier, JT McGuckin, C DuMars, J Booker, J. Ellis, R Srinivasan. 2001. Institutional Adjustments for Coping with Prolonged and Severe Drought in the Rio Grande Basin. New Mexico Water Resources Research Institute Technical Completion Report No. 317. New Mexico State University. Las Cruces, NM. 249pp.
2. Booker, JF, FA Ward. 1999. Instream flows and endangered species in an international river basin: the upper Rio Grande. American Journal of Agricultural Economics. Vol 18 (5) pp 1262-1267.

Problem and Research Objectives
Serving over one-million acres of irrigated land and the domestic and industrial needs of cities like Albuquerque and El Paso, the Rio Grande represents a most significant resource in that portion of the arid southwest. Sixty years ago, an agreement called the Rio Grande Compact was approved by Congress which divided the waters among the three states and Mexico into fixed proportions. Since that time, significant growth in the basin's demand for water, associated with growth in the economy and population and new policies toward fish and wildlife habitat, have strained the region's limited water supply. Although the inevitable severe drought will cause significant economic damages to the regional economy, the present institutional arrangements have not had to actually confront such an event.

The primary objective of the research was to test the hypothesis that new institutions for interstate coordination of surface water withdrawal and reservoir operations could promote more economically efficient spatial and temporal water use patterns, particularly during drought.

Methodology
The following institutional innovations were selected for evaluation, short-term leasing, dry-year options, water banking, water rights markets, and reservoir management options.

A three-state research team of economists, hydrologists and a lawyer was formed to perform the analysis. A linked hydrologic-economic-institution model was developed. At this stage, the modeling effort includeed only the Upper Rio Grande basin, from Colorado through New Mexico to Fort Quitman, Texas, just below El Paso. Modeling of the lower basin, including water uses and inflows from Mexico has not been attempted.

The general approach reflects the random supplies and uncertain demands from economic growth and endangered species policies for water and river and reservoir management rules. Water supplies, which include all major tributaries and interbasin transfers, and hydrologically connected groundwater, are represented in a monthly time-step over a thirty year planning horizon. The portion of the basin selected for study is represented by 16 reaches or nodes. Drought damage functions have been estimated for agricultural water uses, the major source of demands for each significant irrigation district. Urban and instream demands are also represented. The optimization procedure, which maximizes economic benefits subject to hydrologic, engineering and institutional constraints, is solved with GAMS optimization software.

Principal Findings and Significance
This project has developed a model that responds to relative scarcity as those scarcities are reflected through compact deliveries and other institutions. While the model is not designed to generate the precise detail on how all of the institutions would respond and with what economic consequences, it is an important first step in bringing objective science to bear on important water policy decisions.

There is no issue more complex and more important to the people of the Upper Rio Grande Basin than understanding the hydraulic connection between the groundwater pumping in the region and

the flows of the Rio Grande. Computer model results are not facts; they predict outcomes which may or may not ultimately be consistent with what occurs in the future. The model developed for this study had most of the factors built in that were of importance to policymakers to support water policy decisions, at least in a rudimentary way. Important future model improvements would focus on relations between streamflows and environmental benefits of various kinds. Endangered species requirements and human values and benefits associated with those requirements are important issues that are largely untouched by this study. This study needs to be supplemented in future work by an analysis of the impact on water quality at various reaches of the river.

Basic Information

Title:	Detection of Groundwater through Ultra-sensitive Magnetic Measurements with Ultra-short Pulse Lasers
Project Number:	B-06
Start Date:	7/1/1999
End Date:	8/31/2000
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Water Supply, None
Descriptors:	groundwater, monitor, magnetic sensing, laser
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Jean-Claude Diels

Publication

1. Meng, X., J.-C. Diels D, Kuhlke, R. Batchko and R. Byer. 2001. Bidirectional, synchronously pumped, ring optical parametric oscillator. Optics Letters. Vol 26(5), pp 265-267.
2. Jones RJ, JC Diels, J Jasapara, W Rudolph. 2000. Stabilization of the frequency, phase, and repetition rate of an ultra-short pulse train to a Fabry-Perot reference cavity. Optics Communications. Vol 175 (4-6) pp 409-418.
3. Diels, Jean-Claude. 2001. Detection of Groundwater Through Ultra-sensitive Magnetic Measurements with Ultra-short Pulse Lasers. New Mexico Water Resources Research Institute Technical Completion Report No. 313. New Mexico State University, Las Cruces, NM. 29 pp.
4. Jones, RJ and JC Diels. 2001. Stabilization of femtosecond lasers for optical frequency metrolgy and direct optical to radio frequency syntheses. Physical Review Letters. Vol 86(15) pp 3288-3291.

Problem and Research Objectives

There are two basic areas of water resources that this proposal addressed: exploration of new, unknown sources of groundwater, and monitoring of the growth/decay of large aquifer layers. This research project proposed to develop new tools to locate hitherto unknown groundwater reservoirs, and to monitor the growth and decay of known groundwater layers.

The goal for this one-year project was to demonstrate and compare new methods of magnetic sensing (vertical component of the earth magnetic field, or susceptibility measurement), which meet certain criteria. The objective is to produce an experimental demonstration of two approaches, as well as their applicability to the detection of groundwater from the air.

Methodology

Two new techniques were developed, using a mode-locked ring laser, to resolve such variations of magnetic susceptibilities: 1) monitoring the vertical component of the earth's magnetic field, and 2) measurement of a change in resonance frequency of a large coil. Both methods are based on the use of a mode-locked ring laser as the most sensitive detector of variation of phase along a light path.

Principal Findings and Significance

This project developed instrumentation to detect or monitor underground water pockets through 1) change of the vertical component of the earth magnetic field, or 2) extremely accurate measurements of the magnetic susceptibility.

The basic principle was to translate a differential phase shift into a frequency difference between the two output beams of a ring laser. Magnetic field changes were translated into phase shifts when the intracavity beams traverse a resonant atomic vapor inside the cavity. New stabilization techniques had to be developed to stabilize the pulsed laser to a narrow atomic transition. Basic stabilization research was performed with a Ti:sapphire laser. Optical parametric oscillators and solid state diode pumped lasers were developed in order to lead to a practical instrument that could be used in the field. Progress on fiber laser research leading to the development of magnetic susceptibility detector was also reported.

A practical instrument has to be portable, which was not the case with the Ti:sapphire laser. Therefore, development of a diode laser pumped mode-lock was started in parallel. Further research is in progress to try to overcome this difficulty. Another alternative pursued in parallel was the development of a parametric oscillator ring laser gyro. Stabilization problems have hindered the final magnetic field detection phase.

It appears at this point that research must continue in the future before prototypes of the various designs are tested and ready for use. Private support for the continuation of this research is being pursued.

Basic Information

Title:	The Impact of Heterogeneous Consumer Response on Water Conservation Goals
Project Number:	B-07
Start Date:	7/1/1999
End Date:	9/30/2000
Research Category:	Social Sciences
Focus Category:	Economics, Conservation, Law, Institutions, and Policy
Descriptors:	demographics, economics, consumer, policy
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Janie M. Chermak, Kate Krause

Publication

1. Chermak, J.M. and K. Krause. 2001. The Impact of Heterogeneous Consumer Response on Water Conservation Goals. NM Water Resources Research Institute Technical Completion Report No. 315. New Mexico State University, Las Cruces, NM. 55pp.

Problem and Research Objectives
It has long been recognized that water is one of the most critical resources in the Southwest. Growth and demographic changes, as well as refined estimates of the available water resource are requiring suppliers to plan for the future and to implement changes in the current system. In order to assure an adequate supply of water, conservation is and will continue to be an important factor in efficiently managing water resources. Consumer response to policy initiatives will be a decisive factor in the role conservation plays in the effectiveness of water management. To incorporate consumer response into evaluation of proposed conservation programs and into forecasts of future water demand, it is necessary to employ consumer demand models that are sufficiently robust to account for heterogeneity across consumer groups.

The objectives of this research were to 1)identify statistically significant consumer characteristics that are factors of demand for water through a series of economic experiments and surveys, 2) test consumer response to wide ranges of pricing options, 3) econometrically model water demand at a disaggregate level by incorporating the significant consumer characteristics into the model, and 4) design a conservation incentive program that allows individuals to choose their own best conservation alternative while, in aggregate, achieving the conservation program goals.

Methods
Three distinct methodologies were employed in this research: 1) Collection of data - In order to collect a data set that is sufficiently rich in detail to allow modeling of disaggregated demand functions, an experimental game design was used, supplement by a survey administered to all participants to collect salient demographic and economic information. 2) Demand modeling - Using the non-parametric results for guidance, an econometrically estimated consumer demand model was developed for each specific consumer group. 3) Construction of an incentive compatibility (non-linear price) model - Combining the empirical results, specific to this research with the theory presented in the extant literature allowed the development of a non-linear pricing structure which gives the customer flexibility, while allowing the water manager to meet conservation or policy goals.

Principal Findings and Significance
Many policies intended to ameliorate water shortages in the arid Southwest attempt to induce consumers to reduce their use of water. The relative effectiveness of each policy depends on consumer response to that policy. Therefore it is imperative that we understand consumer demand for water.

Water demand varies across consumers. Some of that variation is correlated with observable characteristics. A series of experiments was used to investigate consumer heterogeneity, and consumption differences were found, based on employment status and a variety of social and cultural factors.

Some of the variation in water demand cannot be predicted based on observable characteristics. By disaggregating demand by type, we show that a menu of price systems can achieve conservation goals with less loss of consumer welfare than can alternative polices. Furthermore, these systems can be designed so that each consumer has an incentive to choose the one that is

most beneficial given his or her unique demand. Thus enforcement costs are minimized. Similar analyses can be carried out to determine the impact of other conservation mechanisms, such as offering rebates for xeriscaping.

Extensions to this research include additional experiments to determine the impact of observable characteristics over a wider range of prices. This is particularly relevant, considering the results of the conservation example. In addition, incorporating conservation devices into our analysis will aid in the design of alternative conservation mechanisms.

Basic Information

Title:	Soil Moisture-Rainfall Feedbacks in New Mexico
Project Number:	B-05
Start Date:	7/1/1999
End Date:	6/30/2000
Research Category:	Ground-water Flow and Transport
Focus Category:	Climatological Processes, Hydrology, Drought
Descriptors:	precipitation, climate, rainfall variability
Lead Institute:	Water Resources Research Institute
Principal Investigators:	Eric E. Small

Publication

1. Small, Eric E and Shirley Kurc. 2001. The Influence of Soil Moisture on the Surface Energy Balance in Semiarid Environments. New Mexico Water Resources Research Institute Technical Completion Report No. 318. New Mexico State University, Las Cruces, NM. 30 pp.
2. Hostetler, SW and EE Small. 1999. Response of North American Freshwater Lakes to Simulated Future Climates. Journal of the American Water Resources Association. Vol 35 (6), pp 1625-1637.

Problem and Research Objectives
Roughly half of the annual precipitation in New Mexico accumulates during July, August and September. This precipitation is heavily used in the semi-arid climate of the state. Problems associated with this water resource arise because the amount of precipitation that accumulates during the summer season in New Mexico varies substantially from year to year. Both drought and flood conditions have negative consequences on a wide variety of human activities. The negative effects of summertime precipitation variability could be lessened by a prediction system that allows for planning and preparation for season-long rainfall anomalies.

Prediction of these summertime precipitation anomalies in New Mexico would be aided by a more complete understanding of how different components of the climate system contribute to rainfall variability. One source of persistent rainfall anomalies may be the soil moisture state. The objective of this research is to assess how soil moisture affects land-atmosphere interactions in the semi-arid climate of New Mexico. If soil moisture effects are substantial, then soil moisture-rainfall feedbacks may contribute to the variability of summertime precipitation in New Mexico.

Methodology
The research was conducted in the Sevilleta LTER located in central New Mexico, well suited for the study because the meteorological stations deployed can be linked to the network that is already in place. Numerous data sets already exist which will be used to guide the research. Field measurements were conducted during the summer season which allowed observation of the land surface changes associated with the onset of the Mexican monsoon at the end of June. Data analysis were completed in subsequent months.

A meteorological station designed to measure surface fluxes via the Bowen ratio method was installed. It was designed to take measurements of the following variables: 1) soil moisture; 2) ground temperature; 3) ground heat flux; 4) latent and sensible heat fluxes; 5) downward and upward shortwave and long wave radiation; 6) boundary layer moist static energy; and 7) precipitation. Soil moisture was measured daily, and more frequently after precipitation events at several depths using Time Domain Reflectometry (TDR).

Principal Findings and Significance
Data analysis yielded four major results concerning the nature of soil moisture-rainfall feedbacks in semi-arid regions.

1) The SEB response to rainfall inputs is dramatic: Changes in the evaporative fraction (EF) resulting from wet versus dry soil moisture conditions are dramatic. This demonstrates that the SEB response to rainfall, at least in terms of latent heating, is substantial and could yield a feedback with the atmosphere.
2) Net radiation-soil moisture relationships: Net radiation and available energy both increase when the soil is wet, in both the grass and shrub environments. The ground heat flux is enhanced when the soil is wet, which decreases the intensity of the net radiation and available energy response, however changes in available energy are still substantial. More work is needed to test this result.
3) Hydrologic persistence is limited: The intense EF and net radiation responses to rainfall events

and the attendant rise in soil moisture is short lived, at all locations across the ecotone. During the peak of the monsoon season, EF drops to only 25% of the maximum observed values before the next rainfall event occurs. The high latent heating and net radiation caused by wet soil can only increase the likelihood of precipitation for several days following a rainfall event. Therefore, a soil-moisture rainfall feedback will only exist if the atmospheric conditions conducive for covective precipitation occur within several days after a rainfall event.

4) Plant type does not influence the soil moisture-rainfall feedback: The evaporative fraction and net radiation response to rainfall is nearly identical in grass and shrub-dominated environments. In addition, the persistence of anomalous conditions following rainfall events is similar across the ecotone. Therefore, we conclude that plant type does not influence the nature of soil moisture-rainfall feedbacks in semiarid regions. In these environments, the soil moisture-rainfall interactions appear to be dominated by the magnitude and timing of rainfall events.

Information Transfer Program

The institute maintains a vigorous 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. NMWRRI's homepage http://wrri.nmsu.edu provides on-line information about the institute.

Basic Information

Title:	Information Transfer Program
Start Date:	3/1/2000
End Date:	2/28/2001
Descriptors:	information transfer, information dissemination, education
Lead Institute:	New Mexico State University
Principal Investigators:	Bobby J. Creel

Publication

1. Proceedings of the 44th Annual New Mexico Water Conference, ed. C. Ortega Klett. 2000. The Rio Grande Compact: It's the Law. Santa Fe, NM. December 2-3, 1999. New Mexico Water Resources Research Institute Report 312.
2. Proceedings of the 43rd Annual New Mexico Water Conference, ed. C. Ortega Klett. 1999. Water Challenges on the Lower Rio Grande. Las Cruces, NM. October 22-23, 1998. New Mexico Water Resources Research Institute Report 310.
3. Hawley, JW, B Hibbs, JF Kennedy, B Creel, M Remmenga, M Johnson, M Lee and P Dinterman. 2000. Trans-International Boundary Aquifers in Southwestern New Mexico. New Mexico Water Resources Research Institute Technical Report (EPA X-996350-01-3). 126 pp. Plate, CD-ROM.
4. Creel, B, T Sammis, JF Kennedy, DO Sitze, D Asare, HC Monger and ZA Samani. 1998. Groundwater Aquifer Vulnerability Assessment and Management Practices Evaluation for Pesticides in the Mesilla Valley of New Mexico. New Mexico Water Resources Research Institute Technical Report No. 305. New Mexico State University, Las Cruces, NM. pp 81, maps, CD-ROM

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. 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.

The primary methods for information transfer are conferences, publications and audio/visual presentations. Publications include technical completion reports resulting from NMWRRI sponsored projects, special in-house publications, conference proceedings and a periodic newsletter. Responsibilities for different segments of the program have been assigned to various professional and support staff at the institute.

The institute director and other professional staff were frequently invited to speak at local, regional and national conferences and workshops, in addition to serving on a number of committees that focus on water resources. The NMWRRI staff also regularly provided expertise for solving specific problems and general concerns. The staff played 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.

Since its inception in 1956, the most visible component of the information transfer program has been the Annual New Mexico Water Conference. In December 2000, the 45th annual conference was held in Albuquerque with more than 300 registrants to hear presentations on the topic "Water, Growth and Sustainability: Planning for the 21st Century." A half-day workshop on Water Banking was held in conjunction with the conference. The conference proceedings will be available both in hard copy and on the institute's website in summer 2001.

Three periodic issues of the institute's newsletter, "The Divining Rod" were distributed to more than 1900 individuals, academic departments and agencies during the reporting period.

The institute averages about 125 requests for general information and nearly 50 requests for specific publications each month. A reference room, housed at the institute, contains almost 10,000 documents and is used frequently by faculty, students, and others. A complete catalog of holdings can be searched through the NMWRRI home page on the Internet, along with an extensive water resources and information system database and other information about the institute. Approximately five hundred inquiries per month are received on the home page. newsletters, technical report series, requests for proposals, upcoming conferences, and the research reference library. Starting with the 44th Annual New Mexico Water Conference Proceedings, all papers will have full-text viewing via the institute's homepage. Other federal and state servers, such as the U.S. Environment Protection Agency, Army Corps of Engineers, US Geological Survey and National Weather Service are linked to the WRRI homepage.

USGS Summer Intern Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	5	0	0	0	5
Masters	3	3	0	0	6
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	9	3	0	0	12

Notable Awards and Achievements

Concentration of Viral Particles from Water by Ultrafiltration

In the last year, New Mexico State University Professor Kevin Oshima has initiated two new collaborations as a result of his research. He has entered into an agreement with Neoh, a startup filter company in the Netherlands, to assist in the development of a disposable hollow fiber filter for concentration of pathogens from water. He has also signed a Cooperative Research and Development Agreement with the Centers for Disease Control and Prevention in Atlanta to develop jointly a method to concentrate and detect human secretory IgA from water as an approach to assess whether water has been contaminated with human fecal material. Oshima's graduate student, John Olszewski, received a second place for his presentation on tangential flow ultrafiltration to concentrate viruses at New Mexico State University's Biology Department Research Symposium in March 2000.

Hyperfiltration-Induced Precipitation of Sodium Chloride

The New Mexico WRRI supported research under the direction of Dr. Michael Whitworth of New Mexico Institute of Mining and Technology, which resulted in a reverse osmosis waste reduction system that significantly cuts waste disposal costs, thus improving on the commercial viability of the method. As a follow-up to this project, Dr. Whitworth has received a $1.2 million grant from the Department of Energy for a project entitled Development of a Modified Reverse Osmosis System for Treatment of Produced Water.

Detection of Groundwater through Ultra-Sensitive Magnetic Measurements with Ultra-short Pulse Lasers

Research investigator Jean-Claude Diels, University of New Mexico, was invited to present results related to his project as a plenary talk at the Remtosecond Technology FST2000 conference in Tsukuba, Japan.

Publications from Prior Projects

1. Huffaker, RG, N Whittlesey, AM Michelsen, RG Taylor and T McGuckin. 1998 Evaluating the effectiveness of conservation water pricing programs. Journal of Agricultural and Resource Economics. V23(#1), pp 12-19.
2. Johnson, MD, RM Wingo, CM Vogels and BB Lorenz. 2000. The oxidation and remediation of arsenic compounds by ferrate. Environmental Science and Technology (submitted)
3. Michelsen, A.M., R.G. Taylor, R.G. Huffaker and T. McGuckin. 1999. Emerging agricultural water conservation price incentives: Irrigation district rate structures, water use and objectives. Journal of Agricultural and Resource Economics. V24(#1), pp 222-238.