

**New Mexico Water Resources Research Institute
Annual Technical Report
FY 2017**

Introduction

This annual report provides the required information for projects funded with 2017 USGS 104B base grant and mandatory non-federal matching funds. Please note that there may be some overlap in information with our 2016 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 the Statewide Water Assessment. Institute staff are continuing to work on a modest redesigned for the website; the website is updated and 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 long-term drought in 100 years or longer. After several years of severe drought conditions, as of May 2018, over 90 percent of the state was in severe to exceptional drought status, with all of its entire population of 2,050,791 affected by abnormally dry to exceptional drought conditions. Virtually the entire upper half of the state is in extreme and exceptional drought, which is where the majority of the state's population lives. Long-term drought persists across the Southwest. A recent report by climatologists indicated that the Four Corners region where Arizona, New Mexico, Colorado, and Utah meet, is the hardest hit by drought and there's little relief expected. Farmers, ranchers, and water planners are bracing for a condition much different from just a year ago when only a fraction of the region was experience low levels of dryness.

Additionally, litigation continues between Texas and New Mexico over the apportionment of Rio Grande Project water that supplies irrigators with water in southern New Mexico and El Paso, Texas. Both states are

accusing each other of over pumping groundwater.

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, eight projects received funding from the 2017 Annual Base Program. Four of these projects fit into the water conservation, planning and management category: 1) WRI Information Transfer Program; 2) Geographic Information System for Water Resources Planning; 3) Drought in the West (supplemental grant); and 4) Transboundary Aquifer Assessment Program (supplemental grant). Four water quality projects were supported: 1) New Mexico's Mountain Sources of Water - A Mechanistic Approach to Understand Mountain Recharge and Its Implications for Local and Statewide Water Budgets; 2) What are the effects of the Gold King Mine spill on San Juan County, NM agricultural irrigation ditches and farms?; 3) Digital Soil Mapping for Improving Hydrological Modeling of New Mexico Water Resources; and 4) Effects of Wildfire Ash on Water Quality.

During the reporting period, March 1, 2017 through February 28, 2018, the NM WRI administered a total 48 projects dealing primarily with water planning and management issues as well as water quality. The total value of these projects was \$3,689,192. Dollar amounts per project award ranged from an NM WRI Student Water Research Grant on land-uses changes due to climate change of \$4,720 to over \$1.5 million, of which \$850,000 was awarded for the reporting period, for a multi-university grant from the National Science Foundation for a study on drought impacts. During the reporting period, 24 projects were conducted at New Mexico State University; 4 at the University of New Mexico; 6 at New Mexico Tech; 1 at New Mexico Highlands University; 1 at Eastern New Mexico University; 2 contracts with 2 private entities and one with the USGS; and two in-house 104B projects (GIS and Information Transfer). NM WRI staff managed 7 additional projects (TAAP, EPSCoR, Drought in the West, Gold King Mine conference, NM Dept of Health, INFEWS, USDA/TAMU).

Of the eight projects receiving USGS 104B funding during the reporting period, two were made to a New Mexico State University faculty researchers, one to a NM Tech faculty researcher, and one to a University of New Mexico investigator (the other four projects are in-house efforts, i.e., GIS and Information Transfer programs, Drought in the West, and TAAP). Three of the four research grant projects were led by junior faculty at the assistant professor rank, and one was led by an associate professor.

USGS 104B projects, USGS Supplemental funded project (Drought in the West), and USGS Cooperative Agreement project (TAAP) administered by the NM WRI utilized 22 students during the year including 7 undergraduates, 9 masters, 4 PhD students, and 2 Post-doc appointees in the disciplines of civil engineering, computer science, education, environmental science, finance, geography, geology, hydrology, plant and environmental sciences, public administration, soil science, water science and management.

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.

Is there a relationship between tree canopy cover change on the landscape and the discharge of Gallinas Creek through time (from 1939 to 2015) in Las Vegas, NM?, NM State appropriation, student grant \$4,720

Research Program Introduction

Investigation of soil composition from burned areas affecting water quality changes following wildfires, NM State appropriation, student grant \$5,550

San Jose Mining District Groundwater Investigation, NM State appropriation, student grant \$5,757
Monitoring water quality parameters within a known range of Western River Cooters (*Pseudemys gorzugi*) within Black River Drainage, NM State appropriation, student grant \$5,772

Spatial prediction of soil hydraulic properties accounting for variable wildfire burn severity, Valles Caldera, New Mexico, NM State appropriation, student grant \$5,793

Characterization of Pathogenic Bacterial Regrowth and Impairment Potential along the Rio Grande near Albuquerque, NM State appropriation, student grant \$5,980

Gila National Forest Stream Temperature and Intermittency Monitoring Network for Species of Special Interest, NM State appropriation, student grant \$5,987

Effects of NRCS and BLM conservation practices on plant and soil biological communities and hydrologic processes in the Rio Puerco Watershed, NM State appropriation, student grant \$6,000

Uranium abatement for contaminated, limited water resources using clay pellets, NM State appropriation, student grant \$6,000

Post wildfire geomorphic and hydrological effects in the Upper Santa Fe Municipal Watershed, NM State appropriation, student grant \$6,000

Economic performance of water conservation and storage capacity development to adapt to climate in the American Southwest, NM State appropriation, student grant \$6,000

A lab and pilot scale comparison of attached growth and suspended culture for the algal remediation of arsenic from water, NM State appropriation, student grant \$6,000

Developing the water budget and calculating the recharge for the Mesilla Bolson Aquifer, NM State appropriation, student grant \$6,000

Pore-scale transport of strontium and chromate during dynamic water content changes in the unsaturated zone, NM State appropriation, student grant \$6,000

Improved meteorological Infrastructure for water management in the Middle and Lower Rio Grande, New Mexico, NM State appropriation, student grant \$6,000

Integrated geological, geophysical, and hydrological study of field-scale fault-zone cementation and permeability, NM State appropriation, student grant \$6,000

Solar energy assisted water purification: Incorporation of an environmentally benign porous graphitized carbon nitride (g-C₃N₄) photocatalyst with graphitized polyacrylonitrile (g-PAN) for efficient oxidation of toxic arsenite [As(III)], NM State appropriation, student grant \$6,000

Digital hydrogeologic-framework model of Mesilla Basin Region - Illustration preparation for final review draft of NM WRRI TCR-363, NM State Appropriations, \$10,000

Digital Soil Mapping for Improving Hydrological Modeling of NM Water Resources, USGS 104B \$15,000

Research Program Introduction

Effect of Wildfire Ash on Water Quality, USGS 104G \$17,000

Information Transfer Program, USGS 104B \$21,637

Isotopic and geochemical characterization of deep and shallow groundwater resident time, connectivity, and mixing in the Mesilla Basin, NM, NM State Appropriations, \$29,750

New Mexico's mountain sources of water: A mechanistic approach to understand mountain recharge and its implications for local and statewide water budgets, USGS 104B \$30,000

What are the effects of the Gold King Mine spill on San Juan County, NM agricultural irrigation ditches and farms?, USGS 104B \$30,000

New Mexico Statewide Water Assessment - Regional equations for estimating mean annual streamflow at ungaged stream locations in NM - Yr 3, NM State Appropriations, \$30,000

Groundwater level and storage change in the Southern High Plains Aquifer in two variably confined aquifers, NM State Appropriations, \$36,026

Geographical Information System (GIS) for water resources planning, USGS 104B \$38,698

New Mexico Statewide Water Assessment: Estimation of total available water (TAW) as input for the EvapoTranspiration Recharge Model (ETRM) for statewide ET assessment - Yr 3, NM State Appropriations, \$38,992

Using remote sensing to develop ET fluxes for the Mesilla Valley Aquifer, NM State Appropriations, \$39,249

Drought in the West: Elements of successful science to improve water management and address nationally important issues through the USGS-NIWR partnership, USGS Supplemental Grant, \$60,000

Continued development of the evapotranspiration and recharge model: Focused recharge through ephemeral streams - yr 3, NM State Appropriations, \$67,444

Irrigation with Brackish Groundwater and Desalination Concentrate: Effect on soil microbial properties, plant uptake, and ion deposition in soil, Bureau of Reclamation-NMSU Cooperative Agreement, \$73,164

Biochar for Desalination Concentrate Management cooperative agreement, Bureau of Reclamation-NMSU Cooperative Agreement, \$74,377

Impact of drought on household water quality in rural Southern New Mexico: Second continuation project, NM Dept of Health, \$90,000

Valuing the Potential Contribution of Desalination and Water Reuse to the Water Supply Portfolios of Southern Dona Ana County, New Mexico Bureau of Reclamation-NMSU Cooperative Agreement, \$99,836

Isotopic, Geochemical, and Modeling Evaluation of Source Water, Extraction Potential, and Potential Impacts of Using Brackish Water for Desalination in the Mesilla Basin, NM, Bureau of Reclamation-NMSU Cooperative Agreement, \$102,227

A Dynamic Statewide Water Budget for New Mexico: Yr 3, NM State Appropriations, \$107,150

Research Program Introduction

Low Cost, Low Energy Concentrate Water Desalination using Heat Recuperative Solar Still with Concentrating Solar Technology, Bureau of Reclamation-NMSU Cooperative Agreement, \$116,103

Assessment of Brackish Groundwater Desalination for Municipal and Industrial Water Supply in Santa Teresa, NM, Bureau of Reclamation-NMSU Cooperative Agreement, \$120,000

Chihuahuan Desert Network Administrative Support, National Park Service \$121,800

Gold King Mine Long-Term Monitoring Plan, Information Conference, New Mexico Environment Department, \$135,011

In-situ synthesis of antibacterial ultrafiltration and microfiltration membranes with controllable pore size, Bureau of Reclamation-NMSU Cooperative Agreement, \$149,866

Reducing treatment costs of alternative waters with antifouling ion-exchange membranes, Bureau of Reclamation-NMSU Cooperative Agreement, \$150,000

Transboundary Aquifer Assessment Program (TAAP): NM WRRI effort coordination grant program, USGS Cooperative Agreement, \$166,666

New Mexico's Experimental Program to Stimulate Competitive Research (EPSCoR) - Social and Natural Science Nexus, National Science Foundation \$230,564

Diversifying the Water Portfolio for Agriculture in the Rio Grande Basin, USDA-TAMU, \$245,314

Research for the development and use of alternative water supplies, Directed Research, Bureau of Reclamation, \$301,294

Towards Resilient Food-Energy-Water Systems in Response to Drought Impacts and Socioeconomic Shocks, INFIEWS/T1, NSF multi-university award \$842,465 (for reporting period)

Drought in the West: Elements of Successful Science to Improve Water Management and Address Nationally Important Issues Through the USGS-NIWR Partnership

Basic Information

Title:	Drought in the West: Elements of Successful Science to Improve Water Management and Address Nationally Important Issues Through the USGS-NIWR Partnership
Project Number:	2015NM184S
USGS Grant Number:	
Sponsoring Agency:	U.S. Geological Survey
Start Date:	7/21/2015
End Date:	4/20/2018
Funding Source:	104S
Congressional District:	NM-2
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Drought, Hydrology, Management and Planning
Descriptors:	None
Principal Investigators:	Alexander G. Fernald

Publications

There are no publications.

Description of problem and research objectives

The project objective is to show how state water institute research addresses nationally important issues. Funding authorized by the Water Resources Research Act (WRRRA) is provided to the National Institutes of Water Resources (NIWR) through the United States Geological Survey (USGS) Water Institutes Program. In some respects, through seeking state-specific goals, the water institutes generate an “invisible hand” that forwards USGS national objectives. However, the direct connections between WRRRA funding and USGS objectives have not been fully demonstrated. An improved characterization of how water institute state-based efforts meet regional and national goals is important for justifying and funding the WRRRA.

The Water Resources Research Act (WRRRA) supports research to address national, regional, and state water issues. The WRRRA authorizes four programs: 104B research, 104G competitive grants, internships, and coordination grants. Funding for WRRRA programs is administered through the USGS Water Institutes Program. Of particular interest for this project are 104B and 104G projects. Funding authorized by section 104B of the WRRRA is distributed to the state water institutes to address state and regional water issues. Funding authorized by section 104G is a competitive grant program run through the institutes. The 104G program already is set up to meet national objectives, and is viewed as a success in that regard. The 104B program is set up to meet state water research needs, and even though the state projects meet USGS regional and national objectives, the specific ways in which they meet these broader objectives have not been well documented. Regarding drought, many research projects have been funded to address drought, but the end result of the research is not easily determined.

The Water Institutes Program has a special place in the USGS water area because the NIWR institutes can be involved in research that results in planning or policy. The USGS conducts monitoring and research but does not develop policy. No program other than the Water Institutes program in the USGS can directly develop policy in the water arena. There is a huge opportunity space for NIWR to work on programs that connect the dots from science to policy and that include water use as well as supply, thus complementing USGS programs and enhancing NIWR products. Drought, beyond fundamental water scarcity issues, intersects the full array of water management issues in the western U.S., and is an excellent topic to illustrate research impacts.

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 identifies and illustrate representative research projects funded through the WRRRA 104B program that help address the regional issue important to the USGS of drought in the west. To show the end results of the research, this project identifies successful results from 104B funded research after the research has been concluded.

Also, a 104b project report analysis was performed to narrow in on the focus and/or frequency of “drought” within project reports.

An Interdisciplinary Innovation Working Group (I-IWG) proposal was submitted to New Mexico EPSCoR to help fund a workshop that could generate discussion for a proposal to spawn from this USGS funded project. The I-IWG award allowed for a workshop entitled “Water Resilience in the Intermountain West through Coordinated Research and Innovation” to be held April 23-26, 2018 at the UNM Sevilleta Field Station in La Joya, New Mexico. It’s our branded initiative for adaptive capacity to drought. The workshop brought together a working group of professional water researchers from universities across the West. The purpose of this group’s work would be to find regional commonalities among Western states as the foundation of a regional modeling and data management project, and to adopt a collaborative plan addressing the question of how to better manage the bulk of a water budget to get more economic and ecological value from the water that falls to the ground. This activity is an additional outcome of the “Drought in the West” project. The information gathered about the elements of successful research projects will be used to develop a new project proposal.

Description of methodology

The fact sheet methodology includes:

- Visits to water institutes located in western states;
- Periodic conference calls with Earl Greene, a hydrologist at the U.S. Geological Survey;
- A search for projects on web and in the 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.

The 104b project report analysis methodology includes:

- Talking to a USGS consultant to search the 104b database for the selected western states;
- Going through all reports and picking out the ones that mentioned drought;
- Analyzing the research topic frequency.

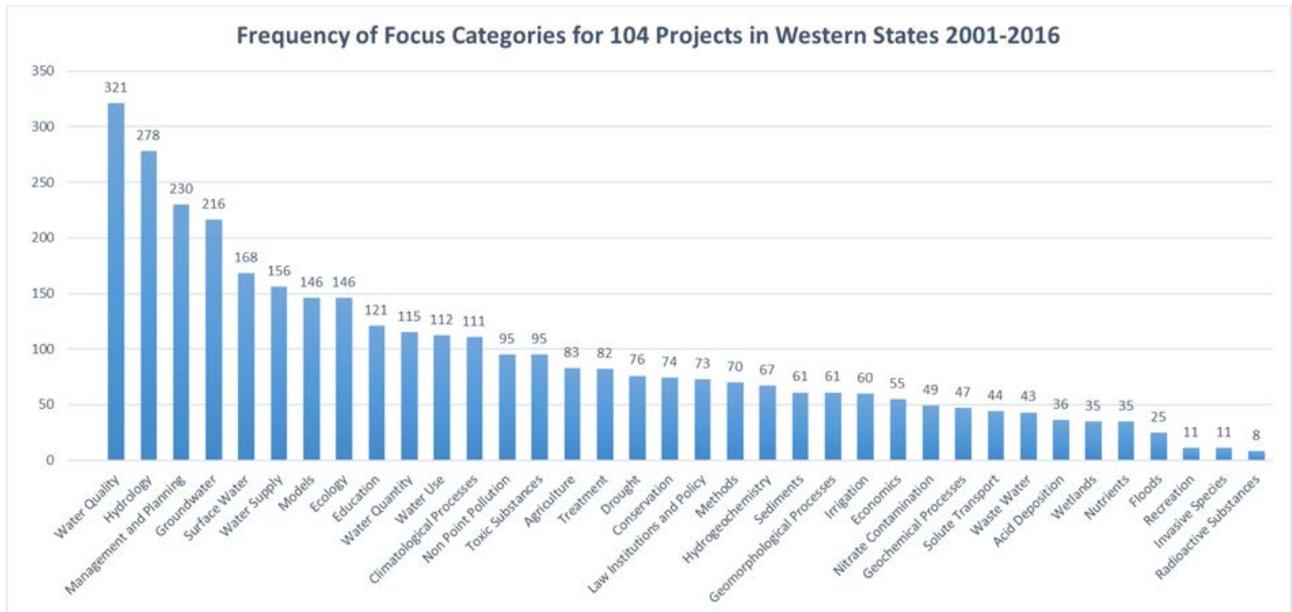
Description of principal findings and significance

The fact sheet findings 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. The final draft of the policy and management fact sheet was submitted to Earl Greene at USGS January 2017.

The 104b project report analysis discovered that a project report with a “drought” keyword does not capture all projects that deal with drought or water scarcity. An example of this is that sometimes reports claimed a reason for water scarcity to be drought, but also included other reasons such as increasing demand and population growth. Another example is that some report authors claimed to

have a water problem, and included drought as a contributing factor, but the project did not focus on drought. Drought is a topic that was not cited that often. We learned that in order to characterize these projects, we need to look at water scarcity or lack of water.

Data showed that only thirty 104B projects mentioned drought as a focus area 2001 through 2015 while two hundred and fifty five 104B projects mentioned drought 2002 through 2015.



The USGS reporting format does not capture what we need. The amount of funding we distributed is the extent of what we report on to USGS. There is no mechanism for reporting on the project outcomes. Our database only says who got the money for the project title.

The final draft of the policy and management fact sheet was submitted to Earl Greene at USGS January 2017.

New Mexico's Mountain Sources of Water: A Mechanistic Approach to Understand Mountain Recharge and Its Implications for Local and Statewide Water Budgets

Basic Information

Title:	New Mexico's Mountain Sources of Water: A Mechanistic Approach to Understand Mountain Recharge and Its Implications for Local and Statewide Water Budgets
Project Number:	2016NM179B
Start Date:	3/1/2016
End Date:	1/31/2018
Funding Source:	104B
Congressional District:	NM-2
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Climatological Processes, Hydrology, Management and Planning
Descriptors:	None
Principal Investigators:	Jesus D GomezVelez

Publications

1. Wang C., J. D. Gomez-Velez, and J. L. Wilson (2017), The importance of capturing topographic features for modeling groundwater flow and transport in mountainous watersheds, Hydrology and Earth System Sciences. In prep.
2. Gomez-Velez J.D. (2017), Exploring the Dynamics of Hydrologic Response and Age Distributions, MS Thesis in Applied Mathematics, Mathematics Dept., New Mexico Tech.
3. Wang C., J. D. Gomez-Velez, and J. L. Wilson (2017), The importance of capturing topographic features for modeling groundwater flow and transport in mountainous watersheds, Hydrology and Earth System Sciences. In review.
4. Gomez-Velez J.D. (2017), Exploring the Dynamics of Hydrologic Response and Age Distributions, MS Thesis in Applied Mathematics, Mathematics Dept., New Mexico Tech.

Description of problem and research objectives

Recharge is an important component of the water budget, and therefore its quantification at local and regional scales is critical for water resources management under current and future conditions. In semiarid environments, such as New Mexico, mountain recharge represents a significant fraction of the total recharge to basin aquifers. With this in mind, a detailed mechanistic understanding of the "mountain's internal plumbing" is critical to adequately quantify recharge fluxes.

We propose to implement fully-coupled groundwater-surface water, three-dimensional models for four watersheds along a climatic and geologic gradient in New Mexico. These watersheds are located in areas where a significant effort is currently underway to estimate recharge rates within the context of project focusing on a statewide recharge map for New Mexico. These models will be used to quantify mountain recharge and explore the limits of applicability of a parsimonious approach that can be easily applied at regional scales, and therefore support the efforts to estimate a recharge map for the state.

Description of methodology

- We will implement 3-D, fully-coupled groundwater-surface water models for four watersheds along a climatic and geologic gradient in New Mexico and southern Colorado. These high-complexity models will be used to estimate recharge fluxes and compare them with fluxes from the New Mexico recharge map project, an effort funded by the NM WRRRI.
- For each watershed, the high-complexity model will be used as a learning tools to quantify the relative importance of (i) topography and river network structure, (ii) geology, (iii) soil cover and vegetation, and (iv) weather and climate.
- The high-complexity models will be used to project how future climatic change might impact mountain recharge in the state of New Mexico.
- For each watershed, we will implement a simple non-linear, lumped parameter model, which we refer as a parsimonious model, to estimate recharge. The high-complexity models will be used to explore the limits of applicability of the parsimonious model.

Description of principal findings and significance

A no-cost extension until December 31, 2017, was granted to this project. This request allowed Chao Wang, the student funded with this grant, to gain teaching experience as the teaching assistant (TA) for the class HYD 508 Flow and Transport in Hydrologic Systems during the spring of 2017. This is a requirement for our PhD students, and Chao's performance was outstanding, leading to the Best Teaching Assistant award for the academic year.

During the first half of this project, we achieved the following milestones:

- We implement a 3-D, fully-coupled groundwater-surface water model for Rio Hondo watershed. Then, we used this model to explore the importance of generating meshes that capture key topographic features and its implications for mountain recharge, runoff generation, residence times, and solute transport. We found that capturing the river network structure is fundamental to appropriately reproduce the nested network of flow paths observed in mountainous terrains. Due to computational

limitations, these features are typically oversimplified in modeling efforts, resulting in misguided interpretations of observations and biased assessments of water resources, solutes, and contaminants. Our findings have fundamental implications for the interpretation of models in water resources assessments, the use and interpretation of environmental tracers, and the estimation of weathering rates.

- We developed the mathematical framework for parsimonious models (see Gomez-Velez, 2017, in the list of publications) and compiled the hydroclimatological information needed for these models.
- Chao Wang and Gomez-Velez continue work on this topic as part of Chao's dissertation. Two new manuscripts exploring the dynamics of residence time distributions in mountain watersheds and the effect of river network geometry and topology are in preparation.

What are the effects of the Gold King Mine spill on San Juan County, NM agricultural irrigation ditches and farms?

What are the effects of the Gold King Mine spill on San Juan County, NM agricultural irrigation ditches and farms?

Basic Information

Title:	What are the effects of the Gold King Mine spill on San Juan County, NM agricultural irrigation ditches and farms?
Project Number:	2016NM180B
Start Date:	3/1/2016
End Date:	12/31/2017
Funding Source:	104B
Congressional District:	NM-3
Research Category:	Water Quality
Focus Categories:	Agriculture, Irrigation, Water Quality
Descriptors:	None
Principal Investigators:	Kevin A Lombard, April Ulery, David Weindorf

Publications

There are no publications.

What are the effects of the Gold King Mine spill on San Juan County, NM agricultural irrigation ditches and farms?

Description of problem and research objectives

During the ban on irrigating crops just after the GKM spill we took the opportunity to investigate dry irrigation ditches to establish a “pre” GKM lead (Pb) census downstream from the Silverton Caldera mining region. At each irrigation ditch sample location, we followed an intensive sampling technique along a cross-sectional transect with sample points spaced at 60 cm intervals and taken at three depths. The objectives were to compare Pb concentrations between transect points x depth, and compare these amounts to human health risk assessment guidelines published by the U.S. Environmental Protection Agency (EPA). A secondary objective was to determine if this “oversampling” method could be made more efficient for repeated measures as part of a long-term, multi-year monitoring project.

Description of methodology

Site Description

The study took place in San Juan County, NM, within the Lower Animas Ditch located in Aztec, NM as part of a larger emergency response to the August 5, 2015 GKM spill. Twelve ditches were sampled in the Animas River watershed during the ban on irrigating crops, when main intakes for irrigation ditches were closed, allowing access to dry irrigation ditches. For most of San Juan County and portions of the Navajo Nation in Northwestern NM, this period was between August 7-15, 2015. Other portions of the Navajo Nation elected to not irrigate until the 2016 growing season. Of the 12 ditches we sampled, this paper focuses on six locations at various points on the Lower Animas (L.A.) Ditch (Figure 1). The New Mexico portion of the Lower Animas Watershed accounts for about 4,050 hectares (10,000 acres) of irrigated agriculture in its 700 km² watershed area (May et al., 2016). A portion of this agricultural use is supplied by the L.A. irrigation ditch runs roughly parallel to the Animas River for 24 km. The sample points were identified with a Global Positioning System (GPS) (Figure 1). Each of the six sites were taxonomically different, including: Blackston gravelly loam, Haplargids-Blackston-Torriorthents complex, Stumble-Fruitland association, Farb-Persayo-Rock outcrop complex, Badland, and Fruitland loam (USDA, 2017).

Soil Sampling

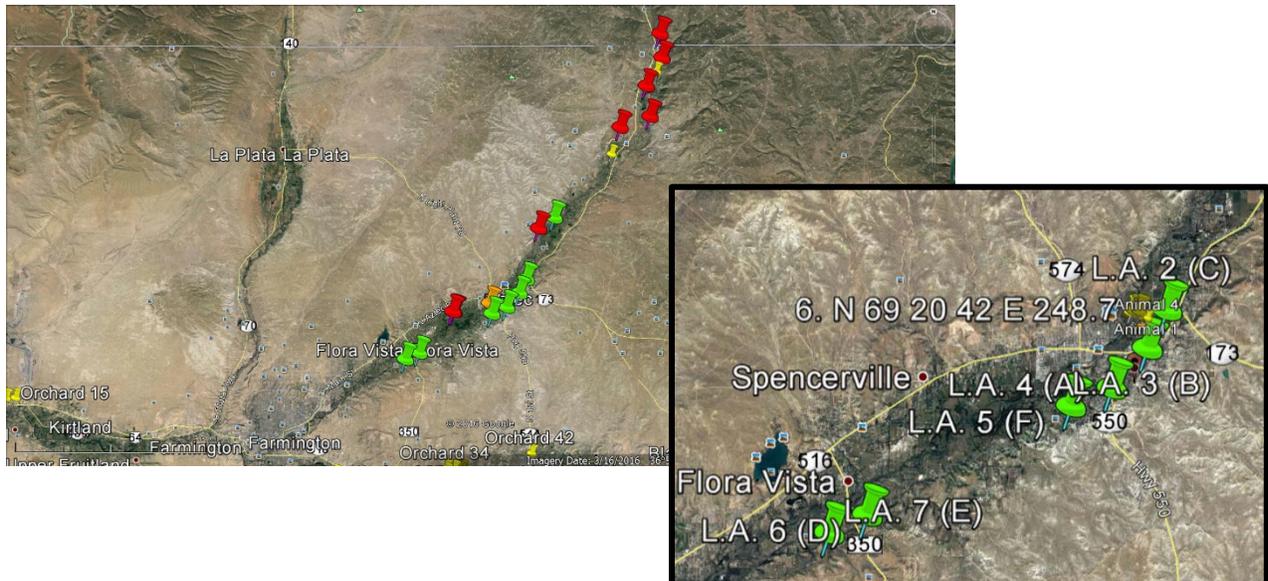


Figure 1. The Gold King Mine and, inset, six focused sampling locations.

Distinct from the EPA's single grab sample per location used for emergency response (USEPA, 2000), we collected samples every 60 cm at each location traversing from one side of the dry ditch, across the center, and ending on the other side. These transects were perpendicular to the flow of ditches (Figure 2). An EPA approved stainless-steel, 3 in (76 mm) diameter auger was used for soil and sediment sampling. Each point along the transect was sampled in three 20 cm increments, perpendicular to the ground surface: 1-20 cm, 21-40 cm, and 41-60 cm depths. In some cases, bedrock or excessive organic matter (e.g. tree roots) impeded taking three sampling depths. The auger was cleaned with deionized (DI) water before continuing to the next 60 cm interval of the transect. Sample bagging, labeling and storing in an ice chest were all done in the field. Samples were shipped overnight or hand-delivered from Farmington, NM to New Mexico State University soil science research laboratory (Las Cruces, NM) for analysis. All samples were logged into a field notebook and lab intake form following standard soil sampling protocols.

Saturation Paste

Water-soluble metals were extracted following the saturated paste extract method described by Rhoades (1996). Briefly, 200-400 grams of air-dried soil was weighed into a plastic container. Deionized water was added to the soil and stirred with a spatula until saturation was achieved. Saturated pastes equilibrated for at least four hours before being measured for pH using a pH electrode (Oakton, Vernon Hills, IL). An aqueous extract was then obtained via vacuum filtration through a Whatman #5 filter paper.

Acid Digestion and Pb Analysis

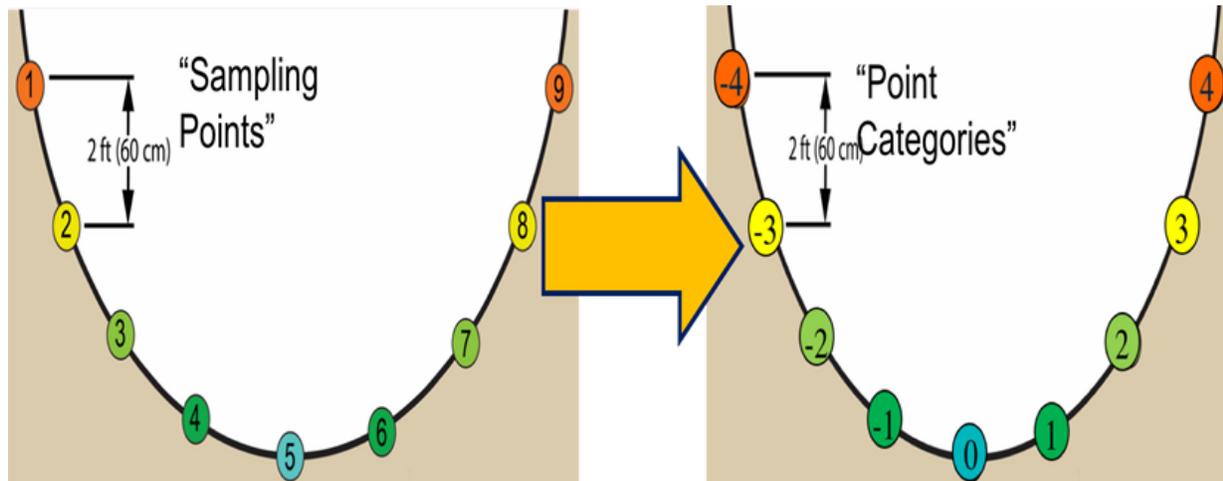
The EPA method 3051A was used for microwave assisted acid digestion of sediments, sludges, soils, and oils. Briefly, 0.5 grams of air-dried sediment were mixed with nine milliliters (mL) of nitric and three mL of hydrochloric acid within Teflon reaction vessels and digested using a MARS 5 Microwave Accelerated Reaction System (CEM, Matthews, NC) at 200 pounds per square inch of pressure (USEPA, 2007). A quality control (NIST 8704 or 2711) and blank were included in each batch of 12 samples digested. All quality control samples fell within the 90-110% acceptance range of the known value for Pb total concentration. The blank ensured that no equipment (flasks, filters, vessels, or the acid) contributed any contamination during the digestion process. Digested solutions were filtered through Whatman #2V filter paper, triple-rinsed with DI water, then brought to 100 mL volume with DI water for analysis of total Pb using an Optima 4300 Dual View Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES; Perkins-Elmer, Waltham, MA), also referred to as Inductively Coupled Plasma/Optical Emission Spectrometry (ICP-OES) (USEPA, 1994). During ICP-OES analysis, each sample duplicate, DI water blanks, a Laboratory Reagent Blank for low concentrations (EPA has an 85-115% acceptance range), Initial Calibration Verification, and a Continuing Calibration Verification (every ten samples) were used as quality controls. Total metal concentrations were measured in mg/L and then converted to mg/kg based on sample weight and digestion volume and reported in parts per million (ppm) for ease of comparison to EPA and NMED risk assessment guidelines. The heavy metal of interest for this research was Pb. No attempt was made to analyze for various species or forms of Pb.

Statistical Analysis

Differences among transect sample point: To explore potential differences in the total concentration of Pb between the ditch sample points (spaced 60 cm apart starting from one bank to the other along a transect) x depth (0-20, 21-40, and 41-60 cm at each sampling point), comparisons were performed on estimates using a mixed model for point category, depth and their interaction. Data were first recoded into point categories according to relative distance from ditch center (Figure 2). This recoding was necessary to identify the center point of the ditch and moving outward in both directions toward the top

of the irrigation ditch transect. Some ditch transects had an odd number of sample points across a transect while other transects had an even number of sample points across a ditch transect. The center points in ditches with odd numbers of total transect sample points were assigned a point category of 0. For transects with an even number of sampling points, the two nearest-center points were designated 0.5 and -0.5. Moving outward with each 60 cm sampling increment away from the center point, +1 or -1 was added to the center point category ("0"). The largest point category occurred in ditches with 10 sampling points, where the topmost bank point categories were numbered 4.5 and -4.5. Point categories were then pooled to whole integers for statistical analysis. So, point locations 4.5 and 4 were grouped as category 4, point locations 3.5 and 3 were grouped as category 3, etc. Sample point locations -0.5, 0, and 0.5 were all grouped as category 0, the only point category which includes three sampling point locations.

Several candidate covariance structures were considered to account for expected correlations among observations from the same transect, correlations among the depths at the same sample point and possible different variances among depths. All analyses were executed using SAS version 9.3 software (SAS Institute Inc., 2010). Significance was defined for $p \leq 0.05$.



Even-numbered "Sampling Points" in Ditch:	1	2	3	4	5	6	7	8	9	10
Even-numbered "Point Categories" in Ditch:	-4.5	-3.5	-2.5	-1.5	-0.5	0.5	1.5	2.5	3.5	4.5

Odd-numbered "Sampling Points" in Ditch:	1	2	3	4	5	6	7	8	9
*Odd-numbered "Point Categories" in Ditch:	[-4	-3	-2	-1	0	1	2	3	4]

*These category groups were used for statistical analysis after both even- and odd-numbered point categories pooled

Figure 2. an example of the sampling schematic; note that nine categorized sample points were used for statistical analysis.

Description of principal findings and significance

Lead (Pb) Ditch Sediment Concentration

Irrigation ditch Pb concentrations ranged from 2.7 to 165.4 ppm, with an average of 39.4 ppm, and a median of 29.2 ppm (Figure 3). All raw data points and estimates fell below EPA Regional Screening Limits (RSL) of 400 ppm and therefore represent no threat to agricultural quality according to this standard.

Only depth was significant ($p=0.0017$) with all depths differing from one another. Lead decreased with estimated Pb total concentrations 53.9 ppm (\pm a standard error of 6.7 ppm), 44.2 ppm (\pm 6.4 ppm), and 28.0 ppm (\pm 4.5 ppm) for depths 0-20 cm, 21-40 cm, and 41-60 cm, respectively. While sampling several depths may be warranted to gain the most understanding of the distribution of other heavy metals in irrigation ditch sediment, when looking for the highest Pb concentration, however, sampling at a 0-20 cm depth was all that was necessary in our study. Higher Pb concentration in the surface sediments may be the result of several factors, including immobilization by soil particles and accumulation over time. It should be noted that these ditches undergo “repairs” as needed, which sometimes comprises clearing weeds along the ditch banks, excavating sediments, and the addition of bentonite clay on the surface sediments to reduce water loss through soil infiltration. Due to the relatively high cation exchange capacity of such clays, adsorption of cationic metals, such as Pb^{2+} , may increase at the surface. However, soil texture was not analyzed in this study.

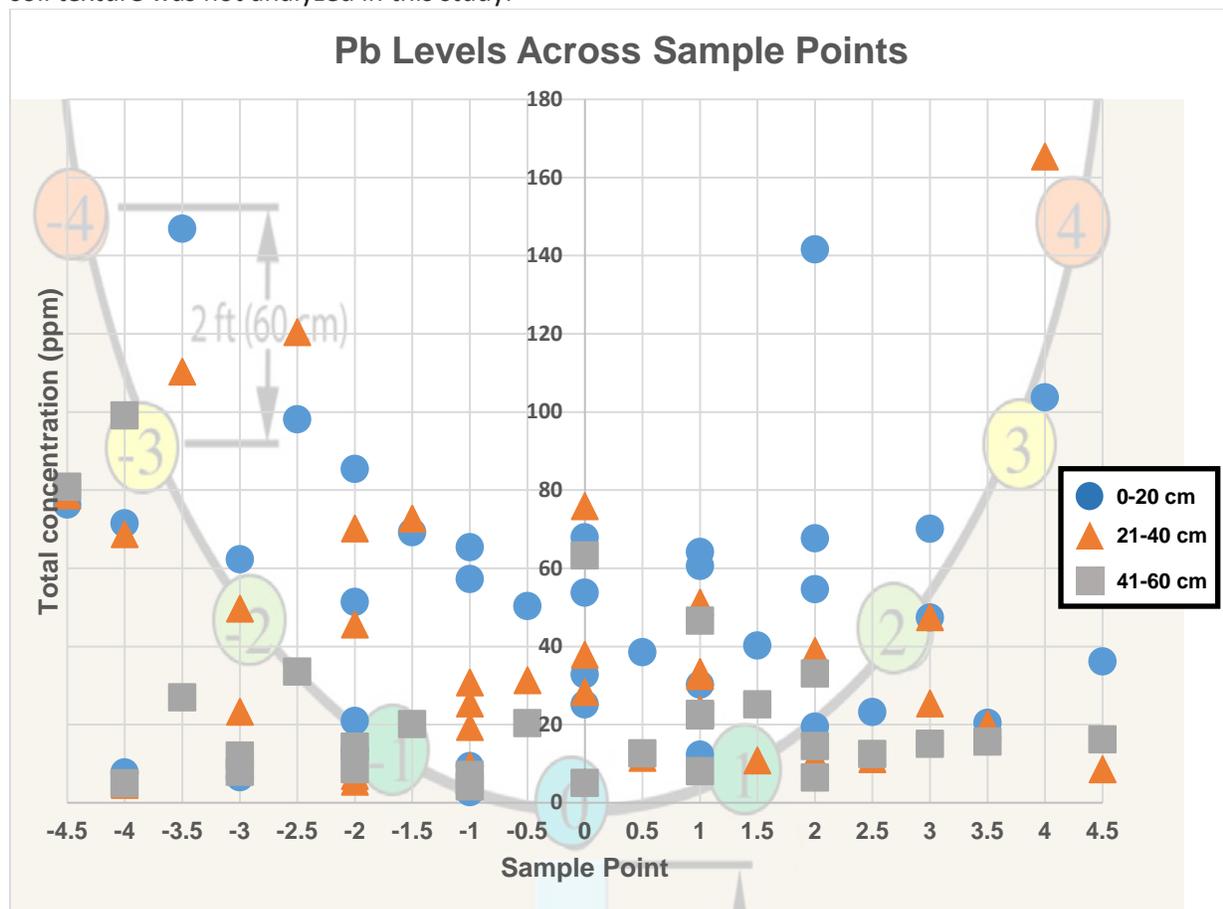


Figure 3. All raw data points of Pb in the Lower Animas ditch sampled at 6 locations to the three successive depths.

A quadratic model identified a significant metal trend ($p=0.0423$) with separate intercepts for depth ($p<0.0001$) suggesting there may be elevated Pb concentrations in sediments sampled furthest from the center of ditches and lowest concentrations to be near ditch centers. In turn, our estimates appear to show lower concentrations of Pb in the center of ditches, and elevated near ditch edges (Figure 4), pointing to the possibility that if sampled alone, edges may provide outlier information misrepresentative of ditch sediment concentration in its entirety.

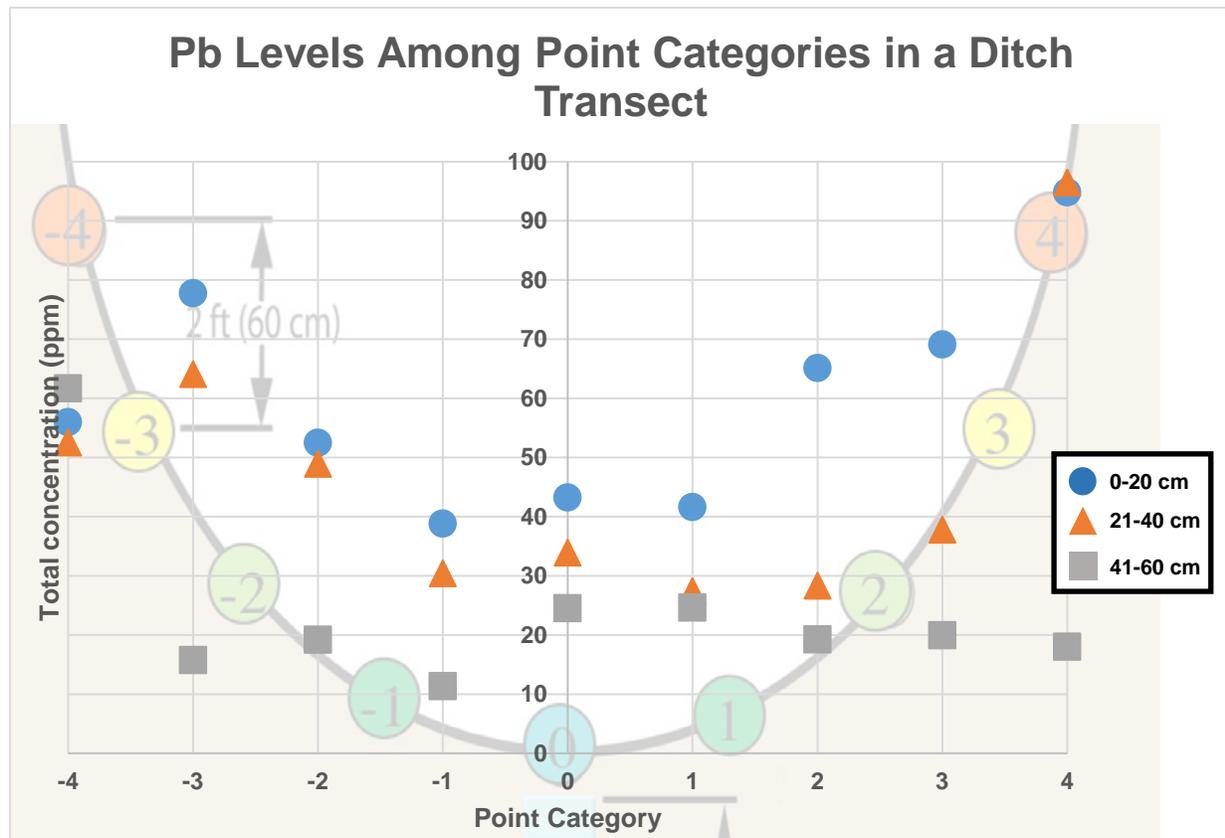


Figure 4. Estimated means of Pb across our point categories in the Lower Animas ditch to three successive depths.

For the model fit using only surface (0-20cm) data, the $sp(pow)$ covariance structure, a structure that accounts for unequally spaced measurements between sampling, estimated a correlation of 0.7077 for sampling points 1 unit apart, a 60-cm distance, following along the curvature of the ditch (for example, the distance between -2 and -1 in Figure 2). The further the sample point was from the ditch bottom, the less correlated the concentrations were. So, for example, a correlation of 0.24, or 24%, would be found at 2.43 meters apart (or four of our sample points away) from the middle sample point. In other words, points closest to one another are similar, so sampling for future research may consider a wider sample point spacing, thus reducing the total number of samples needed to be extracted and analyzed in the lab in order to measure the sediment Pb concentration.

Nriagu (1978) found worldwide uncontaminated soil Pb levels to be approximately 17 ppm. The US Geological Service reported the US average Pb levels to be 19.78 ppm, and the state of New Mexico to have an average of 26.08 ppm, and San Juan County's average total Pb concentration at 32 ppm and 35.12 ppm (with a standard deviation of 45.2), respectively (USGS, 2017a; USGS, 2017b). By comparison, non-irrigated rangeland soils had Pb concentrations between 4.71 ppm to 26.62 ppm, with an average of 11.9 ppm (far under the EPA Regional Screening Limits of 400 ppm) (data unpublished). Our data averages are above these background levels, suggesting there is total Pb concentration accumulation generally occurring at our sites; an addition potentially due to legacy mining activity or previous agricultural practices, but still below the EPA RSL.

Conclusions

Metals and metalloids continue to create uncertainty in terms of public and agricultural soil health in northwestern NM. Heavy metals and metalloids are naturally occurring elements in the Silverton Caldera as well as northwestern NM, but deposition into the Animas River watershed has been influenced by legacy mining since the late 1800s. It is unclear if historic agricultural activities related to orchard production may have increased metal concentrations in the surface soil and sediment San Juan County, NM (for example lead arsenate and lead arsenite were used as early forms of pesticides). Nevertheless, the Gold King Mine spill of 2015 warranted an emergency response followed by long-term monitoring for risk assessment.

As far as we know, this is the first study that takes a step toward understanding total metals, specifically Pb, in irrigation ditch sediments located along the Animas River watershed. The study also allowed us perspective into the efficacy of current emergency sampling. We found that Pb levels were below risk RSL for agriculture (400 ppm), as measured by ICP-OES.

Surface sediment information may not reflect the deeper profile. Also, these results suggest a highly correlated Pb total concentration in adjacent sampling point locations (to 60 cm) in the surface depth. This information helps support the current emergency grab sampling technique used, and the concept of minimizing samples, supporting time and economic efficiencies.

The Gold King Mine spill on August 5, 2015 gave researchers and the public a considerable amount of anxiety from its acute horrifying, enigmatic plume and raised awareness of the Silverton Caldera mining district and its potential legacy on downstream agricultural users. Considerably more research is required to understand total metals and their potential impact in the Animas River Watershed.

Future Recommendations

Consider existing local disease registry metadata in correspondence with known elevated Pb data areas to consider potential implications of elevated Pb on human health.

Research Pb levels of local animals (wild, livestock) to observe potential bioaccumulation and implications to food chain.

Sample plant tissues from adjacent irrigated fields to compare with irrigation ditch soil data to observe potential correlation. This would also give us information concerning bioaccumulation and implications of Pb in the local food chain.

Measure the texture of soils to determine if the sand, silt, and clay fraction supports immobilization or desorption of metals and metalloids into the environment.

Rivers and their sediments support multiple ecosystems, so research of river biota, microbial populations, and processing or accumulation of pollutants in biota is encouraged to understand the ecological impacts as related to Pb.

Expand research onto nearby indigenous reservation land. Consider these data implications per national and state guidelines, as well as community guidelines. Note cultural incorporation of soil (ceremonies or traditions where soil is ingested, used to coat the skin, etc.) could influence exposure routes.

Transboundary Aquifer Assessment Program (TAAP): NM Water Resources Research Institute Effort

Basic Information

Title:	Transboundary Aquifer Assessment Program (TAAP): NM Water Resources Research Institute Effort
Project Number:	2016NM190S
USGS Grant Number:	G16AC00428
Sponsoring Agency:	U.S. Geological Survey
Start Date:	3/1/2016
End Date:	8/1/2017
Funding Source:	104S
Congressional District:	NM-2
Research Category:	None
Focus Categories:	
Descriptors:	None
Principal Investigators:	

Publications

1. Milanés-Murcia, M., 2017, Chapter 5 "Proposed International Legal and Institutional Framework for Conjunctive Management of Surface and Groundwater along the U.S. Mexico Border Region." In the book "Management of Transboundary Water Resources under Scarcity: A Multidisciplinary Approach," World Scientific Publishers.
2. Milanés-Murcia, M. Chapter 11 "International Principles of Groundwater Law. An Analysis of Groundwater Rights [...]" In Handbook on International Water Law. Edward Elgar Publishing (ed. McCaffrey and Leb) (forthcoming in Fall 2017).
3. Milanés-Murcia, M. "The U.S.-Mexico Transboundary Aquifer Assessment Act, 2006. Cooperation between the U.S. and Mexico, Achievements, Current and Future Efforts in the Mesilla Aquifer Basin." Natural Resources Journal (submitted June, 2017).
4. Milanés-Murcia, M. "History and Current International Water Legal Framework of the United States-Mexico Border." American Journal of International Law (submitted June, 2017).
5. Milanés-Murcia, M., 2017, Chapter 5 "Proposed International Legal and Institutional Framework for Conjunctive Management of Surface and Groundwater along the U.S. Mexico Border Region." In the book "Management of Transboundary Water Resources under Scarcity: A Multidisciplinary Approach," World Scientific Publishers.
6. Milanés-Murcia, M. Chapter 11 "International Principles of Groundwater Law. An Analysis of Groundwater Rights [...]" In Handbook on International Water Law. Edward Elgar Publishing (ed. McCaffrey and Leb) (forthcoming in Fall 2017).
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8. Milanés-Murcia, M. "History and Current International Water Legal Framework of the United

States-Mexico Border." *American Journal of International Law* (submitted June, 2017).

9. Tellez, A., Boykin, K., and Fernald, S. (2018). Effects of Changing Available Water Regimes on Riparian Vegetation in the Mesilla Valley Basin Aquifer, New Mexico, USA. Master's Thesis.

Description of problem and research objectives

The New Mexico Water Resources Research Institute (NM WRI) and New Mexico State University (NMSU) are working in close collaboration with the USGS New Mexico Water Science Center to improve understanding of groundwater in the Mesilla aquifers. The New Mexico team is tasked with achieving a better understanding of the Mesilla Basin aquifer through four major research efforts by NMSU and NM Tech faculty: **1)** deep groundwater contribution to shallow groundwater by Dr. Carroll (NMSU); **2)** evapotranspiration modeling using remote sensing with field validations by Dr. Bawazir (NMSU); and **3)** impacts of drought on riparian vegetation habitat and water use by Drs. Boykin and Fernald (NMSU); **4)** estimation of regional groundwater recharge from non-irrigated land by Dr. Cadol (NM Tech).

Description of methodology

- 1) A multi-tracer approach to determine time signatures of groundwater in the Mesilla Aquifer. Specifically, the study will determine and evaluate the concentrations of the environmental isotopes of ^{18}O , ^2H , ^3H , ^{13}C , ^{14}C , and ^3He , including the noble gas isotopes krypton-81 (^{81}Kr), krypton-85 (^{85}Kr), and argon-39 (^{39}Ar). With the advent of a new and accurate analysis technique called Atom Trap Trace Analysis (ATTA), these three noble gas isotopes are being used to more accurately assess groundwater residence times, mixing, and flow paths, as well as to corroborate the results obtained using other isotopes. Twenty samples have been collected at various depths from various wells in the aquifer system. The samples will then be sent to a lab in Bern, Switzerland for analysis.
- 2) The work will assess a remote sensing-simplified surface energy balance (SEEBop) ET model estimates for the Mesilla Valley. A higher resolution ET estimates from SEEBop and REEM will be compared with ground measurements for local conditions. From the assessment, calibration coefficients for the models will be developed and improved ET fluxes for the Valley estimated.
- 3) Aerial imagery used from the 2005 (June) and 2014 (July) growing seasons showed decrease in large vegetation from those years and an increase in dead vegetation. Riparian ET was also calculated based off the Nagler 2013 method. This method proposes an algorithm using vegetation index, EVI, as well as local climate station weather data to calculate ET.
- 4) The project plans to estimate focused recharge using statistical relationships between rainfall, runoff, streambed infiltration and other hydrogeological characteristics. The project will also use the Evapotranspiration and Recharge Model (ETRM) to estimate groundwater recharge in the Mesilla Basin. ETRM will need to be expanded to the Mesilla by using data from the Elephant Butte Irrigation District to calibrate it.

Description of principal findings and significance

- 1) The principal findings and significance of this project is to determine the sources of groundwater within the Mesilla Basin, how groundwater flows between the shallow and deeper aquifer, and the groundwater age distribution between the shallow and deeper aquifer. Continued data collection, additional analysis of Ar isotope by Roland Purtschert at the University of Bern (Switzerland), continued development of a 2D solute transport model for the Mesilla Basin, and a final draft of a technical report are still remaining.

- 2) Evapotranspiration (ET) of a major crop (alfalfa) in the Mesilla Valley will be directly measured using current state of the art technology every 30 minutes for two years. Remotely sensed-based regional ET model estimates will be compared to these ground direct measurements for verification. The ultimate goal is to improve satellite-based model algorithms which can be used to better estimate ET on a regional/basin scale. Continued ET measurements, data analysis, and a final technical completion report are still remaining.
- 3) The principal purpose of this study is to understand the riparian vegetation responses to fluctuating levels of surface/groundwater interactions from frequently occurring drought conditions due to climate change. This project concluded in April 2018 with the submission of a master's thesis by Aracely Tellez. Publications from this project are expected in late 2018.
- 4) Annual estimates of aquifer recharge in the New Mexico portion of the Mesilla Basin for the years 2000-2015. A map of estimated diffuse recharge in the non-irrigated portions of the basin will be delivered by Summer 2018.

Coordination of the research projects and with Mexico will be provided directly by the NM WRRRI Director, Sam Fernald, and a Program Coordinator, Avery Olshefski, who was hired on October 19th, 2017. Project coordination involves big picture discussions to change the future course of the TAAP with Water Institutes and Water Science Centers from NM, TX, and AZ. The international coordination will seek to nurture close working relationships with counterparts in Mexico and setting up bilateral and multilateral international meetings for broad aquifer assessment planning and specific research component coordination. A binational meeting was held in Ciudad Juarez for the Mesilla Aquifer on March 27th, 2018.

Note that this report is the same for the two TAAP projects: 2016NM190S and 2017NM191S.

Geographic Information Systems for Water Resources Research Planning

Basic Information

Title:	Geographic Information Systems for Water Resources Research Planning
Project Number:	2017NM186B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	NM-ALL
Research Category:	Not Applicable
Focus Categories:	None, None, None
Descriptors:	None
Principal Investigators:	Alexander G. Fernald

Publication

1. Cram, DS, R Sabie, Jr., ST Smallidge, and NK Ashcroft. 2017. Assessment of Postfire Debris-flow Hazards, La Jara Watershed, North-central New Mexico. Range Improvement Task Force Report 86, New Mexico State University, 28 pp.

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

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 WRI 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 WRI 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 WRI also maintains an Internet web server site through which both spatial and tabular water resource data can be provided.

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 WRRRI-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 statewide 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.

Currently, the GIS laboratory is working on calibration and installation of a suite of sensors on an aircraft for measurements of evapotranspiration. This project is part of a USDA funded project focused on diversifying the water portfolio of the Rio Grande basin. The GIS laboratory will be responsible for processing and analyzing imagery acquired from the sensors. Future projects are expected to leverage the sensors and laboratory expertise in image analysis.

Digital Soil Mapping for Improving Hydrological Modeling of NM Water Resources

Basic Information

Title:	Digital Soil Mapping for Improving Hydrological Modeling of NM Water Resources
Project Number:	2017NM187B
Start Date:	3/1/2017
End Date:	8/31/2018
Funding Source:	104B
Congressional District:	NM-2
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Hydrology, None, None
Descriptors:	None
Principal Investigators:	Colby W Brungard

Publication

1. Allan, M.J, Brungard, C.W. Geostatistical mapping of soil properties and soil depth in a small watershed. Master's Thesis. In preparation.

Description of problem and research objectives

Water in arid soils is highly temporally and spatially variable, complicating mechanistic models which quantify the hydrological budget of arid watersheds. Accounting for fine-resolution (1-5 m) spatial variability of key soil properties is likely to improve surface soil moisture, evapotranspiration, and runoff modeling. However; predictive soil maps at the resolution needed to test the influence of fine-scale soil spatial variability on hydrological models does not exist. The objective of this research is to utilize digital soil mapping techniques to predict key soil properties (depth + texture) necessary for parameterizing water balance, evapotranspiration, and ecohydrologic models.

Description of methodology

We produced initial fine-resolution soil maps of soil surface texture and depth to root-restrictive layer across approximately 71 ha on the Jornada Experimental range. The study area was constrained to the landform surrounding the Tromble Weir watershed, a small heavily-instrumented watershed. The study area was constrained to this landform to meet assumptions of stationarity needed for geostatistical methods.

Forty-nine sampling locations were generated using a multi-stage sampling design to estimate a rough variogram for modest effort (Webster et al., 2006). Sampling locations were visited in the field and were excavated (30-50 cm wide) to a depth of either 150 cm or a root restrictive horizon. If a root restrictive horizon was not reached after approximately 100 cm, soil pits were augered from 100-150 cm. Soil profiles were described according to (Schoeneberger et al., 2012) and 100-200 g of soil was collected from each horizon. Soil profile descriptions included horizon depth and designation, rock fragments (percent, type, size), structure (grade, size, type), carbonate stage development, texture (textural class and clay percentage), ped and void surface (percent, distinction, continuity, kind, location), and depth to petrocalcic horizon.

Predictions of soil surface percent sand and clay were generated by first fitting variogram models to the soil observations obtained by field sampling, then by using these models to predict soil surface sand and clay.

Description of principal findings and significance

Initial results indicate a range of soil surface sand of 120 m, and a range of soil surface clay at 100 m. These range values indicate that soil surface sand and clay are spatially autocorrelated over these distances and that future grid sampling of the soil surface soil should be done at distances less than 100 m.

Geostatistical predictions of subsurface texture and soil depth are ongoing. However; we encountered an unforeseen problem. Because a portion of this area is in an instrumented watershed we were prohibited from traditional methods of excavation by shovel to avoid significant disturbance. This problem is usually solved with a small-diameter auger, but because of the sandy and rocky soil texture we were unable to use standard augering methods. Instead, we built and tested a vacuum powered auger. Initial results are promising, but this auger is likely not sufficient to fully excavate these soils.

Work remaining involves purchasing a gas-powered auger which has recently become commercially available and additional field sampling to refine and validate predictions.

EFFECT OF WILDFIRE ASH ON WATER QUALITY

Basic Information

Title:	EFFECT OF WILDFIRE ASH ON WATER QUALITY
Project Number:	2017NM188B
Start Date:	3/1/2017
End Date:	7/31/2018
Funding Source:	104B
Congressional District:	NM-1
Research Category:	Water Quality
Focus Categories:	None, None, None
Descriptors:	None
Principal Investigators:	Jose Cerrato

Publication

1. Rahman, Asifur, El Hayek, Eliane, Blake, Johanna M., Bixby, Rebecca, Ali, Abdul-Mehdi S., Spilde, Michael, Otieno, Amanda, Miltenberger, Keely, Ridgeway, Cyrena, Artyushkova, Kateryna, and Cerrato, José M. (2018). Metal reactivity in laboratory burned wood from a watershed affected by wildfires. Environmental Science & Technology, In Revision.

Description of problem and research objectives

This project investigated interfacial processes affecting metal mobility in wood ash burned under laboratory-controlled conditions using aqueous chemistry, microscopy and spectroscopy analyses. Wood was collected from the Valles Caldera National Preserve (VALL) in New Mexico which has experienced two wildfires since 2011 that have caused devastating effects. Wood samples (e.g. Ponderosa Pine, Quaking Aspen, and Colorado Blue Spruce) collected from this site were exposed to temperatures of 60°C, 350°C and 550°C and reacted under controlled laboratory conditions.

Description of methodology

Water and soil sampling were done to assess the current availability of metals in the VALL which is a fire affected watershed. Wood was collected from a nearby unburned area to experiment with laboratory burn temperatures. Wood samples of Ponderosa Pine, Colorado Blue Spruce and Quaking Aspen were collected from higher elevation mixed coniferous forest areas which have a fire disturbance history.

For DOC dissolution experiments, batch reactors were operated in triplicates by reacting 0.1g sample of 350°C and 550°C Pine, Spruce and Aspen ash with 30 mL of 18MΩ deionized water. Replicates (n=3) were sampled at 0, 4, 24 and 72 hrs and were analyzed using a Shimadzu TOC-5050A TOC analyzer, following 5310-C persulfate-ultraviolet (UV) method.⁴² For metal dissolution experiments, 0.1g samples of 350°C and 550°C Pine ash were reacted with 30 mL of 18 mΩ water. Samples were collected at 0, 4, 24 and 72 hours, centrifuged at 3000 rpm for 15 minutes and processed for further ICP analyses.

Batch sorption experiments in triplicates were conducted to investigate the effect of 350° Pine ash on mobilization of Cu(II) and Cr(VI) in water. We selected Cu(II) and Cr(VI) as examples of a cation and an oxyanion that could negatively impact surface waters.

olid phase analyses were performed on the unreacted and reacted 350°C Pine ash from the batch sorption experiments applying X-ray photoelectron spectroscopy (XPS), scanning electron microscopy coupled to energy dispersive X-ray spectroscopy (SEM/EDX), electron probe microanalysis (EPMA) and X-ray diffraction (XRD).

Description of principal findings and significance

The 350°C Pine ash had the highest content of Cu ($4997 \pm 262 \text{ mg kg}^{-1}$), Cr ($543 \pm 124 \text{ mg kg}^{-1}$), and labile dissolved organic carbon (DOC, $11.3 \pm 0.28 \text{ mg L}^{-1}$). Sorption experiments were conducted by reacting 350°C Pine, Spruce and Aspen ashes separately with 10μM Cu(II) and Cr(VI) solutions. Up to 94% decrease in Cu(II) concentration was observed in solution while Cr(VI) concentration showed limited decrease (up to 13%) after 180 mins of reaction. X-ray photoelectron spectroscopy (XPS) analyses detected increased association of Cu(II) on the near surface region of the reacted 350°C Pine ash from the sorption experiments compared to the unreacted ash. The results suggest that dissolution and sorption processes should be considered to better understand the potential effects of metals transported by wood ash on water quality that have important implications for post-fire recovery and response strategies.

TAAP: New Mexico Water Resources Research Institute Effort

Basic Information

Title:	TAAP: New Mexico Water Resources Research Institute Effort
Project Number:	2017NM191S
USGS Grant Number:	G17AC00441
Sponsoring Agency:	U.S. Geological Survey
Start Date:	9/5/2017
End Date:	9/4/2018
Funding Source:	104S
Congressional District:	None
Research Category:	None
Focus Categories:	
Descriptors:	None
Principal Investigators:	

Publication

1. Tellez, A., Boykin, K., and Fernald, S. (2018). Effects of Changing Available Water Regimes on Riparian Vegetation in the Mesilla Valley Basin Aquifer, New Mexico, USA. Master's Thesis.

Description of problem and research objectives

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Description of methodology

- 1) A multi-tracer approach to determine time signatures of groundwater in the Mesilla Aquifer. Specifically, the study will determine and evaluate the concentrations of the environmental isotopes of ^{18}O , ^2H , ^3H , ^{13}C , ^{14}C , and ^3He , including the noble gas isotopes krypton-81 (^{81}Kr), krypton-85 (^{85}Kr), and argon-39 (^{39}Ar). With the advent of a new and accurate analysis technique called Atom Trap Trace Analysis (ATTA), these three noble gas isotopes are being used to more accurately assess groundwater residence times, mixing, and flow paths, as well as to corroborate the results obtained using other isotopes. Twenty samples have been collected at various depths from various wells in the aquifer system. The samples will then be sent to a lab in Bern, Switzerland for analysis.
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- 1) The principal findings and significance of this project is to determine the sources of groundwater within the Mesilla Basin, how groundwater flows between the shallow and deeper aquifer, and the groundwater age distribution between the shallow and deeper aquifer. Continued data collection, additional analysis of Ar isotope by Roland Purtschert at the University of Bern (Switzerland), continued development of a 2D solute transport model for the Mesilla Basin, and a final draft of a technical report are still remaining.

- 2) Evapotranspiration (ET) of a major crop (alfalfa) in the Mesilla Valley will be directly measured using current state of the art technology every 30 minutes for two years. Remotely sensed-based regional ET model estimates will be compared to these ground direct measurements for verification. The ultimate goal is to improve satellite-based model algorithms which can be used to better estimate ET on a regional/basin scale. Continued ET measurements, data analysis, and a final technical completion report are still remaining.
- 3) The principal purpose of this study is to understand the riparian vegetation responses to fluctuating levels of surface/groundwater interactions from frequently occurring drought conditions due to climate change. This project concluded in April 2018 with the submission of a master's thesis by Aracely Tellez. Publications from this project are expected in late 2018.
- 4) Annual estimates of aquifer recharge in the New Mexico portion of the Mesilla Basin for the years 2000-2015. A map of estimated diffuse recharge in the non-irrigated portions of the basin will be delivered by Summer 2018.

Coordination of the research projects and with Mexico will be provided directly by the NM WRRRI Director, Sam Fernald, and a Program Coordinator, Avery Olshefski, who was hired on October 19th, 2017. Project coordination involves big picture discussions to change the future course of the TAAP with Water Institutes and Water Science Centers from NM, TX, and AZ. The international coordination will seek to nurture close working relationships with counterparts in Mexico and setting up bilateral and multilateral international meetings for broad aquifer assessment planning and specific research component coordination. A binational meeting was held in Ciudad Juarez for the Mesilla Aquifer on March 27th, 2018.

Note that this report is the same for the two TAAP projects: 2016NM190S and 2017NM191S.

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. Of the past 62 annual water conferences, 59 conference proceedings have full-text viewing via the institute's homepage and others are in preparation; recent water conference speaker slides are available on the conference website. 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

Title:	Information Transfer Program
Project Number:	2017NM185B
Start Date:	3/1/2017
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	NM-ALL
Research Category:	Not Applicable
Focus Categories:	None, None, None
Descriptors:	None
Principal Investigators:	Catherine T. Ortega Klett

Publications

1. Sarpong, K, C Brewer, and O J Idowu. 2018. Biochar for Desalination Concentrate Management. New Mexico Water Resources Research Institute Technical Completion Report No. 377. 32 pp.
2. Herman, J and C Scruggs. 2017. T he Cost of Direct and Indirect Potable Water Reuse in a Medium Sized Arid Inland Community. New Mexico Water Resources Research Institute Technical Completion Report No. 376. 43 pp.
3. Ward, E, C Brown, and H Rojas. 2017. Household Water Quality in Rural Southern New Mexico. New Mexico Water Resources Research Institute Miscellaneous Report No. M33. 44 pp.

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 audio/visual presentations. For the past 62 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. The 2017 conference was held at New Mexico Tech in Socorro, NM, a site that had never hosted the annual conference before. For the past seven years, the annual water conference has included a poster session, which highlights water research taking place across the state and region. A record number of posters were presented, 48, of which 40 were given by students. NM WRRI funded 16 Student Water Research Grants in 2016, and most of the recipients attended the annual water conference and presented a poster.

The NM WRRI was asked by the New Mexico Environment Department to coordinate a conference that would facilitate the exchange of data and research results associated with monitoring efforts related to the August 2015 Gold King Mine spill. The institute worked with a multi-agency planning committee to host a conference on the *Environmental Conditions of the Animas and San Juan Watersheds with Emphasis on Gold King Mine and other Mine Waste Issues*. The conference took place at San Juan College in Farmington, NM on May 17-18, 2016 and due to its success, NM WRRI was asked to host the conference again on June 20-22, 2017. Over 150 participants took part in a two-day meeting in 2016 and 125 attended in 2017. The conference featured technical oral and poster presentations and a panel discussion that was open to the public at no charge. The conference is supported financially by the U.S. Environmental Protection Agency through the New Mexico Environment's Long-Term Monitoring Plan: *Evaluating the Effects of the Gold King Mine Wastewater Spill in Northern New Mexico*. Plans for the June 19-22, 2018 conference are underway, and this year's conference will include a two field trips including a post-conference field trip to the Navajo Shiprock Chapter House where a Teach-In is planned. A pre-conference field trip will explore the geology, mining, agriculture,

and water resources issues in the Animas River and San Juan watersheds of northern New Mexico and southwestern Colorado.

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 59 years are also available online in full text. In recent years, water conference speaker slides are posted on the conference website with the permission of the speaker.

In 2015, the institute began producing a monthly newsletter via email, “New Mexico Water eNews.” The online news-feed reaches about 1,568 recipients and keeps its recipients informed of institute activities, upcoming meetings, publications, and research projects.

The institute-housed reference room recently 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, 8,919 books and references, can be searched through the NM WRRI website, reference room link at <https://nmwri.nmsu.edu/reference-room/>, accessible by faculty, students, and the general public.

NM WRRI’s homepage (<https://nmwri.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 currently undergoing another redesign. Website contents are updated on a regular basis and the website 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 13,465 “visits” to its website.

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. Director Sam Fernald currently is the National Institutes for Water Resources President. The director also contributes to proposal development on funding opportunities; many of these proposals are interdisciplinary, multi-university efforts.

Accomplishments

The 62nd Annual New Mexico Water Conference took place in Socorro, NM on August 15-16, 2017. The conference theme was *Hidden Realities of New Water Opportunities*. The conference brought together the state's water community to discuss many critical water issues facing the state. A highlight of the conference was U.S. Senator Tom Udall who was joined by his cousin Brad Udall – a senior water and climate research scientist at Colorado State University's Colorado Water Institute – in a lively and informative exchange on our limited water resources in the arid Southwest. Senator Udall also updated the attendees with his efforts at the federal level associated with the 2012 NM WRRI water conference, which he co-hosted. The conference also included a panel of former Rio Grande Compact commissioners and administrators. The 2017 conference was attended by 180 participants and included a record number of posters, 48 of which 40 were presented by students. PowerPoint presentations given at the conference are available on the institute's website. The conference proceedings is in preparation and will be posted on the website.

Two Technical Completion Reports were published during the reporting period (and several are in preparation):

Biochar for Desalination Concentrate Management by K Sarpong, C Brewer, and O J Idowu, New Mexico State University (April 2018)

The Cost of Direct and Indirect Potable Water Reuse in a Medium Sized Arid Inland Community by J Herman and C Scruggs, University of New Mexico (April 2017)

One Miscellaneous Report was published:

Household Water Quality in Rural Southern New Mexico by E Ward, C Brown, and H Rojas, NM WRRI (July 2017)

For the past year, the institute's website has averaged 1,137 online visits each month. 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 about 1,568 recipients with an average open rate of 26 percent each month. The news feed aims to keep its readers informed on the latest water topics, emphasizing

those in which the NM WRI is involved. An archive of all eNews issues is at:
<https://nmwri.nmsu.edu/enews/>.

The holdings of NM WRI's reference room are online with a search engine for finding references by author name, title, publisher, and keywords. One student and a part-time institute staff member recently reorganized the institute-housed water reference room and maintain it throughout the year. Books previously housed at the institute, but which are now online, are noted on the institute's online library database with a link – 5,642 books are linked this way. A complete catalog of holdings, 8,919 books and references, can be searched through the NM WRI website reference room link at http://nmwri.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 President of the National Institutes for Water Resources and as part of his duties, he and his staff hosted the NIWR Annual Meeting in Washington DC on February 27-March 1, 2017. Currently Dr. Fernald presides over monthly NIWR Board meetings and participates in NIWR regional meetings. He 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. Recently, the director was elected to the Western Regional Big Data Steering Committee. He was also recently selected to serve on the Chihuahuan Desert Rangeland Research Center Steering Committee. The director also serves on the STATEMAP Advisory Committee, a statewide committee supporting USGS for geologic mapping in New Mexico.

The NM WRI staff regularly provides expertise for solving specific problems and general concerns. They play a central role in planning for the water future of the region by cooperating with a host of water resources entities throughout the state and region, particularly in the Paso del Norte area. The institute also coordinates meetings for the Lower Rio Grande Water Users group that consists of New Mexico State University, City of Las Cruces, Doña Ana County, New Mexico Pecan Growers Association, Elephant Butte Irrigation District, Public Service Company of New Mexico, Camino Real Regional Utility Authority, and Southern Rio Grande Diversified Crop Farmers Association.

The director works on legislation impacting the NM WRI at both the state and national levels. The director addressed the New Mexico Legislature House Agriculture and Water Resources Committee to update committee members on the institute's programs and to request financial support for continuing work on the Statewide Water Assessment initiative. At the national level, particularly as a Board member for the National Institutes for Water Resources, the director met with New Mexico U.S. Senators and Representatives on the reauthorization of the Water Resources Research Act and FY19 appropriation.

The New Mexico State Legislature held a 30-day session in early 2017. The legislature approved, and the Governor of New Mexico signed, a bill that provided the institute with state base funding of \$615,600 and one-time funding of \$500,000 to support the institute's Statewide Water Assessment effort. Although last year the Governor vetoed a special appropriation for the SWA, in the previous three years, the NM WRI had received a total of \$2 million in funding.

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

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	7	0	0	1	8
Masters	5	0	0	4	9
Ph.D.	3	0	0	2	5
Post-Doc.	2	0	0	0	2
Total	17	0	0	7	24

Notable Awards and Achievements

An NM WRRI Student Water Research Grant recipient, Manuel Lopez, is now working for the USGS in Santa Fe, NM performing fire regime analysis. He indicated that the student grant helped him obtain his position.

Dr. Kevin Lombard and several students participated on the 104B grant, What are the effects of the Gold King Mine spill on San Juan County, NM agricultural irrigation ditches and farms? Dr. Lombard and his students presented project results at several meetings and were highlighted in a newspaper article, Study continues monitoring Gold King Mine spill aftermath, published on February 6, 2018 by Farmington Daily Times. The funding for this project leveraged funding for Gold King Monitoring by the U.S. Department of Agriculture/Natural Resources Conservation Service and from the New Mexico Environment Department/U.S. Environmental Protection Agency.

Doctoral student Chao Wang, Dr. Jesus Gomez-Velez's student on his 104B project, New Mexico's Mountain Sources of Water: A Mechanistic Approach to Understand Mountain Recharge and Its Implications for Local and Statewide Water Budgets, won the Hantush Fellowship from the Earth & Environmental Science Department at New Mexico Tech, passed his PhD candidacy exam, won the Best Teaching Assistant award for the academic year 2017, and gave an oral presentation at the 2017 American Geophysical Union meeting: Wang C., J. D. Gomez-Velez, and J. L. Wilson. The importance of capturing topographic features for modeling groundwater flow and transport in mountainous watersheds. 2017 AGU Annual Meeting, New Orleans, Louisiana. December 2017.

Dr. Gomez-Velez's 104B grant also resulted in an added course at NM Tech: HYD 520/GEOP 520/MATH 583 Data-driven Modeling in Science and Engineering. This course introduces students to statistical learning techniques and data assimilation for science and engineering applications. Given the wide variety of topics, the course focuses on practical applications and emphasizes the understanding of the assumptions underlying different techniques. This approach allows students to learn the basics of useful tools for data-driven modeling and revisit their theoretical and practical underpinnings as needed. Topics may include supervised and unsupervised learning, regression, classification, importance sampling, ensemble forecasting, and Kalman Filtering. The codes R or Python will be used for the class.

New Mexico State University's Water Science and Management (WSM) Graduate Program currently has 37 master's and PhD students enrolled in the program, representing 10 countries. Twenty-four students have graduated from the WSM Program since it began in 2011. 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.

A 104B grant, Understanding the Costs of Arid Inland Communities' Potable Water Reuse Options, provided funding to PhD student Jason Herman who graduated with distinction in Spring 2017. Jason Herman subsequently was hired by the New Mexico Environment Department in what his advisory, UNM faculty advisor Caroline Scruggs described as ...a great job, largely due to his water reuse research that was supported by NM WRRI.

Amanda Otieno, University of New Mexico graduate student participating on the 104B funded award, Effect of Wildfire Ash on Water Quality, received an NM WRRI Student Water Research Grant, Characterization of metals in soil contributions to runoff events following wildfires.

Publications from Prior Years

1. 2014NM166B ("Self-Sustaining Produced Water Treatment for Concurrent Renewable Energy Production, Desalination and Organic Removal") - Articles in Refereed Scientific Journals - Ma, Z., H. Song, Z.A. Stoll, and P. Xu, 2017, Melamine modified carbon felts anode with enhanced electrogenesis capacity toward microbial fuel cells. *Journal of Energy Chemistry*, 26, 81-86.
2. 2010NM123S ("Monitoring and Forecasting Climate, Water, and Land Use for Food Production and Business Development in Iraq") - Articles in Refereed Scientific Journals - Shokhrukh-Mirzo, J., SA Amer, and FA Ward. 2018. Managing the water-energy-food nexus: Opportunities in Central Asia, *Journal of Hydrology*, 557:407-425.
3. 2015NM177B ("Understanding the Costs of Arid Inland Communities") - Articles in Refereed Scientific Journals - Herman, JG, CE Scruggs, and BM Thomson. 2017. The Costs of Direct and Indirect Potable Water Reuse in a Medium-sized Arid Inland Community, *Journal of Water Process Engineering*, 9:239-247, DOI: 10.1016/j.jwpe.2017.08.003
4. 2013NM160B ("The transport and accumulation of pyrogenic black carbon in fire-prone watersheds and implications for water quality") - Articles in Refereed Scientific Journals - Galanter, A, D Cadol, and K Lohse. 2018. Geomorphic influences on the distribution and accumulation of pyrogenic carbon (PyC) following a low severity wildfire in northern New Mexico. *Earth Surface Processes and Landforms*. <https://doi.org/10.1002/esp.4386>