DIVINING ROD
NEW MEXICO WATER RESOURCES RESEARCH INSTITUTE
Vol. XXVII, No. 1 Spring 2004

NMSU Scientists Developing a Laser-based Detection System for Water-borne Pathogens

New Mexico State University biologists Geoffrey B. Smith and Kevin H. Oshima have teamed up with NMSU's physics department to develop a detection system for pathogens that could one day help provide a timely warning of biological contamination of water supplies. The ultimate goal of the project is to produce an ultra-sensitive handheld device for quickly detecting pathogens in a variety of application areas, including border inspection and homeland security situations.

To this end, state-of-the-art laser technology supplied by physicists Robert Armstrong and Joseph R. Montoya is being conjoined with Smith and Oshima's expertise in immunoassay techniques to identify distinct light signals from irradiated pathogens. In particular, they are seeking to exploit the light scattering phenomenon known as surface-enhanced Raman scattering.

When laser light impinges on particles, some of the light is absorbed and some is scattered. If some of the scattered part is collected by a suitable detector, it may be found to contain information about the particles interacting with the light. This is the case for the process known as Raman scattering, in which the incident light is inelastically scattered and shifted in frequency by the energy of its characteristic molecular vibrations, which pro-vides a spectroscopic fingerprint for the observer.

In the past, the main drawback of this approach has been the weakness of the returned signal. However, when molecules are adsorbed onto metal colloids, their Raman spectra exhibit a very large signal enhance-ment. This effect has been studied repeatedly since its discovery in 1974 and is known as surface-enhanced Raman spectroscopy or "SERS". The signal enhancement comes about because an additional resonant electric field is induced when electromagnetic radiation is incident on a metal colloid particle. This resonance effect is a result of the electrons in metals behaving like a sea of free negative charges, or a plasma. In effect, the scattering molecules find themselves sitting on "hot spots," which can magnify their scattering signal millions of times.

To apply SERS for use in detection of biological materials, it is necessary to tag them with metal colloid particles,

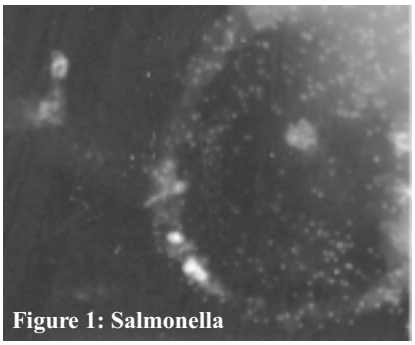
Figure 1: Salmonella

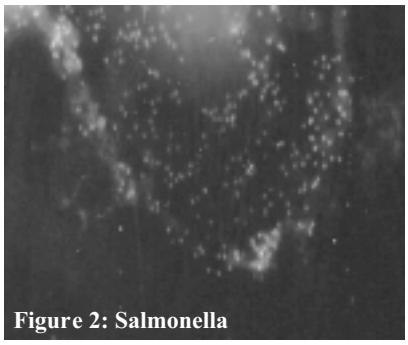
Figure 2: Salmonella

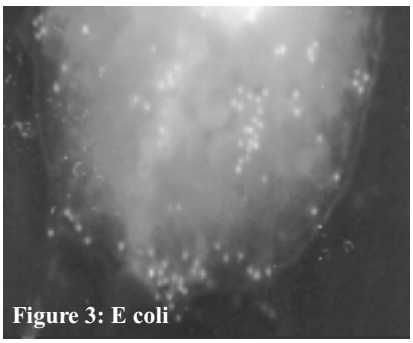
Figure 3: E coli

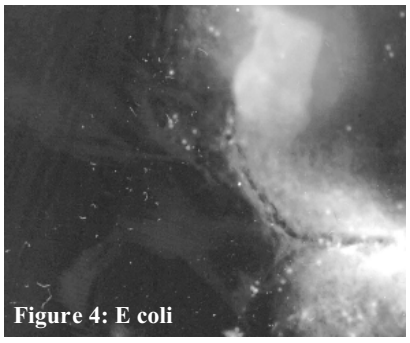
Figure 4: E coli

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Meet the Researcher

Geoffrey Smith

Associate Professor, Biology Dept.
New Mexico State University

Research Focus
environmental microbiology

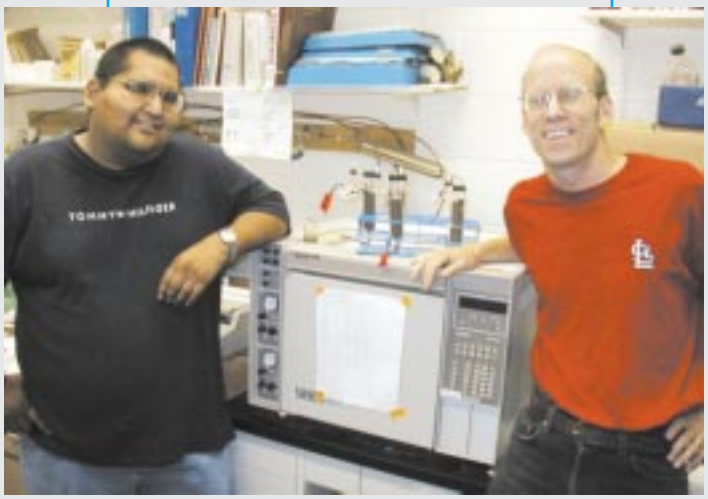
Education
Ph.D. soil microbiology, North Carolina State University
M.S. soil science, Univ. of Kentucky
B.A. biology and literature, Pitzer College

Experience
Geof Smith heads the environmental microbiology lab at NMSU that studies biodegrading and pathogenic bacteria in the context of the environment in which they are found. His group is interested in the bacteria, enzymes, and genes involved in the microbial biodegradation of environ-mental contaminants, which range from compounds such as TNT and chloroform to material such as municipal solid waste. Biodegradation activity is monitored with batch and flow-through systems, often under anaerobic conditions. Toxicity changes occurring as a result of catabolism are also studied. In a joint project with Mexican collaborators, the group is surveying the impact that urban and border areas have on microbial pathogen populations in the Rio Grande.

Dr. Smith is carrying out numerous collaborative projects with physicists (Dr. Bob Armstrong, NMSU Physics and Dr. Egor Degtiarev, Lasen, Inc) and chemists (Dr. Gary Eiceman, NMSU Chemistry) in an effort to develop rapid and sensitive microbial detection systems for pathogens in the environment.

Courses Taught
Applied and Environmental Microbiology
Microbial Physiology
Microbial Ecology
General Microbiology
Cell and Organismal Biology

Current Projects
Principal investigator: *Development of a Laser-based Detection System for Water-borne Pathogens*; New Mexico Water Resources Research Institute, final report under review (story on page 1).



Paul Lansing (Dine Community college, Shiprock, NM) and Geoffrey Smith with TNT-biodegrading soil columns.

Principal Investigator: *Microbial Pathogen Survival and Extraction from Point-of-Use Filters*. (CDC-AWWARF).

Co-principal investigator with Kevin H. Oshima: *Pilot Study Examining Pathogen Incidence and Distribution Patterns in the Rio Grande*, Southwest Center for Environmental Research & Policy (EPA-SCERP)

Co-Principal investigator with Gary A. Eiceman: *Development of an Ion Mobility Spectrometer for Space Station Detection of Microbes.* (NASA)

Recent Publications

Smith, G.B. 2004. Development of a Laser-based Detection System for Water-borne Pathogens; NMWRRI, in preparation.

da Silva Nunes-Halldorson, V., R.L. Steiner, and G.B. Smith. 2004. Residual toxicity after biodegra-dation: Interactions among benzene, toluene and chloroform. *Ecotoxicol. Environ. Safety*. 57:162-167.

Clark, S. and G.B. Smith. Outbreak! - Teaching Clinical and Diagnostic Microbiology Methodologies with an Interactive Online Game. *J. of College Sci. Teach,* accepted 2004. Morales-Morales, H.A., G. Vidal, J. Olszewski, C.M. Rock, D. Dasgupta, K.H. Oshima, and G. B. Smith. 2003. Optimization of a reusable hollow fiber ultrafilter for the simultaneous concen-tration of enteric bacteria, protozoa and viruses from water. *Applied & Environ. Microbiol.* 69:4098-4102.

Olivas,Y., J. Dolfing, and G.B. Smith. 2002. The influence of redox potential on the degradation of C1-halogenated hydrocarbons. *Environ. Toxicol. & Chemistry.* 21:493-499.

Yu, H.W., Z. Samani, A. Hanson, and G.B. Smith. 2001. Energy recovery from grass using two-phase anaerobic digestion. *J. Waste Management.* 22:1-5.

Ruiz, T.R., S. Andrews and G.B. Smith. 2000. Identification and character-ization of nuclease activities in anaerobic environmental samples. *Canad. J. Microbiol*. 46:736-740.

Yu, Z. and G.B. Smith. 2000a. Inhibition of methanogenesis by C1 and C2-polychlorinated aliphatic hydrocar-

continued on page 3

USGS recent publications

The U.S. Geological Survey has recently published several reports of interest to New Mexico water experts. Copies are available for inspection at the USGS District Office in Albuquerque (5338 Montgomery Blvd NE, Suite 400; 505-830-7923). The Water Resources Research Institute library also has the reports on file. They may be ordered from the USGS, Federal Center, Box 25286, MS 517, Denver, CO 80225. You may call 1-888-ASK-USGS for price information or go to http://www.usgs.gov.

Water and the Environment by S.J. Vandas, T.C. Winter, and W.A. Battaglin. This is the fifth booklet in the American Geological Institute's Environmental Awareness Series in cooperation with the U.S. Geological Survey, Bureau of Reclamation, National Park Service, U.S. Army Corps of Engineers, and the USDA Forest Service. It is a handy reference on water that will serve as an outreach tool for increasing public understanding of water and its importance to society, according to USGS Director Charles G. Groat. Copies are available at http://www.agiweb.org/publications.html.

USGS Open-File Reports

Water Quality and Depth to Water, 2001-02, and Graphs of Selected Constituents and Depth to Water, Period of Record Through 2002, in Selected Wells, Eastern Bernalillo County, New Mexico by P.J. Blanchard (Open-File Report 03-81)

A Review of Literature for Methyl *tert*-Butyl Ether (MTBE) in Sources of Drinking Water in the United States by G.C. Delzer and T. Ivahnenko (Open-File Report 01-322)

USGS Investigations Reports

Water-Quality Assessment of the Rio Grande Valley, Colorado, New Mexico, and Texas – Surface-Water Quality, Shallow Ground-Water Quality, and Factors Affecting Water Quality in the Rincon Valley, South-Central New Mexico, 1994-95 by S.K. Anderholm (WRIR 02-4188)

Ground Displacements Caused by Aquifer-System Water-Level Variations Observed Using Interferometric Synthetic Aperture Radar near Albuquerque, New Mexico by C.E. Heywood, D.L. Galloway, and S.V. Stork (WRIR 02-4235)

Summary of Flow Loss Between Selected Cross Sections on the Rio Grande In and Near Albuquerque, New Mexico by J.E. Veenhuis (WRIR 02-4131)

Simulated Effects of Ground-Water Management Scenarios on the Santa Fe Group Aquifer System, Middle Rio Grande Basin, New Mexico, 2001-40 by L.M. Bexfield and D.P. McAda (WRIR 03-4040)

A National Survey of Methyl *tert*-Butyl Ether and Other Volatile Organic Compounds in Drinking-Water Sources: Results of the Random Survey by S.J. Grady (WRIR 02-4079)

Occurrence and Temporal Variability of Methyl *tert*-Butyl Ether (MTBE) and Other Volatile Organic Compounds in Select Sources of Drinking Water: Results of the Focused Survey by G.C. Delzer and T. Ivahnenko (WRIR 02-4084)

Other USGS publications

Volatile Organic Compounds in Ground Water from Rural Private Wells by M. Moran and P. Hamilton (available at http://water.usgs.gov/nawqa/vocs)

Water Lecture Series
presents

Dr. Stephen Merrett
economist and philosopher
Water Resource Economics
and Management, London

River Basins under Stress

April 20, 2004
NMSU
3:00 p.m.
Wooten Hall, Room 105

sponsored by

NMSU College of Agriculture
Water Task Force
NMSU Civil Engineering Dept
Water Resources Research Institute

continued from page 2

bons. *Environ. Toxicol. Chem.* 19:2212-2217.
Yu, Z. and G.B. Smith. 2000b. Dechlorination of polychlorinated methanes by a sequential methanogenic-denitrifying bioreactor system. *Appl. Microbiol Biotechnol*. 53:484-489.
da Silva Nunes, V. and G.B. Smith. 1999. The importance of utilizing toxicity tests in groundwater biodegradation studies. *Brazil J. Tox.* 12:42.
Yu, Z. and G.B. Smith. 1997. Chloroform dechlorination by a wastewater methanogenic consor-tium and cell extracts of Methano-sarcina barkeri. *Water Research.* 31:1879-1886.

WRRI helps host brackish water workshop

The New Mexico Brackish Groundwater Assessment Program Workshop was convened on January 15, 2004 to provide a forum for the discussion and development of an approach and roadmap to be utilized by the state to quantify and develop brackish groundwater resources that can help supplement existing fresh water supplies.

Over 120 participants from interested parties from state and federal agencies, New Mexico's national laboratories, private consulting firms, industry, water agencies, communities and municipalities, and academic institutions attended the one-day workshop. The forum directed attention on developing a strategy that would result in cooperative efforts, specifying the key information components needed, and identifying priority aquifers.

The workshop program included presentations on various engineering and earth science aspects of desalination technology and saline aquifer characterization. Presenters included Anne Watkins, Office of the State Engineer; Eddie Livingston, Livingston Associates; Rick Huff, U.S. Geological Survey; John Shomaker, Shomaker and Associates; and Peggy Johnson and Lewis Land of the New Mexico Bureau of Geology and Mineral Resources. Most of the visual presentations are available for viewing on the WRRI's webpage at http://wrri.nmsu.edu/conf/brackish.

Recommendations (see page 5) generated by workshop attendees in discussion sessions indicate that there is much to do in order to prioritize saline aquifers for development and define what data are needed to fully characterize them. However, a framework for developing a roadmap for economic development of saline water resources in New Mexico was established. This roadmap includes several recommended steps, both short and long term, that address issues of immediate concern and also allow various levels and scales of study by several agencies.

The workshop was sponsored by WRRI, Office opf the State Engineer, Interstate Stream Commission, University of New Mexico, New Mexico State University, New Mexico Bureau of Geology & Mineral Resources, John Shomaker and Associates, Inc., Hawley Geomatters, Sandia National Laboratories, Los Alamos National Laboratory, U.S. Geological Survey, and the U.S. Bureau of Reclamation. The workshop report is available in its entirety at http://wrri.nmsu.edu.

Recommended steps for developing saline water resources in New Mexico

Short Term (6 months to 2 years)

1. The New Mexico Office of the State Engineer (NMOSE) should establish a Brackish Water Task Force to expand understanding and expertise in the area of brackish water resource development, ensure communication among the state's experts, and provide a forum for review and evaluation of proposed projects and aquifer prioritization.
2. The NMOSE, working with the Brackish Water Task Force, should establish a decision matrix that prioritizes saline aquifers and communities or groups of communities in need of water supply.
3. The NMOSE should work with other appropriate state and federal agencies to compile and review existing data and identify data needs for characterizing and evaluating suitability of potential aquifers.
4. The NMOSE should work with other agencies to develop a saline aquifer web page as a clearinghouse for saline groundwater information accessible to the public.
5. The NMOSE, in cooperation with appropriate state and federal agencies, should prepare a summary report of saline aquifer resources.
6. If indicated, the NMOSE, working with other agencies, should develop a hydrogeologic characterization and computer model to support an impact assessment and feasibility study.

Long Term (2 to 5 years)

1. The NMOSE, in cooperation with other agencies, should work to collect any additional data needed for proper evaluation of potential aquifers.
2. If indicated, the NMOSE, working with other agencies, should develop a hydrogeologic characterization and computer model to support an impact assessment and feasibility study.
3. The NMOSE, working with subject communities, should pursue plant design and pilot projects.

continued from page 1

either directly through a coaggregation process, or indirectly by having previously tagged antibody particles attach themselves to the biological cell surfaces. Both approaches have been explored by Smith and Oshima, and some of their principal findings to date include the following:

1. Using a dual antibody approach, the SERS-based detection method was able to distinguish clearly between a *Salmonella* target pathogen and non-pathogenic *E. coli* and *Bacillus* species. In contrast, traditional methods of assay (enzyme-linked immunosorbent assay and electron microscopy) produced ambiguous results when applied to the same samples.
2. A direct SERS-based assay that took less than five minutes to complete was shown to distinguish effectively between a surrogate for *Bacillus anthracis* (*B. subtilis*) and other species of *Bacillus.* This could provide a means for distinguishing between the anthrax agent used in bioterrorism and other naturally occurring species of *Bacillus*.
3. The Raman shifts documented from bacteria in their study correlate well with standards they have run of amino acids, suggesting as expected, that the scattering signal originates from cell surface protein components.

Some of Smith and Oshima's findings are shown in figures 1-4. Figure 1 displays electron microscope pictures of biological particles that have been tagged indirectly with gold nanometer-sized particles (one nanometer = one billionth of a meter) through attachment of antibodies previously tagged with the gold colloid particles. Figure 2 shows the SERS signal from the particles described in Fig. 1 when they were irradiated with green laser light at a wavelength of 532 nanometers. Figures 3 and 4 show SERS signals at the same incident laser frequency scattered respectively from bacteria and virus particles (bacteriophage) directly tagged with silver colloid.

These results are very encouraging, suggesting we can look forward to the investigator's successful creation of a detection device that would be of great benefit on many fronts.

In cooperation with

Sandia National Laboratories
Los Alamos National Laboratory
University of New Mexico
New Mexico Tech
New Mexico State University
Interstate Stream Commission
Office of the State Engineer
U.S. Geological Survey
AWRA - New Mexico Section

Abstracts for consideration for presentations and/or posters at the 2004 New Mexico Water Research Symposium will be accepted through **July 9, 2004**. Abstracts related to any and all water research and management topics will be considered. Abstracts must not exceed 250 words or a single page and must be submitted online via the New Mexico Water Resources Research Institute's homepage at http://wrri.nmsu.edu. All accepted abstracts will be made available to participants.

Presenters whose papers are accepted for oral presentations will be limited to a 20-minute talk. All speakers and poster presenters must register for the Symposium by July 30, 2004. The registration fee for everyone, including speakers, poster presenters, and other attendees is $20. The fee will be waived for students presenting an accepted paper or poster. The fee includes lunch, breaks, and notebooks with abstracts. All registration is online via the WRRI's homepage at http://wrri.nmsu.edu.

Final symposium agendas will be emailed to all registrants in early August and will be posted on the WRRI website. Technical sessions will be organized around the following topics:

- Water and wastewater treatment and reuse
- Erosion and sediment control
- Economics and policy analysis
- Fish and wildlife/endangered species
- Pollution prevention
- Atmospheric, surface, and groundwater modeling
- Agricultural, industrial, and municipal water use
- Watershed assessment, planning, and management
- Groundwater
- Water management
- Water quantity
- Impaired water
- Desalination
- Water security
- Water quality and pollution
- Wetlands and riparian issues

Students are especially welcome!

WRRI provides students with water research awards

A new program was initiated by WRRI this year with the awarding of twelve student research grants. The program was made possible by an increase to the WRRI budget passed by the 2003 New Mexico Legislature and approved by the Governor.

The purpose of the awards is to support graduate and undergraduate student research in disciplines relevant to water resources issues. Students must be currently enrolled as a full-time student in a degree program at one of New Mexico's six public education institutions.

A Request for Proposals was made in late summer 2003 for these one-year projects, with a start date for projects of October 1, 2003. Awards were made for up to $5,000 per project.

Future issues of *The Divining Rod* will provide summaries of the student research. Congratulations to the following students.

Maceo Carrillo Martinet, Department of Biology, University of New Mexico
The Fate of Pharmaceutically Active Drugs in the Rio Grande and Groundwater

Anthony Darrington, Department of Animal and Range Sciences, New Mexico State University
Effects of Burning and Thinning on Forest Hydrology

Sam Earman, Department of Earth and Environmental Science, New Mexico Tech
Using Natural Tracers to Improve Estimates of Groundwater Recharge Resulting from Snowmelt

Jordan Evans, Department of Civil and Geological Engineering, New Mexico State University
Mapping Lake Evaporation Using Satellite Imagery

Thomas Evans, Environmental Geology Program, Department of Natural Sciences, New Mexico Highlands University
Water Quality Assessment Along Surface Water and Groundwater Pathways at the Las Vegas National Wildlife Refuge

Stacy K. Galassini, Department of Anthropology and Applied Archaeology, Eastern New Mexico University
Prehistoric Water Management in the American Southwest

Greg Huey, Department of Natural Resources Management, New Mexico Highlands University
Escherichia coli Source Tracking by DNA Fingerprinting in Diverse Watersheds of Northern New Mexico

Casey Johnson, Department of Agronomy Horticulture, New Mexico State University
Can Non-Potable Saline Groundwater be Used for Turfgrass Irrigation?

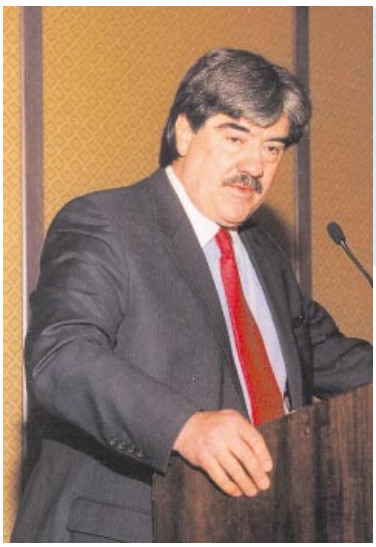
Khalid Mehboob, Department of Civil Engineering, University of New Mexico
Identification of Membrane Foulants in Natural Waters

Dennis L. Newell, Department of Earth and Planetary Sciences, University of New Mexico
Geochemistry of Rio Grande Rift Travertine Depositing Springs: Implications for Rio Grande Valley Water Quality

Tony Spitzack, Department of Biology, Eastern New Mexico University
Effects of Gender and Predation Risk on Depth Choice in the Mosquitofish, *Gambusia affinis*

Robert Wyckoff, Department of Earth and Environmental Science, New Mexico Tech
Climate, Land-Use Change, and Hydrologic Response - Modeling the Rio Puerco River Basin

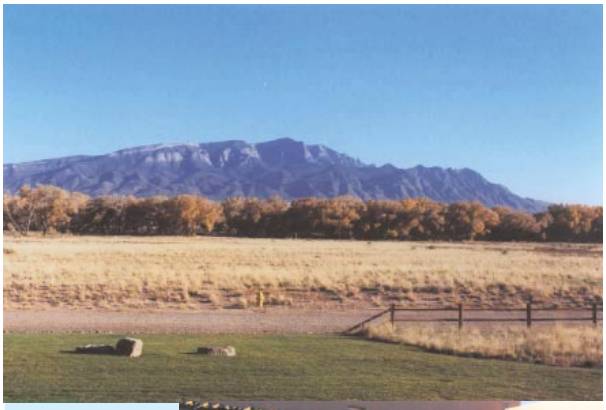
48th Annual New Mexico Water Conference
November 5-6, 2003
Hyatt Regency Tamaya, Santa Ana Pueblo



Mexican Ambassador Alberto Székely gave the Albert E. Utton Memorial Lecture. He was introduced by good friend and colleague, Charles DuMars (right).

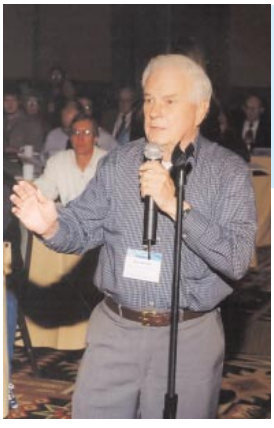
Bill Hume, Office of the Governor (left), moderated a panel of water experts discussing the challenges facing the state when planning for its water future.

Frank Titus paid tribute to recently deceased W.K. "Kelly" Summers as one of New Mexico's preeminent groundwater scientists.



The Tamaya Resort at Santa Ana Pueblo provided a bucolic setting for the conference. The nearly 300 participants raved about the facility and its surroundings.

John W. Keys, III, Commissioner, Bureau of Reclamation described *Water 2025* among other Bureau initiatives.



Conference participants Jim Smith and Amy Lewis direct questions to the speakers.

State Engineer John D'Antonio prepares to give his presentation while WRRI Director Karl Wood keeps speakers on time.

New Mexico Water Planning 2003

Each of the sixteen regional water planning areas were invited to display information regarding their plans and efforts.

The WRRI staff relaxes after the first day of the conference.

The annual New Mexico water conference provides an opportunity for those interested in water to share their concerns and solutions.

Upcoming conferences

April 16, 2004, National Environmental Policy Act; Austin, TX; http://www.cle.com

April 21-22, 2004, Identifying Technologies to Improve Regional Water Stewardship - North-Middle Rio Grande Corridor, University of New Mexico; http://research.unm.edu/opst/

April 28, 2004, The Future of Agricultural Water Use in Arizona, Casa Grande, AZ; http://ag.arizona.edu/AREC/dept/agwaterforum.html

May 13-14, 2004, Colorado River SuperConference, The Venetian Hotel, Las Vegas, NV; http://www.cle.com

May 17-19, 2004, GIS & Water Resources III, American Water Resources Association, Nashville, TN; http://www.awra.org

August 10, 2004, 2004 New Mexico Water Research Symposium, Socorro, NM; http://wrri.nmsu.edu

August 31-September 3, 2004, The Utton Transboundary Resources Center Conference, Hyatt Regency Tamaya, Santa Ana Pueblo, NM; http://lawschool.unm.edu/utton

September 21-22, 2004, 49th Annual New Mexico Water Conference, Ruidoso, NM; http://wrri.nmsu.edu

October 13-15, 2004, SAHRA Conference, Marriott, Albuquerque; http://www.sahra.arizona.edu/

October 18-20, 2004 New Mexico Environmental Health Conference, Sheraton Old Town, Albuquerque; http://www.nmehc.org

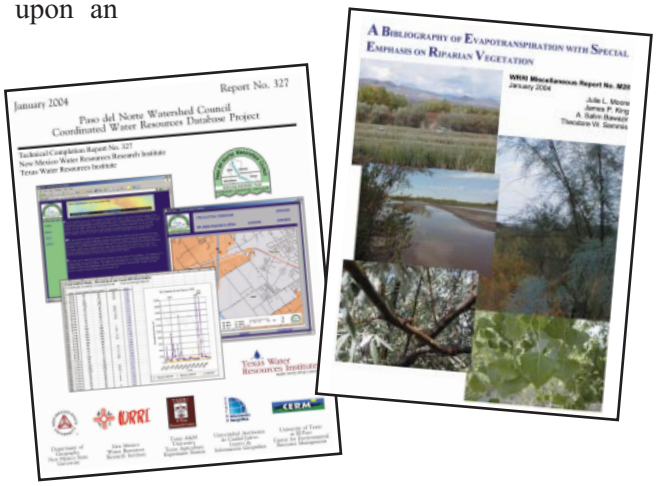
November 1-4, 2004, 40th Anniversary Annual Water Resources Conference, American Water Resources Association, Orlando, FL; http://www.awra.org

WRRI Director M. Karl Wood
named
2004 - 2005 President
of
The Universities Council on Water Resources
(UCOWR)

WRRI publishes three new reports

Coordinated Water Resources Database Project (WRRI Technical Report No. 327) by Christopher Brown, Department of Geography, NMSU; Zhuping Sheng, Texas Agricultural Research & Extension Center, El Paso, The Texas A&M University System; and Matt Rich, Department of Geography, NMSU

During the last 18 months, researchers at New Mexico State University, The Texas A&M University, and la Universidad Autonoma de Ciudad Juárez have collaborated on the development of a web-based data portal that employs geographic information systems (GIS) technologies to serve a wide range of water resource data in the Paso del Norte region of the Rio Grande Basin through an Internet user interface. Specifically, the database is built upon an ArcIMS (Internet Map Server) interface that serves up basic GIS maps as a foundation upon which spatial area of interest tools can be used to extract water resource data. This report details the process by which the project was developed, discusses various technical challenges encountered, offers a series of "lessons learned," and also outlines a future research agenda. Basic metadata of the underlying data elements are also detailed in an appendix, along with sampled graphics from the project website and various other database projects examined.



Sources of Salinity in the Rio Grande and Mesilla Basin Groundwater (WRRI Technical Report No. 330) by James C. Witcher, Southwest Technology Development Institute, NMSU; J.P. King, Department of Civil and Geological Engineering, NMSU; and John W. Hawley, WRRI, NMSU; John F. Kennedy, WRRI, NMSU; Jerry Williams, Department of Civil and Geological Engineering, NMSU; Michael Cleary, WRRI, NMSU; and Lawrence R. Bothern, Department of Geological Sciences, NMSU

An integrated geologic and geochemical investigation of groundwater, coupled with a study of temporal changes in surface water chemical balances for basins along the Rio Grande from San Marcial to Ft. Quitman, is used to investigate salinity in the Mesilla Basin of southcentral New Mexico and West Texas. A conceptual hydrogeologic framework delineates the major geologic influences on flow, storage characteristics, and chemical evolution of groundwater in the basin. The conceptual framework is integrated into a GIS and is general enough to be used in adjacent basins and with groundwater flow models. The report indicates that the salinity balance in the Rio Grande during the last 40 years for the Mesilla Basin is positive, meaning that more salts are entering the basin than are transported by the Rio Grande out of the basin at El Paso. Higher salinity in shallow groundwater and the Rio Grande in the southern and southeastern Mesilla Basin is probably dominated by structurally forced upwelling of brackish and saline water from deep hydro-stratigraphic units and by upflow of geothermal water from shallow bedrock structures and bedrock boundaries.

A Bibliography of Evapotranspiration with Special Emphasis on Riparian Vegetation (WRRI Miscellaneous Report No. 28) by Julie L. Moore, Department of Civil and Geological Engineering, NMSU; J.P. King, Department of Civil and Geological Engineering, NMSU; A. Salim Bawazir, Department of Civil and Geological Engineering, NMSU; and Theodore W. Sammis, Department of Agronomy and Horticulture, NMSU

This bibliography was prepared in an effort to collect information related to methods and techniques used in measuring and/or estimating evapotranspiration (ET) of riparian and agricultural crops. It focuses on those studies the authors thought to be relevant to the ET of agricultural and riparian vegetation in the Middle Rio Grande with a major emphasis on the water use of phreatophytes such as saltcedar, cottonwood, Russian olive, and saltgrass. Evapotranspiration of agricultural crops have been studied and documented for many years but less is known about the riparian vegetation.

The bibliography includes information on: 1) the methods and techniques used in the past and present in measuring and estimating ET in both agricultural and riparian vegetation; 2) riparian ecosystem changes and various methods of management and control of exotic species such as saltcedar; 3) water requirements of agricultural crops and riparian vegetation; and 4) crop coefficients based on heat units (growing degree days).

Mark Your Calendars

49th Annual New Mexico Water Conference

September 21-22, 2004

Ruidoso Convention Center

This year's theme: Desalination

The 48th Annual New Mexico Water Conference Proceedings are being prepared and will be mailed to conference participants in late spring. Check the WRRI website at http://wrri.nmsu.edu for conference papers.

The ***Divining Rod*** is published by the New Mexico Water Resources Research Institute.

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