Introduction

This annual report provides the required information for projects funded with 2015 USGS 104B base grant and mandatory non-federal matching funds. Please note that there may be some overlap in information with our 2014 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 (NM WRRI) 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. In 2005, the New Mexico state legislature gave NM WRRI statutory authority. 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 NM WRRI 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 NM WRRI homepage (http://nmwrri.nmsu.edu/) provides online information about the institute, newsletters, technical report series, requests for proposals, upcoming conferences and symposia, links to related entities, research reference library, and special projects such as Produced Water and the Statewide Water Assessment. The institute's website was redesigned in 2015 and is being maintained daily.

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. As of April 2016, 44 percent of New Mexico was in moderate drought status, with 469,230 residents, or 23 percent of its total population, living in drought affected areas. Long-term drought persists across the Southwest, and warm and dry weather has further exacerbated regional drought. It was hoped that a strong El Niño might help ameliorate drought conditions. Instead, 2015-2016 winter precipitation patterns looked more La Niña than El Niño, and water year precipitation, along with snowpack and reservoir storage, is unexpectedly average to below-average in much of the region. Forecasters see the drought impacts continuing for a significant amount of time with future water supplies not meeting future water demand in the state.

In 2014, New Mexico's State Legislature funded a New Mexico Universities Working Group to look at the state's water supply vulnerabilities. The Group was asked to (1) assess the current status of water supply and demand after years of severe drought in New Mexico; (2) put the current drought into long-term context with
reduced surface water, groundwater depletions, and economic activity; and (3) develop a list of vulnerabilities and promote policy strategies to mitigate these vulnerabilities. The research focused on the Lower Rio Grande. The Groups Final Report to the Interim Committee on Water and Natural Resources was presented in August 31, 2015. The report includes an executive summary with Key Findings, Recommendations, and Principal Vulnerabilities and is available on the NM WRRI website at:

Solving the dire and complex water problems facing New Mexico and the Southwest requires the highest quality research and the NM WRRI is dedicated to assisting in this effort.
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 (USGS 104B).

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, five projects received funding from the 2015 Annual Base Program. Three of these projects fit into the water conservation, planning and management category: "WRRI Information Transfer Program," "Geographic Information System for Water Resources Planning," and "Measuring the Impact of Rate Increases on Consumer Acceptance of Potable Water Reuse Options in the Albuquerque Area." A water quality project was supported, "Arsenic Removal from Water by Porous Polymers" and a project that focused on saline and other impaired waters, "Self-Sustaining Produced Water Treatment for Concurrent Renewable Energy Production, Desalination, and Organic Removal." In addition, multiyear projects that terminated during the reporting period, received supplemental funding through the USGS, "Monitoring and Forecasting Climate, Water and Land Use for Food Production in Afghanistan," "Monitoring and Forecasting Climate, Water, and Land Use for Food Production and Business Development in Iraq," and "Groundwater Exploration, Assessment and Monitoring for Humanitarian Assistance in Ethiopia." A new supplemental project started during the reporting period, "Drought in the West: Elements of Successful Science to Improve Water Management and Address Nationally Important Issues Through the USGS-NIWR Partnership."

During the reporting period, March 1, 2015 through February 29, 2016, the NM WRRI administered a total of 57 projects dealing primarily with water planning and management issues as well as water quality. The total value of these projects was $1,260,280. Dollar amounts per project award ranged from a Student Water Research Grant on groundwater recharge of $3,194 to a project in the amount of $224,092 supported by the National Science Foundation focusing on ways to improve efficiency of sustainable energy resources in New Mexico while minimizing water impacts. During the reporting period, 14 projects were conducted at New Mexico State University, 14 at the University of New Mexico, 11 at New Mexico Tech, 2 at New Mexico Highlands University, 2 at Eastern New Mexico University, one with the USGS, one with a private entity, and two in-house 104B projects. NM WRRI staff managed 12 additional projects.

Of the five projects receiving USGS 104B funding during the reporting period, three were made to New Mexico faculty researchers (the other two projects are in-house efforts, i.e., GIS and Information Transfer programs). All three of the research projects were led by junior faculty at the assistant professor rank.

USGS 104b and USGS Supplemental funded projects administered by the NM WRRI utilized 21 students during the year including undergraduates, masters, and Ph.D. students in the diverse disciplines of agricultural economics, chemical engineering, civil engineering, community and regional planning, engineering technology, environmental engineering, finance, geography, computer science, mechanical engineering, water science, water management, and water resources.

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 can include multi-year funding.
Research Program Introduction

Monitoring and forecasting climate, water and land use for food production in Afghanistan, Phase I - USGS Supplemental $0 for reporting period; terminating program

Monitoring and forecasting climate, water and land use for food production in Afghanistan, Phase 2 - USGS (non WRRA) $0 for reporting period; terminating program

Monitoring and forecasting climate, water, and land use for food production and business development in Iraq, USGS Supplemental (extended) $0 for reporting period; terminating program

Groundwater exploration, assessment and monitoring for humanitarian assistance in Ethiopia USGS Supplemental $406 for reporting period; terminating program

Effects of ground heat flux on a transitional snowpack in the arid Southwest climate, NM State appropriation, student grant $5,717

Using chloride mass balance to quantify groundwater recharge in the mountains of New Mexico, NM State appropriation, student grant $3,193

Fire ash influences on aquatic primary producers through changes in water quality, NM State appropriation, student grant $5,220

Temporal analysis of non-snow fed streams in New Mexico, NM State appropriation, student grant $5,771

Water politics and cultural difference: Fostering community relationships to promote environmental health and community wellbeing in times of drought, NM State appropriation, student grant $5,815

Evaluation of impacts of silvicultural operations such as thinning treatments on water quality and quantity in New Mexico forests, NM State appropriation, student grant $5,823

Real time monitoring of flood control dams for emergency action management, NM State appropriation, student grant $5,932

3-D bathymetric model of a shallow lagoon measured by a solar powered low-cost autonomous surface vehicle prototype in Cuauhtemoc, Chihuahua, Mexico, NM State appropriation, student grant $5,937

How does nutrient processing change along a river continuum? NM State appropriation, student grant $5,938

Evaluating the impacts of particulate matter deposition on snow melt processes in the Upper Rio Grande, NM, NM State appropriation, student grant $5,938

Effects of turbidity on group cohesion in Sand Shiners and Red Shiners from the Pecos River in New Mexico, NM State appropriation, student grant $5,973

Development of a design and calibration manual for simple flow measurement devices in open channel, NM State appropriation, student grant $5,978D

Development of a bio-indicator to assess water quality in ephemeral ponds, NM State appropriation, student grant $5,989

Hydro-Weirs: A technology for low-head hydropower generation, NM State appropriation, student grant $5,990

Research Program Introduction
Research Program Introduction

Linking forests to faucets: Investigating alternative approaches for securing long-term funding for watershed restoration in New Mexico, NM State appropriation, student grant $5,994

Assessment of water quality in the irrigation drainage canals as a source of reusable irrigation water, NM State appropriation, student grant $5,994

Application of HydroGeoSphere to model climate change effects on three-dimensional hydrological processes in the Valles Caldera, New Mexico, NM State appropriation, student grant $5,994

Potential interactions of turbidity and water velocity on group cohesion in cyprinid fishes from two NM river drainages (Pecos and Canadian Rivers), NM State appropriation, student grant $5,994

Measuring the impact of rate increases on consumer acceptance of potable water reuse options in the Albuquerque Area, NM State appropriation, student grant $5,995

Combining empirical relationships with data-based mechanistic modeling to inform solute tracer investigations across stream orders, NM State appropriation, student grant $6,000

5 cents is still a lot: New generation of anti-bacterial absorbents based on functionalized cellulose aerogels for water treatment in rural areas, NM State appropriation, student grant $6,000

Development of calibration procedures for large aperture scintillometers for validation of statewide NM ET maps, NM State appropriation, student grant $6,000

Aquatic and morphological assessment of the Gallinas River within the Las Vegas, New Mexico city limits, NM State appropriation, student grant $6,000

Cost-efficient detection of endocrine-disrupting compounds in drinking water, NM State appropriation, student grant $6,000

Test of the new LAS MkII Scintillometer for validation of statewide New Mexico evapotranspiration maps, NM State appropriation, student grant $6,000

Implementation of drip irrigation system facilitates collaboration between future agricultural leaders, NM State appropriation, student grant $6,000

The detection of antibiotic resistant bacteria (ARB) in the Gallinas River, NM State appropriation, student grant $6,000

Submerged aquatic macrophytes - Ecosystem engineers in New Mexico mountain streams Effects of forest fire, NM State appropriation, student grant $6,000

Enhanced photocatalysis for water purification and disinfection using optical fibers coated with nanocomposite thin films, NM State appropriation, student grant $6,105

Geographical Information System for water resources planning, USGS 104B $13,306

Information Transfer Program, USGS 104B $15,776

Arsenic removal from water by porous polymers, USGS 104B $20,547
Research Program Introduction

Implementing a web-based streamflow statistics tool for New Mexico (stream states)  Yr 2, NM State Appropriations, $22,600

Drought, salinity, and invasive plants: A new model for sustainable water management, NM State Appropriations, $29,070

Doing hydrology backwards in New Mexico to estimate a statewide water budget, NM State Appropriations, $29,904

Improving evapotranspiration estimation using remote sensing technology - Year 2, NM State Appropriations, $29,970

Policy alternative for controlling nitrate pollution from New Mexico's dairies, NM State Appropriations, $29,978

Assessment of water table and water quality variations with respect to river flow along Rio Grande between Garfield NM and Fabens TX, NM State Appropriations, $29,981

Identification of law and policy options for best water management practices, NM State Appropriation, $29,996

Understanding the Costs of Arid Inland Communities' Potable Water Reuse Options, USGS 104B $30,000

Self-sustaining produced water treatment for concurrent renewable energy production, desalination and organic removal, USGS 104B $30,000

Comparison of operational precipitation and evapotranspiration products for statewide water assessment, NM State Appropriations, $30,000

Characterization of produced water in New Mexico - Yr 2, NM State Appropriations, $30,003

New Mexico statewide water assessment: Soil water balance method for statewide evapotranspiration assessment - Year 2, NM State Appropriations, $36,434

Research for the Development and Use of Alternative Water Supplies, Bureau of Reclamation, $40,725

Recharge quantification and recharge model assessment for the State of New Mexico - Yr 2, $41,901

Groundwater level and storage changes in alluvial basins along the Rio Grande, New Mexico - Yr 2, NM State Appropriations, $41,945

A dynamic statewide water budget for New Mexico - Yr 2, NM State Appropriations, $49,905Sustaining the environment at the New Mexico-Chihuahua Border, New Mexico Environment Department, $60,644

The Feasibility of Utilizing Produced Water to Improve Drinking Water Supply in Southeastern New Mexico, New Mexico Environment Department, $73,257

Impact of drought on household water quality in rural southern New Mexico, New Mexico Department of Health, $75,000

Chihuahuan Desert Network Administrative Support, National Park Service $75,548
Research Program Introduction

New Mexico's Experimental Program to Stimulate Competitive Research (EPSCoR) - Social and Natural Science Nexus, National Science Foundation $224,092
Monitoring and Forecasting Climate, Water and Land Use for Food Production in Afghanistan

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Publications

Brief description of problem and research objectives

This cooperative agreement between NMSU and USGS supported reducing food poverty through development of improved irrigation systems and institutions in Afghanistan. Activities focused on the application and development of techniques for monitoring the physical variables governing crop growth, such as timing and level of precipitation, evapotranspiration and temperature, along with human-related factors such as cropped area, agricultural inputs, and economic indicators.

These data have been integrated into an analysis of policy options for improving farm income, rural food security, and improved livelihoods. Recent work has developed and applied a framework to inform farmers, extension personnel, mirabs, and ministry personnel on uses of land and water resources in the Balkh River Basin to improve farm income and reduce food poverty.

Three journal articles have been published and two more are currently under review summarizing connections between irrigation institutions and food poverty in Afghanistan. The research examined the development of irrigation institutions that could contribute to reducing food poverty by improved water allocation among canals.

Brief description of methodology

Funding under Agromet has supported the following activities:

Installation of 113 weather observation sites:
1) all 113 observation sites are recording daily rain and snow;
2) 80 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 phonological 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) of 113 sites, 21 sites are complete agrometeorological stations (three observations daily), with 19 classical stations recording seven weather parameters and five automatic stations that can report on up to 20 weather parameters daily.

Using weather, hydrologic, agronomic, and economic data, several arrangements for allocating water through an existing network of irrigation canals were analyzed for their impacts on land and water use, farm profitability, and food security at both the canal and basin levels.

Principal findings and significance

Findings show that total water supply and institutional arrangements for allocating water during periods of shortages have important influences on farm income and food security.
The methods used and results found provide a framework for informing decisions on the sustainable use of land and water for improved food security and rural livelihoods in the developing world’s irrigated areas.

An article was recently published in the journal *Food Security*, summarizing findings that indicate that a proportional sharing of shortages in periods of drought combined with water trading is the best method for assuring both food security and farm income in the Balkh Basin, Afghanistan.

Work this year also examined potential economic benefits of additional reservoir storage that could be developed in the Balkh Basin, Afghanistan. A paper on that work was recently published in the *Journal of Hydrology* in January 2013.
Monitoring and Forecasting Climate, Water, and Land Use for Food Production and Business Development in Iraq

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<tr>
<td>Principal Investigators</td>
<td>Alexander G. Fernald, Frank Ward</td>
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Publications

Problem and Research Objectives

This cooperative agreement between NMSU and the US Geological Survey aimed to contribute to food poverty reduction through development of improved irrigation management systems and institutions in Iraq. Activities focused on the application and development of techniques for monitoring the physical variables governing crop growth, such as timing and level of precipitation, evapotranspiration, and temperature, along with human-related factors such as cropped area, agricultural inputs, and economic indicators.

These data were integrated into an analysis of policy options for improving farm income, rural food security, and improved livelihoods. Much of the work over the project’s history developed and applied a framework to inform farmers, extension personnel, and ministry personnel on uses of land and water resources in the Tigris-Euphrates River Basin. That work was conducted for most provinces of Iraq, with the intent of improving farm income and reducing food insecurity through economic assessments of improved water sharing irrigation institutions from areas of water and economic surplus to areas of water and economic deficit.

One master’s thesis and three published journal article were completed. One workshop on water economics was held in Erbil, Iraq, in August 2013, describing and illustrating the use of optimization models to inform policy choices for addressing drought and climate variability. Workshop presenters included Dina A. Salman, Saud Amer, and Frank A. Ward. NMSU has stayed in touch with several of the 12 workshop participants for the last three years since the time of the workshop. One additional journal article is currently in preparation and near completion. In addition, the Iraqi government in late 2014 sent, at their considerable expense, two visiting scholar doctoral students to work with us in the NMSU agricultural economics/agricultural business department for a year on groundwater prediction and economic optimization models to address falling groundwater tables in the lower part of the Tigris Euphrates Basin. A workshop was held at NMSU in March 2015, staffed by Dr. Jack Eggleston, of the Boston Office of the U.S. Geological Survey. The goal of this workshop was to present essential principles of the USGS MODFLOW model to NMSU’s visiting Iraqi scholars. MODFLOW has been and remains the ‘gold standard’ of groundwater flow models worldwide.

The work activities under this project generally has analyzed and summarized connections between irrigation institutions, farm income, and food security in Iraq as well as policy-mitigating measures for adapting to drought and climate variability. Much of the work funded by this project examined the development of irrigation institutions that could contribute to reducing food poverty by more economically productive water allocation among most of the provinces in Iraq in which crop irrigation occurs.

Methodology

Using weather, hydrologic, agronomic, and economic data, several arrangements for allocating water through an existing network of irrigation canals were analyzed for their
impacts on land and water use, farm profitability, and food security at both the canal and basin levels.

Taking advantage of the weather station data as well as other data from published sources, an optimization framework was developed to support policy analysis, through the development and application of several mathematical programming models. The workshop material as well as the model codes are posted in several locations at the NMSU web site http://agecon.nmsu.edu/fward/water/. The framework developed can be used to identify economic values of several climate and policy choice instruments within an allowed range that maximize or minimize the numerical value of an economic benefits objective function that depends on the development of water allocation rules for handling water shortages from drought or climate variability in innovative ways.

Optimization of water resource systems and irrigation institutions through empirical mathematical programming models provides a method to address a complex problem like water development and allocation for irrigation for the lower Tigris-Euphrates Basin in Iraq. In this country, an important objective is improvement of rural livelihoods, improved economic opportunity, and reduction of food insecurity. The optimization framework carefully specified, has the potential to perform well in the face of minimum data, a complex economic objective, variables that are both under and outside control of the policymaker as well as numerous constraints required to be respected for an acceptable policy response. Integrated optimization models offer considerable utility to address interrelated processes, such as hydrology, economics, environment, institutions, and policy applications.

Our optimization framework, described in detail in Salman et al. (2014) cited below, contains several elements: scenarios, water supply conditions, reservoir storage capacity levels, water-shortage sharing rules, farm behavior, and observed as well as predicted food grain prices. The base condition describes the historical observed characteristics of most of the provinces in Iraq. Historical observed water is the observed period of record water inflow pattern, which reflects the basin’s ‘normal’ water supply over that period. Future stochastic supplies reflect an amount equal to the long run historical mean and variance of streamflow supplies in the base. Average annual supplies are about 41.4 bcm for the Tigris, based on a period of record 1931-2004, and 30.8 bcm for the Euphrates, for a period of record 1932-1997. The base water shortage sharing arrangement is an upstream priority system. It is contrasted with three alternative possible rules for sharing water supplies.

The models developed under this research project predicts base farm cropping patterns and adjusted cropping patterns under the alternative water institutional scenarios. The model’s most important outcomes are the maximized discounted net present value of farm income plus additional consumer food security produced by reduced food prices and increased food grain security.
Principal Findings and Significance

Summaries are presented below for several lines of work funded by this project that have been ongoing since this project commenced in September 2010. Citations for each is presented at the end of each summary, for which research articles have been published. A reference for the detailed research articles are presented at the end of each summary.

**Financing Irrigation Water Management and Infrastructure: A Review**

**Summary:** Many of the world’s irrigated regions, including those located in the lower Tigris-Euphrates River System in Iraq, face the problem of aging infrastructure and declining revenues to maintain and repair irrigation structures. Policy debates over climate change, population growth, food security, and impacts of irrigation on ecological assets compound the problem, raising the urgency to invest in irrigation infrastructure. Meanwhile, a global call for full cost recovery for water infrastructure investments increases the need to identify the economic value of sustaining irrigation infrastructure. Despite the growing debates, little comprehensive research has been conducted summarizing factors affecting irrigation investments or policy options available for sustaining irrigation infrastructure. This investigation reviews research on factors affecting the level and value of irrigation infrastructure investments. It also reviews previous studies on policy instruments for sustaining irrigation infrastructure, considering both market and institutional approaches. Several market approaches have been found to have the potential to influence the economic attractiveness of investments in irrigation infrastructure. These include infrastructure subsidies, clearing titles to water rights, marginal cost pricing, and non-volumetric pricing. Institutional approaches described include regulatory measures, transboundary agreements, and water user associations. Results may contribute to current debates in various regional, national, and international forums on whether and how water should be priced for agricultural use.


**Economic Analysis of Water Shortage Adaptation Measures in Iraq**

**Summary:** Climate change and population growth have intensified the search internationally for measures to adapt to fluctuations in water supplies. An example can be found in the Lower Tigris-Euphrates Basin where recent water supply reductions have resulted in high economic costs suffered by irrigation farmers. Losses to irrigators in this basin have made a compelling case to identify flexible measures to adapt to water shortage. Few published studies have systematically examined ways to enhance the flexibility of water right systems to adapt to water shortages.

This investigation examines how profitability at both the farm and basin levels is affected by various water appropriation methods. Four water allocation methods are compared for impacts on farm income under three water supply scenarios. Results show that a (1) proportional sharing of water shortages among provinces and (2) unrestricted water trading perform as the top water appropriation methods. The shadow price of water for irrigation rises from zero at a full water supply level to US $93 per thousand cubic meters.
when supply falls to 20 percent of full levels. Results carry important implications for the
design and efficient implementation of water appropriation systems in the world’s
irrigated regions.

to Shortage in Iraq, Unpublished M.A. thesis, New Mexico State University, July 2013.”

Institutional Innovations for Adapting to Water Shortages in Iraq
Summary: Climate variability and population growth have intensified the search
internationally for measures to adapt to fluctuations in water supplies. A significant
example with important management implications can be found in the lower part of the
transboundary Tigris-Euphrates Basin in Iraq, where water shortages in 2008-2009
resulted in high economic costs to irrigation farmers. Losses to irrigation farmers that
occurred in 2008-2009 in the lower Tigris-Euphrates basin have made a compelling case
to identify flexible methods to adapt to water shortage. Few previously published studies
had systematically examined ways to enhance the flexibility of water appropriation
systems to adapt to water shortage in the lower part of that basin. This investigation
addressed an ongoing challenge in water governance in Iraq by examining how
profitability at both the farm and basin levels is affected by various water appropriation
systems for sharing shortages when they occurred. Four water appropriation systems
were compared for impacts on farm income under each of three water supply scenarios.
Results show that a (1) proportional sharing of water shortages among Iraqi provinces
and (2) unrestricted water trading rank as the top two appropriation systems. The shadow
price of water for irrigation rises from zero at a full water supply level to US $ 93/1,000
cubic meter when supply falls to 20% of full levels. Similar methods can be used to
analyze challenges facing the design or implementation of water shortage sharing
measures in the world’s irrigated regions, methods for which relevance will grow in
future years as drought and climate variability become potentially growing problems.

Water Appropriation Systems for Adapting to Water Shortages in Iraq. Journal of the
American Water Resources Association (JAWRA) 1-18. DOI: 10.1111/jawr.12186

Policy Innovations for Sustainable Adaptation to Water Shortages in Transboundary
Basins
Summary: Few international water-sharing agreements to date have shown the flexibility
to adjust to extended drought; fewer still provide safeguards for adaptation to modern
climate variability. Yet, current conflicts over the development and use of transboundary
rivers, such as the lower Tigris-Euphrates River System, continue to motivate the search
for negotiated water-sharing arrangements that can provide flexibility in the face of
drought and climate variability. To avoid future conflicts, an agreement must include
measures that allow for adaptation to changes in water supplies, population, climate,
technology, infrastructure, and economic activity while also guiding water use patterns.
The benefits of a flexible agreement can be a more predictable water supply for all
riparians, greater incentives to develop needed water infrastructure and a more open,
transparent, and accountable set of water institutions. Other benefits include increased
food production, water security, environmental protection, reduced flood damages, better
adaptation to the costs of extreme weather and variable climate, and a reduced need for
complex legal, administrative and enforcement activities. This investigation examines measures to design and implement sustainable transboundary water-sharing agreements. It investigates barriers to forging water-sharing agreements, describes errors that could undermine settlements and presents takeaway lessons from three selected basins worldwide. Finally, the paper proposes an approach by which information on headwater flows and historical use patterns could be used to allocate supplies between riparians that adapt with flexibility to changes in water supply and demand. Outcomes from the implementation of structured, but flexible agreements could help guide future negotiated settlements for the world’s international rivers.


Water Right Systems to Protect Food Security in the Lower Tigris Euphrates

Summary: In arid regions where irrigation is important, food security through domestic grain production is tied to the supply and efficient use of water. Ongoing climate change and variability continues to compel the search for science-informed water management to protect food security in the face of an uncertain future. Much research has examined climate-related impacts on food security, but little has systematically examined alternative water right systems for protecting food security. This investigation addresses that gap by examining the performance of alternative water right systems and food production subsidies that protect food security while adapting to ongoing water supply fluctuations. It is based on a case study of water supply shortages in Iraq, where food grain shortages have been experienced periodically over a long history as a consequence of those shortages. It examines three alternative water allocation rules for adapting to drought while protecting food grain security in the Lower Tigris-Euphrates Basin, Iraq. The most widespread method for sharing water shortages when they occur in Iraq is an upstream priority allocation system. Two alternative methods for addressing reduced supplies are a proportional sharing of shortages and a market motivated system for trading water. These three water shortage sharing systems are reviewed for their performance for sustaining domestic food grain security. It does so by formulating a national scale farm income optimization framework to assess the performance of three water shortage sharing methods under each of two potential food subsidy programs based on how each contributes to national food security. Surprisingly, a proportional sharing of shortages and unrestricted water trading outperforms an upstream priority system, the customary way of sharing water shortages in Iraq. Results point to the importance of carefully designed rules for allocating water shortages to ensure food grain security in the world’s irrigated regions.

Publication Information: not yet published

Publications under this project


Two graduate students participated on the project, Dina Salman, who completed an M.S. thesis on this project, and Shahruh Jalilov. Also as a result of this project, New Mexico State University offered a PhD seminar course through its Water Science and Management graduate program, Water and Sustainable Economic Development (WSAM 610).
Self-Sustaining Produced Water Treatment for Concurrent Renewable Energy Production, Desalination and Organic Removal

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<td>Principal Investigators</td>
<td>Pei Xu</td>
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Publications

Description of problem and research objectives

The oil & gas exploration and production plays a critical role in national energy security and economic development. Management of produced water is a significant challenge to oil & gas producers and operators. Produced water contains contaminants such as suspended and colloidal solids, petroleum hydrocarbons, salts, and chemical additives. The water is considered hazardous waste and must be treated or disposed safely. The common disposal method – deep well injection is costly and waste of valuable water resources. Conventional thermal evaporation and membrane-based water treatment technologies such as reverse osmosis are cost and energy intensive.

In this study, we propose to develop an innovative microbial capacitive deionization cell (MCDC) to simultaneously remove organic substances and salts from produced water so it can be recycled and reused. Moreover, compared to other energy intensive systems, MCDC uses bacteria to convert biodegradable pollutants into direct electricity, which offsets operation energy use or supplies additional energy for other systems.

Therefore the objectives of the research are threefold: 1) develop modular MCDC to substantially increase system performance in produced water treatment and energy production; 2) optimize the systems with novel electrode materials to make the technology more efficient; 3) evaluate the MCDC process at system level for treating produced water.

Description of methodology

MCDC is the latest application of bioelectrochemical systems (BESs). BESs use microorganisms as biocatalysts to oxidize biodegradable electron donors and generate electricity (microbial fuel cell, MFC) or value-added chemicals (microbial electrolysis cells, MEC). For example, in a two-chamber MFC reactor, bacteria oxidize organic compounds in the anode chamber to acquire energy for metabolisms. Some of the electrons derived from this oxidization are transferred from the bacteria to the anode and then flow to the cathode through an external circuit, where they are harvested for direct current generation. In the mean time, equal amount of protons are released into the anolyte. If a pair of anion exchange membrane (AEM) and cation exchange membrane (CEM) is installed in the MFC reactor, with the AEM next to the anode and the CEM by the cathode, the two-chamber MFC becomes a three-chamber microbial desalination cell (MDC), which is able to desalinate salty water, such as seawater, brackish water, and produced water.

MCDC, which integrates capacitive deionization (CDI) into the MDC design, has the advantages of using electrodes to electrically adsorb ions while overcoming the challenges of pH imbalance and preventing salt transport to anode and cathode. A schematic of the MCDC is illustrated in Figure 1. Modular MCDC reactors were built treating a produced water from shale gas production. Produced water was deionized through electrochemical ion adsorption driven by the electrical field generated by microorganisms. Activated carbon cloth (ACC) – membrane assemblies were designed to connect with the anode and cathode and adsorb ions from water. During desalination, the ions are stored in the electrical double layer capacitors between the solution and the ACC assembly interfaces, thus preventing the salinity increase in treated wastewater. After the ACC is saturated with adsorbed ions, the assembly can be regenerated by removing the electrical potential and the retained salts can be fully recovered in situ for disposal or further salt recovery.
**Principal findings and significance**

During Yr2 study, we focused on understanding the interplay of anode, cathode and current in microbial fuel cells for wastewater treatment. In addition, inexpensive and innovative materials such as carbon felt, carbon foam, and stainless steel mesh coated with activated carbon were synthesized and used as electrodes in order to reduce the costs of MFC and MCDC.

- The anode and cathode potential determine the overall performance of a MFC or MCDC. Thus far, research has focused on understanding the performance of individual electrodes, but there has been no investigation on how the anode or cathode potential changes as a function of the other. This study demonstrates for the first time that interplay exists between the anode and cathode electrode, a phenomenon whereby reducing voltage loss at one electrode increases voltage losses at the other. Using our experimental data and results from literature, a model was developed to quantify the interplay at theoretical and applied levels for wastewater treatment. The cause of interplay was attributed to the reactant/product concentration gradient that exists between the bulk catholyte-cathode and biofilm-anode electrode surfaces. These findings advance our fundamental understanding of bioelectrochemical systems and provide new insight on how to improve performance for wastewater treatment and energy production.

- Graphite brush used in this study is a standard material that has been widely used in bioelectrochemical systems research. Although graphite brush is highly effective as anode, it is
expensive. We conducted additional experiments to evaluate two new anode materials - hard carbon felt and carbon foam - against graphite brush to determine if using inexpensive materials with less than ideal properties can achieve more cost-effective treatment than high-cost, high-performing materials. Although the carbon felt generated 14% less power and 15% less anodic current during treatment of wastewater, the power output to electrode cost (W/$) was 2 times greater than graphite brush. 16S rRNA sequencing showed the microbial community compositions were not statistically different on graphite brush, carbon felt and carbon foam while organic removal rates were nearly identical for all materials. Our results demonstrate that, from a system standpoint, high-performing materials may not be necessary when treating wastewater and that inexpensive materials are capable of achieving more cost-effective treatment despite generating lower power.
Geographic Information Systems for Water Resources Research Planning

Basic Information

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Publication

Description of 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 for this GIS lab project is to increase availability and accessibility of water resource information and development of new datasets to support water resource planning and management in the state. The first objective is to provide spatial data library accessibility. Accessibility to the NM WRRI Spatial Library is being pushed towards a user friendly web application user interface. The web applications consists of JavaScript produced web maps, water budget models, meta data regarding data processing procedures, and easy data download/hosting functionalities. This objective also maintains arrangements and establishes those necessary to provide access to spatial data maintained by other agencies and organizations. The second objective is spatial data development which evaluates needs, establishes priorities, and undertakes development of spatial data that is otherwise unavailable. This second objective was previously being executed through surveys. This task is being redirected toward the creation of focus groups that consist of stakeholders, users, and developers. The idea behind these focus groups is purely to illustrate the data needs and demonstrate current capabilities for the purpose of creating dialogue for delivering future data products in an effective way. 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.

Description of 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 NM WRRI 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 NM WRRI maintains a GIS laboratory consisting of computer workstations; data storage devices; input/output devices; software for mapping and analysis (ArcGIS, ENVI); 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 NM WRRI also maintains an ArcGIS Internet web server site through which both spatial and tabular water resource data can be downloaded.

Description of 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 has utilized GIS mapping products for use in their regional plans and in public outreach. 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.

The GIS sophisticated mapping and geo-spatial database management system, originally designed to support NM WRRI-funded research activities, has been used for external research grants (e.g., the compilation and creation of statewide maps for water planning and budgeting funded by the New Mexico Office of the State Engineer (NMOSE) and the National Science Foundation (NSF), Examination of Mesilla Basin Aquifer Pollution Sensitivity Using DRASTIC for the Border Environment Cooperation Commission (BECC), and Creation of a Digital Hydrogeologic Framework Model of the Mesilla Basin and Southern Jornada del Muerto Basin) by water resources management and planning agencies in the state. A research grant has also 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.

During the reporting period, projects funded through the GIS lab were sponsored by the USGS, BECC, the Experimental Program to Stimulate Competitive Research (EPSCoR) funded by the National Science Foundation, and the National Park Service.

The EPSCoR and Statewide Water Assessment water budget for New Mexico 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.
Arsenic Removal from Water by Porous Polymers

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<td><strong>Principal Investigators:</strong></td>
<td>Reza Foudazi</td>
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Publications

3. R. Zowada, R. Foudazi, Porous Hydrogels based on High Internal Phase Emulsion Templating, 2016 American Institute of Chemical Engineers Rocky Mountain Student Regional Conference, Poster Presentation, April 1-3, 2016, Tucson, AZ.
Description of problem and research objectives

With the rapid development of industries such as metal plating facilities, mining operations, fertilizer manufacture, tanneries, battery manufacture, paper pulping, and pesticide manufacturers, wastewaters containing heavy metals are discharged into the environment at an increasing rate. Heavy metal contamination in the environment is a major public health concern worldwide as the regulations established by U.S. Environmental Protection Agency (EPA) and the World Health Organization (WHO). Unlike organic contaminants, heavy metals are not biodegradable, and tend to accumulate in living organisms. The presence of heavy metals, particularly arsenic, has been confirmed in brackish groundwater sources in New Mexico. The EPA has regulated the arsenic maximum contaminant level (MCL) to 10 ppb in 2006.

The main goal of this work is to remove arsenic contamination from water resources in order to provide economical strategies for drinking water in New Mexico. Therefore, porous polymers were synthesized through polymerization of continuous phase of high internal phase emulsions (HIPEs) and subsequently functionalized with chemistry designed for arsenic adsorption. Acrylamido-2-methyl-1-propanesulfonic acid (AMPS) was used as monomer for the production of cation exchange porous polymers. In order to functionalize porous polymer for arsenic adsorption, hydrated iron(III) oxide nanoparticles were synthesized in the matrix of porous polymers.

The specific objectives of this project were: (i) study the emulsion formation and polymerization of AMPS, (ii) investigate the formation of hydrated iron(III) oxide nanoparticles on the polymer chains, and (iii) exploring the adsorption/desorption of arsenic on/from synthesized porous polymers.

Description of methodology

Acrylamido-2-methyl-1-propanesulfonic acid (AMPS) monomer was first mixed with N,N’-Methylene(bis)acrylamide (MBA) as cross-linker, potassium or sodium persulfate as initiator, Pluronic surfactants as emulsifier, and water to form the aqueous phase. Then, about 80 vol.% cyclohexane was emulsified in the aqueous phase, and subsequently polymerized by placement in the oven at 65°C for 24 hr. The ration of AMPS to MBA was changed in the formulation.

To produce hydrated iron(III) oxide nanoparticles in the polymer matrix, monoliths were soaked in a 4% FeCl₃ solution at pH of ~2, then they were immersed in a solution of NaCl and NaOH, each at 5% w/v concentration, to precipitate the iron(III) hydroxides within the polymer matrix, and finally were washed with a 50/50 ethanol-water solution and dried at 50-60 °C for 60 min.

The produced porous polymer and nanoparticle formation were studied by Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM), respectively. The sorption behavior of monoliths was studied by using batch isotherm tests. The monoliths were immersed in a solution with 10 mg/L arsenic. The pH of the solution was kept at 7.0 – 7.5 (i.e. drinking water) using dilute NaOH and HCl. Samples were placed into solution and allowed to soak for an extended period of time i.e. 12-36 hours. The reduction of ions through desorption was measured by the induced coupled plasma mass spectrometry (ICP-MS) for arsenic removal efficiency.
Principal findings and significance

- Production of porous hydrogels with about 3000% water sorption capacity (a significant achievement in the field of hydrogels with potential intellectual property registration)
- Synthesis of porous polymers with arsenic removal capabilities
Understanding the Costs of Arid Inland Communities

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Publication

Description of problem and research objectives

In the face of increasing population, development pressures, and climate change, many regions around the world face freshwater shortages. Planned potable water reuse can improve sustainability and reliability of water supplies by generating high-quality drinking water from wastewater. Most potable reuse research has focused on large coastal communities with relatively high mean household incomes. However, the US Department of Interior predicts that “hot spots” of conflict over water in the arid West are “highly likely” in numerous small-to-medium-sized inland communities with low-to-moderate household income levels. Potable reuse options may be different for larger, wealthier coastal communities as compared to small-to-medium-sized inland ones, not only in terms of the technologies used, but also in the communities’ knowledge of, attitudes toward, and ability to pay for the required technologies. Significant knowledge gaps exist regarding these issues for the arid, inland context, making it difficult for inland water managers to understand the feasibility of potable reuse for their communities. This research aims to inform decision-making about planned potable reuse in small-to-medium-sized, arid inland communities by estimating the total present worth of several proven indirect and direct potable reuse treatment scenarios that are appropriate for the inland context.

Description of methodology

In order to estimate the total present worth of several proven indirect and direct potable reuse treatment scenarios that are appropriate for the inland context, we selected a medium-sized urban area in New Mexico to use as a case study. Each of the indirect and direct potable reuse scenarios was examined with two different options for advanced treatment: reverse osmosis and ozone/biological activated carbon, both of which were preceded by microfiltration and followed by ultraviolet disinfection.

Capital and O&M cost data for full advanced treatment facilities, individual treatment components, piping, pumping, and storage facilities were collected from multiple sources including costing manuals, research reports, municipal reports, and journal articles. Cost data for existing water reuse plants were also obtained through personal communication with personnel at several facilities. Two sets of costing software, the Engineering News-Record (ENR) Construction Index, and the RSMeans database were also important costing tools used in the study. The 20-year present worth for each treatment scenario was calculated by inputting the collected and condensed capital and O&M costs into present worth equations from the peer-reviewed literature that are appropriate for the purposes of this study.

Principal findings and significance

The results showed that the present worth for indirect potable reuse was higher than that for direct potable reuse because of additional pumping and piping requirements. Surprisingly, the present worth values of the two advanced treatment options (reverse osmosis and ozone/biological activated carbon) were almost identical in each reuse scenario because the higher capital and operations and maintenance costs for reverse osmosis systems were balanced by higher equipment replacement costs for ozone/biological activated carbon systems.
Drought in the West: Elements of Successful Science to Improve Water Management and Address Nationally Important Issues Through the USGS-NIWR Partnership

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Publications

There are no publications.
**Description of problem and research objectives**

The goal of this project is to improve the effectiveness of the Water Institutes Program by showing how unique characteristics of the water institutes and their state oriented research help meet regional and national goals. The science question asked is: Research to address drought is funded based on the importance of the issue, but is the science actually implemented in terms of planning and policy for improved water management?

The research objectives are threefold:

- Determine if research produces science that is used for planning
- Identify common elements of successful projects
- Document (tell 3-4 stories) successful inception to completion

Specifically, this project will identify and illustrate representative research projects funded through the WRRA 104b program that help address the regional issue important to the U.S. Geological Survey (USGS) of drought in the West. To show the end results of the research, this project will identify successful results from 104b funded research after the research has been concluded.

**Description of methodology**

The methodology includes:

- visits to water institutes located in western states;
- periodic conference calls with Earl Greene, a hydrologist at the USGS;
- A search for projects in web and literature;
- A search for published papers spawned by research;
- Analyzing science topics and their connection to policy;
- Using the research to write three stories that begin with 104b seed funding and end with an impact on policy.

**Principal findings and significance**

Findings thus far have proved there are various cases where research projects within the United States began with 104b funding from USGS to address a state issue, and resulted in an impact on policy. The cases provide a direct connection between water science and policy. While 104b funding may have not been the only means of funding for the particular research projects that impacted policy, it is accurate to say that it did allow researchers to begin research to prove the need for more funding after 104b.

A draft policy and management fact sheet was submitted to Earl Greene at USGS. Dr. Greene expects the policy and management fact sheet to be published by USGS by February 2017.
Important Advances in Water Policy and Management Made Possible by Federal Funding to National Institutes of Water Resources

Alexander G. Fernald¹, Jesslyn P. Ratliff¹, Marcus R. Gay¹, John Tracy/Idaho director², Jon Yoder³, Paul Ziemkiewicz⁴, Earl A. Greene⁵

Federal funding is made available through the water resources research act (WRRA) to national institutes of water research (“the water institutes”) of which there are 54, one in each state plus the District of Columbia and 3 territories: Guam, US Virgin Islands, and Puerto Rico. WRRA total funding ($6.5M in 2015) supports multiple programs, the largest being the institute program funding that provides federal funding ($92,335 to each institute) directed through the US Geological Survey (USGS). In some states, the WRRA institute program funding constitutes the entire budget of the state water institute, while in other states the funding is augmented with additional state and federal support. The USGS does not have policy as part of its mission, but the state water institutes are able to engage in research focused on management and policy. Therefore, a special avenue of opportunity exists for federal funding to have a meaningful impact on policy when WRRA funds are directed through the USGS to the water institutes. This fact sheet uses three examples to illustrate policy and management successes that stemmed from federal “104B” Funding from the water resources research act to state water research institutes has led to: 1) newly improved water quality regulations in West Virginia; 2) improved conjunctive management of surface water and groundwater in Idaho; 3) new comprehensive policy for water basin integrated planning in Washington; and the unique ability of the state institutes to engage in policy and management oriented work bolstered by the federal funding established the foundation for these successes. Some common themes for success emerge when we look at these three examples:

Research Supported by WRRA Institute Program Funding Initiates Entirely New State Policy and Responsive Monongahela River Water Quality Monitoring Program in West Virginia

Science:

A specific case (Appeal No. 10-34-EQB) in West Virginia proves to be a successful example of 104b funding impacting policy. The presentation of the Monongahela River water quality data lead to the determination that TDS (total dissolved solid) limits were not sufficient to ensure the protection of West Virginias water quality standards. The Environmental Quality Board (EQB) acknowledged the fact that science has demonstrated the problems that arise form surface coal mine discharges. The board also acknowledged that science shows the relation between the coal mine discharge and the harm to aquatic life and aquatic ecosystems. These acknowledgments led to the change in TDS discharge limits. (Appeal No. 10-34-EQB) http://www.courtswv.gov/supreme-court/calendar/2015/briefs/feb15/14-0247reply.pdf
Dunkard Kill Zone Expands Most Larger Fish Gone From Creek
Morgantown Dominion Post. 2 October 2009 – David Beard

Policy:

“Increases in water usage, recreational usage, and industrial impacts to the river have caused considerable debate about the adequacy of existing water quality regulations. The data generated from this study has provided crucial information to inform many of these concerns. It has provided the accurate and current water quality information necessary to inform the public and to aid regulatory personnel in making sound policy decisions. For example, information provided by this watershed monitoring program was important in drafting the newly proposed water quality regulations by the WV Department of Environmental Protection (WVDEP).”
(WV 2009 104B Annual Report)

“In December 2010, the Pennsylvania Department of Environmental Protection (PADEP) declared the Monongahela River impaired for potable water use due to the presence of sulfate salts. While sulfate compounds generally do not make water unsafe for humans, they can affect taste and interfere with industrial processes that require cleaner water.”

“Noticing a strong correlation between low river flows and high sulfate levels, WVWRI called for collaboration with the coal industry because their high output treatment facilities were making significant contributions to the river’s sulfate levels and thus to total dissolved solids (TDS) concentrations. A novel problem solving approach, spearheaded by WVWRI, combined water science with stakeholder collaboration and sought to restore the river in less time than the traditional regulatory process. Coal industry officials willingly shared water quality and quantity data (discharge volumes and TDS concentrations). Using this data in combination with a computer program showing maximum discharges for each treatment plant derived from the river’s flow, a collaborative and strictly voluntary discharge
management system was implemented. By 2010, the program was in effect, and sulfate concentrations in the Monongahela River began to decrease. As a result, the U.S. Environmental Protection Agency approved PADEP’s decision to remove the Monongahela River from the “impaired for potable water use” listing in late 2014.”


Three Rivers QUEST Addresses Sulfate Salts
Data Map: Provides the ability to view the differences in water quality at different locations at a glance and view changes over time.

Science:

Central Development: CONCEPTUAL MODEL FOR THE SNAKE RIVER PLAIN AQUIFER

Developing a Conjunctive Water Resources Planning and Management Model for the Eastern Snake River Plain

A geochemical investigation of groundwater sources in the Blackfoot River and Snake River floodplain 2006

Climate Change Impacts on the Snake River Plain's Surface & Ground Water Resources 2008

Improving estimates of tributary underflow in the Eastern Snake River Plain 2010

2006

“The development of ground-water and surface-water irrigation on the eastern Snake River Plain has necessitated conjunctive management of the ground and surface water resources. To facilitate this management approach, the Idaho Department of Water Resources (IDWR) has placed a strong emphasis on the development, use and refinement of scientific tools which help quantify the impacts of changing
water use practices on ground water and surface water supplies on the eastern Snake River Plain. Recognizing the importance of the ground-water model as a water management tool, the IDWR, the State Legislature and the water user community agreed to embark on a model reformulation process.”

“The technical effort was initiated in 1999 and involved data collection for a 22-year calibration period (Spring, 1980 through Spring, 2002), establishing a new model grid and boundary conditions and an exhaustive calibration of the new model.”

“Calibration parameters indicate an excellent fit to the observed data, providing confidence that the ESPAM provides an excellent representation of the complex hydrologic system of the eastern Snake River Plain. Complex water management decisions on the eastern Snake River Plain will be greatly enhanced by use of the ESPAM.”


Idaho ESPAM Pictures come from www.idwr.idaho.gov 12/10/2012

**Policy:**
Recognizing the importance of the ground-water model as a water management tool, the IDWR, the State Legislature and the water user community agreed to embark on a model reformulation process. 1999 Senate Concurrent Resolution No.136, passed by the Idaho Legislature in April of 2006, requested that the IWRB “expeditiously pursue, with support from the Idaho Department of Water Resources (IDWR),
development of a comprehensive aquifer management plan for the Eastern Snake River Plain Aquifer for submission to and approval by the Idaho Legislature.” The Resolution directed the Board to solicit public input regarding development of the “goals, objectives and methods” for aquifer management from “affected water right holders, cities and counties, the general public and relevant state and federal agencies.” The Legislature also asked the Board to provide a status report during the next legislative session, together with a “framework for the plan, including appropriate interim goals and objectives in accordance with state law, a method to fund implementation of the plan and a time schedule for finalization of the plan.”

“In Concurrent Resolution 136, the Legislature listed factors driving the need for a comprehensive aquifer management plan, including:
Reduced spring discharges and areas of declining aquifer levels resulting from extended drought, changes in irrigation practices and ground water pumping; Conflict between water rights holders stemming from insufficient water supplies to satisfy existing beneficial uses; the threat to the state’s economy posed by ongoing conflict between water users; Resources already committed to the Conservation Reserve Enhancement Program (CREP); Previous actions taken by the Legislature to manage the ESPA, including legislation to create water measurement districts and groundwater districts, and previous funding for project implementation and mediation between parties; Previous actions taken by IDWR, including the expansion and creation of water districts for the purposes of conjunctive administration; the authority vested in the Board to cooperate in water studies, planning and research, and the work already done by the board to inventory data and information related to the ESPA; the good faith efforts of water rights holders to contribute to a resolution to the conflict; and the determination of the legislature to facilitate and encourage a resolution of the surface/groundwater rights conflict that respects existing water rights and protects the welfare of the people of the state of Idaho by ensuring the aquifer is managed in accordance with state law.” (Diane Tate CDR Associates 2006 Incorporating Modeling into Decision-Making for a Comprehensive Aquifer Management Plan: A Facilitator's Observations on Idaho's Eastern Snake Plain)

“Idaho Department of Water Resources and US Bureau of Reclamation (BOR) are studying options including ground water banking, off-season canal recharge, water buyouts or leases and curtailment of groundwater pumpers to remedy shortages in the Eastern Snake Plain Aquifer and prevent damages to senior right holders.” (2008 Idaho 104B USGS Report)

“The Idaho Legislature directed the Idaho Water Resource Board to develop a Comprehensive Aquifer Management Plan (CAMP) for the eastern Snake River Plain aquifer. The CAMP has recently been approved by the Legislature and lays out plans to modify the aquifer water budget by about 600,000 acre-feet per year.” (2009 Idaho 104B USGS Report)


2012
Developing a Conjunctive Water Resources Planning and Management Model for the Eastern Snake River Plain – 2012ID178B
In this study, we propose a new modeling framework using Riverware software to characterize water flux dynamics between surface and groundwater interactions. This project has three major benefits: (1) it tests the ability of Riverware to be used to model conjunctive management as it relates to the Snake River
system without the time and expense of developing a completely new reservoir operations model, (2) uncertainties in estimates of tributary underflow, natural recharge, crop selection, and irrigation methods is quantified, while (3) initiating a project that could potentially lead to the development of a new state of the art planning and management model to complement IDWR’s groundwater model, the Eastern Snake Plain Aquifer Model (ESPAM). While the first benefit focuses on providing practical support to IDWR, from a scientific perspective, the second benefit is the most intriguing. (2012 Idaho 104B USGS Report)


Research Leads to an Integrated Water Resource Management Plan that Benefits Fish, Communities, and Agriculture

Science:

Fish Habitat Enhancement
Surface Water-Groundwater interactions and quality.
Integration of Surface Irrigation Techniques to Reduce Sediment and Nutrient Loading in the Yakima River Basin. 2000
Using Stable Isotopes to Trace Nitrate Sources and Surface Water-Groundwater Interactions in the Upper Yakima River Drainage 2005
Influence of Large Wood Addition on Nitrogen Transformations at the Surface water/groundwater Interface 2009
The congressional objectives of the YRBWEP study were to develop a plan that would provide supplemental water for presently irrigated lands, water for new lands within the Yakama Indian Reservation, water for increased instream flows for aquatic life, and a comprehensive plan for efficient management of basin water supplies. Early in the YRBWEP study process, fish passage problems were identified as needing immediate early attention and congressional legislation in 1984 authorized YRBWEP Phase 1, which primarily involved rebuilding fish ladders and constructing fish screens on river diversions. (US Department of the Interior Cascades Area Office) [http://www.usbr.gov/pn/programs/yrbwep/](http://www.usbr.gov/pn/programs/yrbwep/)

Congress passed legislation in 1994 for what is generally referred to as YRBWEP Phase 2. This legislation provided for significant water conservation and acquisition activities, studies to define the long-term water needs of fish and current irrigators, improvements to the Wapato Irrigation Project, and development of an interim plan for management of basin water supplies. (US Department of the Interior Cascades Area Office) [http://www.usbr.gov/pn/programs/yrbwep/](http://www.usbr.gov/pn/programs/yrbwep/)
(Title XII, Public Law 103-434) authorized the development of an Interim Comprehensive Basin Operating Plan. This plan provides a general framework within which the Yakima Project Superintendent operates the Yakima Project, including measures implemented under the Yakima River Basin Water Enhancement Project. The document also provides several recommendations for possible implementation. (US Department of the Interior Cascades Area Office) [http://www.usbr.gov/pn/programs/yrbwep/](http://www.usbr.gov/pn/programs/yrbwep/)

State of Washington Departments of Ecology and Reclamation brought representatives from the Yakama Nation, irrigation districts, environmental organizations, and federal, state, county, and city governments together to form the Yakima River Basin Water Enhancement Project (YRBWEP) Working Group to help develop a consensus-based solution to the basin’s water problems. (Department of Ecology office of Columbia River) [http://www.ecy.wa.gov/programs/wr/cwp/YBIP.html](http://www.ecy.wa.gov/programs/wr/cwp/YBIP.html)

Reclamation was awarded up to $1.3 million to partner with Washington State Department of Ecology, who will provide matching funds up to $1.3 million. In addition, Ecology will also cover remaining costs associated with finalizing the Preliminary Integrated Water Resource Management Plan (IWRMP), which was developed by the Yakima River Basin Water Enhancement Project 2009 Workgroup. (US Department of the Interior Cascades area office) [http://www.usbr.gov/pn/programs/yrbwep/](http://www.usbr.gov/pn/programs/yrbwep/)

Policy:

“This research is in response to Section 5057 of the State of Washington Capital Budget for 2013, which charges the State of Washington Water Research Center “to prepare separate benefit-cost analyses for each of the projects proposed in the 2012 Yakima River basin integrated water resources management plan.” (Yakima integrated plan)

“Water markets show potential for reducing the impacts of basin-wide curtailment. Fish habitat restoration is unlikely to satisfy a B-C test. Reservoir fish passage projects are likely to provide positive net benefits through their pivotal role in supporting wild sockeye reintroduction into the basin. Instream flow benefits are insufficient to support the full suite of IP water storage projects given the net benefit shortfall in out-of-stream benefits, but proposed instream flows may be supportable through market purchases. No individual water storage project provides positive net benefits for out-of-stream uses when implemented as part of the full IP, even under the most adverse climate and restrictive market conditions. Net benefits for out-of-stream use of individual water storage projects implemented with no other projects implemented are negative, with some exceptions under the most adverse climate and water market conditions. When implemented together as part of the IP, the major water storage projects as a group do not pass a B-C test.”

Because each of the proposed IP projects would operate within the Yakima Basin hydrologic system, there are extensive interdependencies among projects, so that the benefits of one project are often dependent on the implementation status of other projects. We show that the value of any given water storage projects is highest when no other water storage project is implemented, and that water market development also affects the value of water storage projects. The economic tradeoffs between instream flows for fish and out-of-stream water uses are also dependent on these factors.

A snapshot of IP benefit estimates for moderate climate, water market, and baseline fish scenarios.

Agricultural irrigation benefits: $117 million.
Municipal and domestic benefits: $32 million.
Fish benefits: $1 to $2 billion. (Benefit Cost Analysis report to the Washington State Legislature: Principal Investigators: Jonathan Yoder, Jennifer Adam, Michael Brady, Joseph Cook, Stephen Katz.)

BENEFIT-COST ANALYSIS OF THE YAKIMA BASIN INTEGRATED PLAN PROJECTS - Jonathan Yoder
“Time series of recent adult spawner estimates for A) spring chinook, B) fall chinook, C) coho and D) steelhead trout in the Yakima Basin. In each case the time series are compared with the estimates of escapement for each species from the Fish Benefits Memorandum for the Baseline, Restoration and Restoration plus Passage scenarios.” (U.S. Bureau of Reclamation, HDR Engineering Inc., and Anchor QEA 2011).

2015
“The total cost of all the projects in the Integrated Plan is projected to be approximately $3.812 billion. That cost will be spread out over 30 years and will be shared by local, state, and federal governments and water users. An initial investment of $45 million by the state for 15 early action projects would yield nearly $90.7 million in economic benefit and create over 680 jobs.”

Overall conclusions

- WRRA institute program funding resulted in improved water policy and management by:
  - Funding science that led to and supported policy implications
  - Enabling actual policy modeling and research
  - Leading to meaningful research based policy outcomes

- Three examples show policy and management impacts:
  - West Virginia – determined aquatic impairment, set up new monitoring system, and developed new water quality regulations
  - Idaho – characterized and modeled hydrology and water quality of connected surface water and groundwater; studied management options; agreed on comprehensive aquifer management plan
  - Washington – researched various agriculture, storage, instream aquatic, and conservation aspects of integrated water resource management plan; did cost benefit analysis that showed aquatic benefits provided most economic impact

- In addition to the important policy and management outcomes of the directly funded projects described in this fact sheet, federal funding provides the additional critical funding that keeps institutes going. In 2012, a survey within the NIWR group showed that about one third of the water institutes would not exist without the WRRA institute program funding.
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. The institute's website, technical publications, newsletters, conferences, symposia, press announcements, and presentations keep practitioners aware of new water-related technology and research advances. The NM WRRI homepage (http://nmwrri.nmsu.edu/) provides online information about the institute's programs, newsletters, technical report series, requests for proposals, upcoming conferences and symposia, the research reference library, and special in-house projects. All 58 past annual water conference proceedings have full-text viewing via the institute's homepage. New Mexico universities, federal and state servers, including the NM Office of the State Engineer, the USGS, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, Bureau of Reclamation, and National Climatic Data Center are linked to the NM WRRI homepage.
Information Transfer Program

Basic Information

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Publications

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, including the state’s policy makers, 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 agencies and 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 the institute’s website, conferences, publications, and audiovisual presentations. For the past 60 years, the NM WRRI has sponsored the Annual New Mexico Water Conference focusing on a topic of importance to the New Mexico water community, usually policy oriented. The annual conference is held in different locations around the state 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 150 and 200 people, depending on the location and topic of the conference. However, the past four years have seen an increase in attendance: the 2012 conference had an attendance of over 500, the 2013 conference attracted 326 participants, the 2014 conference had nearly 350 participants, and the most recent conference had 250 in attendance. For the past four years, the annual water conference has included a poster session, which highlights water research taking place across the state and region. Students are encouraged to present posters at the annual water conference and in 2015, 20 students did so. NM WRRI made 14 Student Water Research Grants in 2015, and most of the recipients attended the annual water conference and presented a poster.

Publications include technical completion reports resulting from NM WRRI-sponsored projects, special in-house publications, and conference proceedings. The institute has published more than 400 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 available via the NM WRRI 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. NM WRRI water conference proceedings for the past 58 years are also available online in full text.

In 2015, the institute began producing a monthly newsletter via email, “New Mexico Water eNews.” The monthly online news feed is meant to supplement its quarterly newsletter, The Divining Rod, which focuses on research and current water issues. The online news feed reaches over 1,500 recipients and keeps its recipients informed of NM WRRI activities, upcoming meetings, publications, and research projects.
The institute-housed reference room underwent a major reorganization. All books and documents were checked for online availability; for books found to be available online, the institute’s online library database was noted with the link. A complete catalog of holdings, 10,200 books and references, can be searched through the NM WRRI website, reference room link at http://nmwrri.nmsu.edu/?page_id=2897, accessible by faculty, students, and the general public.

NM WRRI’s homepage (http://nmwrri.nmsu.edu/) provides online information about the institute’s newsletters, technical report series, requests for proposals, upcoming programs, special in-house projects such as the Statewide Water Assessment, and the research reference library. All NM WRRI reports are available for viewing online via the institute’s website. The website, originally created in 1995, has undergone a complete redesign and was launched in the summer of 2015. The website is updated on a regular basis and continues to be a focal point of information on New Mexico’s water resources with many links to other related sites such as the U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, USGS, Bureau of Reclamation, and National Climatic Data Center. For the reporting period, the NM WRRI website received 41,498 unique visits.

NM WRRI has developed a state-of-the-art geographic information system on water resources in New Mexico and has become the focal point for GIS data and information concerning water resources in the state. It combines database management with digital mapping into spatial-tabular data models. These models are powerful tools for representing and manipulating earth-science information. The primary objective of the system is to increase availability and accessibility of water resource information to support water resource planning and management in the state. Efforts are coordinated with cooperating agencies and organizations to ensure no duplication of effort and to establish guidelines for map coverages and priorities. The staff maintains, updates as necessary, and makes the data available to cooperating agencies and organizations through both formal and informal arrangements to facilitate water resource planning activities. In recent years, the NM WRRI has provided GIS expertise on a regular basis to the National Park Service.

The institute director is 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 60th Annual New Mexico Water Conference was held in Taos on October 8-9, 2015. The conference theme was "Coloring Outside the Lines: Can Science Help Us Be Creative and Innovative in Managing our Water?" The conference focused on New Mexico’s reliance to the coming water supply challenges. Participants were urged to push beyond the edges of what is typically discussed at water conferences and were encouraged to discuss these ideas with colleagues. For example, a prominent New Mexico faculty researcher challenged attendees to think about the legal and policy tools that New Mexico has available to address what science tells us will be a shrinking water supply and a growing population in the state, including consideration of a new water code. The 2015 was attended by 250 participants and included 44 posters, of which 20 were presented by students. PowerPoint presentations made at the conference are available on the institute's website. The conference proceedings is in preparation and will be posted on the
The 58th Annual New Mexico Water Conference proceedings were completed and produced in hardcopy, on CD for distribution to conference participants, and posted on the institute’s website as are all publications.

Six Technical Completion Reports were published during the reporting period:

- Distribution and Transport of Pyrogenic Black Carbon in Soils Affected by Wildfires, Valles Caldera, New Mexico, with Implications for Contaminant Transport, by NM Tech researchers D. Cadol, A Galanter, and P. Nicholls (Rpt no. 365, March 2015)


- Exploring Policy Alternatives for Controlling Nitrate Pollution from New Mexico's Dairies, UNM researchers J. Wang and J.R. Joshi (Rpt no. 369, December 2015)


For the past year, the institute’s website has averaged 3,773 unique online visits each month. It averages 2,024 online unique visits for publications from its technical and miscellaneous report series and an average of over 19,484 unique visits and pdf downloads per month of its proceedings series. Because of the ability to view and print all institute publications online, the NM WRRI is averaging only a few requests for hard copies of specific publications each month via postal mail or visits to the institute. Requests online have continued to increase each year.

In order to get water-related information out more quickly and efficiently, the NM WRRI began an online news feed in March 2015, New Mexico Water eNews. Each month the institute emails the online newsletter to over 1,500 recipients with an average open rate of 28 percent each month. The news feed aims to keep its readers informed on the latest water topics, emphasizing those in which the NM WRRI is involved. The online newsletter augments the institute’s long-running quarterly newsletter, *The Divining Rod*, an eight- to twenty-page newsletter that focuses on research projects administered by the NM WRRI 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 of The Divining Rod and the New Mexico Water eNews is available on the NM WRRI’s website.

Online unique visits per month of the NM WRRI’s reference room averaged 71 for the reporting period. Two students and a part-time institute staff member continued the reorganization of the institute-housed water reference room; 2,900 holdings were reviewed during the reporting period (and 2100 remain to be checked) for online availability; for books found to be available online, the institute’s online library database was noted with the link. Hard copies of these books were recycled. Over 750 books were donated to the New Mexico State University Library. Currently, remaining books and documents are being catalogued. A complete catalog of holdings, 10,200 books and references, can be searched through the NM WRRI website reference room link at http://nmwrri.nmsu.edu/?page_id=2897.

The institute’s director participates in local, state, and national conferences and workshops and speaks before many groups. He is an active member of the National Institutes for Water Resources and is the chair of the NIWR-USGS Partnership Committee. The director is also a member of the Universities Council on Water Resources and serves on their board. The NM WRRI 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. Of particular note this year, the director went before the state legislature’s House Committee on Agriculture, Water & Wildlife to update committee members on the institute’s programs and to request additional funding to continue working on the Statewide Water Assessment initiative.

The New Mexico State Legislature held a 30-day session in early 2016 and wrestled with a very tight state fiscal budget that was impacted by falling revenues in the oil and gas industry. State funding to the institute’s base budget received a 2.44% cut. The base budget of recurring funds will support operations of the NM WRRI and water research throughout the state including faculty and student grants to NM universities. In addition to the competitive research grants and ongoing programs, a special focus this year will be a more precise measurement of vegetation water use with remote sensing technology. In addition to its base budget, NM WRRI received $500K from the New Mexico Office of the Attorney General with funds from the Consumer Settlement Fund. These one-time funds will support NM WRRI special projects, like the Statewide Water Assessment effort that aims to improve water management in New Mexico.

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

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Notable Awards and Achievements

New Mexico State University's interdisciplinary Water Science and Management graduate degree program currently has 29 students enrolled representing 10 countries. Ten students have graduated from the program. The program has increased enrollment in graduate education, increased water research, and offers doctoral level courses in the departments of civil engineering, geography, plant and environmental sciences, agricultural economics/agricultural business, and animal and range sciences. Naimi Khan, an NMSU student in the Water Science and Management program received an International Peace scholarship (IPS). This scholarship is for international students already enrolled in their MS/PhD program at any university in USA or Canada and also are willing to go back their country after finishing their degrees. NM WRRI graduate student in the Water Science and Management program, Connie Maxwell, was awarded honors from Tau Sigma Delta, an honor society for architecture and design fields for high scholastic standing and leadership. She also completed a master's degree from the University of New Mexico in community and regional planning and her master's thesis passed with distinction. NMSU Chemical Engineering Department undergraduate student, Ryan Zowada, placed first in the AIChE Rocky Mountain Regional Poster Competition. He is working with Dr. Reza Foudazi on the USGS base supported grant entitled, Arsenic Removal from Water by Porous Polymers. Two faculty members who received grants from the USGS 104b base grant, Dr. Pei Xu and Dr. Reza Foudazi, also recently received grant support through a Cooperative Agreement between New Mexico State University and the Bureau of Reclamation. Drs. Pei's and Foudazi's proposals were selected among proposals received in a 2016 Request for Proposals. A 104B grant, Understanding the Costs of Arid Inland Communities' Potable Water Reuse Options, provided funding to offer a water-related course called, The Orphaned Land, in the Fall of 2015 at the University of New Mexico. The results of the research will also be used by the PI, Dr. Caroline Scruggs in a course, Water & Energy in New Mexico in the upcoming Fall semester.
