

**Nevada Water Resources Research Institute
Annual Technical Report
FY 2016**

Introduction

Success and dedication to quality research has established the Division of Hydrologic Sciences as the recognized "Institute" under the Water Resources Research Act of 1984 (as amended). A total of 54 Institutes are located at colleges and universities in the 50 states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands.

The primary mission of the Nevada Water Resources Research Institute is to inform the scientists of Nevada.

Research Program Introduction

Nevada is the most arid state in the United States and it is experiencing significant population growth and possible future climate change. With competing water demands for agricultural, domestic, industrial, and environmental uses, issues surrounding water supply and quality are becoming more complex, which increases the need to develop and disseminate sound science to support informed decision making.

As the NWRRI, the continuing goals of DHS are to develop the water sciences knowledge and expertise that support Nevada's water needs, encourage our nation to manage water more responsibly, and train students to become productive professionals. Therefore, DHS has chosen to make a valuable contribution to water research and education in Nevada by judiciously distributing its Section 104 research funds among numerous subject areas. Projects must be of significant scientific merit (as determined by the review process) and relevant to Nevada's total water program to be considered worthy of funding.

To ensure collaboration and coordination among water-related entities throughout the state, DHS maintains a Statewide Advisory Council on Water Resources Research composed of leading water officials who may be called upon to assist in selecting the research projects that will be supported by Section 104 funds.

Theoretical Analysis of Optimal Groundwater Basin Development

Basic Information

Title:	Theoretical Analysis of Optimal Groundwater Basin Development
Project Number:	2016NV211B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	NV-02
Research Category:	Ground-water Flow and Transport
Focus Categories:	Groundwater, Water Supply, Drought
Descriptors:	None
Principal Investigators:	Clay Cooper

Publications

There are no publications.

Theoretical Analysis of Optimal Groundwater Basin Development

Problem and Research Objectives

It is thought by many hydrologists that groundwater pumping can be made “sustainable” if the amount of water pumped annually is less than annual recharge to the aquifer. Interpretation of a simple mass balance equation, however, shows that for many aquifers, this is not the case. For example, prior to pumping, unconfined aquifers are considered to be a state of dynamic equilibrium (or steady state), where mean annual recharge rate (\bar{R}) equals mean annual discharge rate (\bar{D}) when averaged over some suitable length of time. When an aquifer under a condition of steady-state is then pumped, the pumping rate (Q) disrupts the equilibrium and places a new stress on the previous stable system. So under natural conditions $\bar{R} - \bar{D} = 0$, while under development, however, a perturbation is introduced to the system such that

$$(\bar{R} + R') - (\bar{D} + D') - Q = \frac{dV}{dt} \quad (1)$$

where an overbar signifies mean values, the prime signifies changes (perturbations) to the mean values, and V is the volume of pumped water removed from the aquifer. Since $\bar{R} - \bar{D} = 0$, the above equation becomes

$$R' - D' - Q = \frac{dV}{dt} \quad (2)$$

Indicating that natural recharge and discharge have nothing to do with the water balance of an aquifer that is undergoing development. The above equation indicates that pumping is balanced by a combination of (1) an increase in recharge, (2) a reduction in discharge, and (3) a loss of stored water. If the sum of these three terms is able to match, or exceed, Q , the unconfined aquifer can be brought back to a new equilibrium, although one with a lower water table.

The main objective of the research is to develop analytically the condition(s) in which a groundwater basin may become unstable during pumping, resulting in a drastic drop in the water table. This is in contrast to normal aquifers in which the hydraulic head drops gradually over time, and can therefore be managed in real time. The product will likely be a function that a water manager could use to determine the conditions that should not be exceeded in order to prevent groundwater mining.

Methodology

I start with a partial differential equation (PDE) for one-dimensional, transient groundwater flow with a nonlinear pumping term, where pumping is a function of hydraulic head. This is in contrast to “normal” cases where pumping is either constant or a function of time. The nonlinear term is a sine function; this is used because its properties can be easily exploited for the analysis. More complicated (and possibly realistic) pumping scenarios would be developed in further research using numerical simulation. Using an appropriate set of scales, the governing equation, boundary, and initial conditions were dimensionless. The boundaries are finite, leading to a nonhomogeneous PDE. This equation was made homogeneous by subtracting the slope of the initial hydraulic head profile, resulting in an equation with a nonzero, but known, initial

condition (so that the equation could still be solved analytically). The sine function was written as a Taylor series, and a small positive parameter (ϵ) defining a critical (i.e., drastic) change in the character of the solution. A second time scale is introduced into the problem, and the dependent variable (hydraulic head) is written out as series in powers of ϵ . Solutions are collected in powers of ϵ , resulting in a general recursive relationship.

What is left to do is to determine an orthogonality condition for the nonhomogeneous forms of the separate, perturbed (in ϵ) equations. Each of the sub-equations (again, in ϵ) can then be solved in terms of the hydraulic head, and a general, recursive expression is developed that includes the higher order powers of ϵ .

I have been working closely with a mathematics professor (Aleksey Telyakovskiy) at the University of Nevada, Reno, on the analysis.

Principal Findings and Significance

Since the governing equation has not yet been solved, there are no principal findings yet. I expect to have the analysis completed before the end of July 2017. The mathematical analysis is about 80 percent completed, with much of the work occurring after the grant money was spent.

Information Transfer Activities

Aleksey and I expect to submit a manuscript to a peer-reviewed journal by late August. Publication of the work will lead to proposals being written to foundations to continue the work for different recharge, discharge, and pumping conditions; the problem will be extended to two dimensions, meaning that further work will be largely computational.

Student Support

I had requested support for an undergraduate student to write scripts to allow computed output from a computer program be inputted into open-source software for plotting. The student was also to search for groundwater data to be used to evaluate the theoretical results. At the time, I thought that I would not be able to complete the project using analytical methods, and would instead have to rely on less-optimal computations. I was unable to complete the project under the conditions of the contract and am still working on it on my own time. The next phase of the project, implementing more realistic parameters will involve either a Ph.D. student or post-doctoral researcher.

Uptake of Pharmaceutical and Steroidal Compounds by Quagga Mussels in Lake Mead

Basic Information

Title:	Uptake of Pharmaceutical and Steroidal Compounds by Quagga Mussels in Lake Mead
Project Number:	2016NV212B
Start Date:	3/1/2016
End Date:	8/31/2017
Funding Source:	104B
Congressional District:	NV-01
Research Category:	Water Quality
Focus Categories:	Water Quality, Toxic Substances, Invasive Species
Descriptors:	None
Principal Investigators:	Xuelian Bai, Kumud Acharya

Publications

There are no publications.

**TITLE: UPTAKE OF PHARMACEUTICAL AND STEROIDAL
COMPOUNDS BY QUAGGA MUSSELS IN LAKE MEAD**

Annual Progress Report

PIs: Xuelian Bai and Kumud Acharya

Problem and research objectives

Emerging contaminants have become an increasing concern in the environment due to their ubiquitous distribution and potential adverse effects to wildlife and humans. Municipal wastewater is a major source of emerging contaminants including steroidal hormones and pharmaceuticals and personal care products, where highly prescribed pharmaceuticals, widely used antimicrobial products, and naturally occurring hormones are discharged into the sewage systems. Conventional wastewater treatment plants cannot remove these organic compounds completely, and thus they are frequently detected at trace levels (parts per billion to parts per trillion) in wastewater effluents. Surface water sampling programs have shown the presence of various types of trace organic chemicals worldwide, and some of the chemicals can be environmentally persistent. The Las Vegas Wash receives discharges from four major wastewater treatment plants in the Las Vegas Valley and acts as one of the major inflows to Lake Mead. The wastewater discharge carrying untreated trace organic chemicals travels through the Las Vegas Wash and ends up in Lake Mead eventually.

Quagga mussel (*Dreissena bugensis*) is an aquatic invasive species that has spread in Lake Mead, the Lower Colorado River, and other connected waterways. Lake Mead exhibits year round warm temperatures, high calcium levels and a lack of natural predators, all of which are strongly favorable conditions for their growth and spread. Quagga mussel is likely exposed to the trace organic chemicals in Lake Mead via water or the food chain. The uptake and bioaccumulation of trace organic chemicals in quagga mussels are poorly understood so far, and the role that quagga mussel plays in the removal and food-web transfer of trace organic chemicals in the aquatic ecosystem is still unclear. Therefore, the goal of this proposed research is to understand the uptake rates and pathways of trace organic chemicals by quagga mussels in the Lake Mead ecosystem.

This research will provide crucial information of the exposure routes and ecological effects of trace organic chemicals in Lake Mead. Also, this research will help evaluate the health of the aquatic ecosystem in Lake Mead by addressing the impacts of trace organic chemicals on the non-target species, quagga mussel. The objectives of this research are: 1) to measure the concentrations of a suite of trace organic chemicals in water and quagga mussels collected from different locations in Lake Mead; 2) to determine the uptake rates of the target trace organic chemicals by quagga mussels; and 3) to clarify the exposure pathways of the trace organic chemicals in a lake ecosystem, either via water directly or via the food chain (i.e., algae feeding).

Methodology

1. Quagga mussel and water sampling

Quagga mussels were collected from Lake Mead Marina (36°01'45.5"N, 114°46'19.4"W) on January 9, 2017 at 3 feet, and from Las Vegas Bay (36°06'06.1"N, 114°48'59.8"W) and Boulder Island (36°02'13.8"N, 114°46'03.1"W) on February 14, 2017 at 40 feet (Figure 1 and Table 1). Mussels were rinsed with lake water and placed in ventilated containers filled with lake water and transported to the laboratory immediately. Mussels between 12 mm and 20 mm were considered adults, and the adult mussels were deshelled. Approximately 10 g (wet weight) of mussel tissue from each sampling location was obtained and kept frozen at -20 °C until further analysis.

Lake Mead water was collected from the same sites mentioned above in duplicate using 1 L amber glass bottles preserved with sodium azide (1 g/L) and ascorbic acid (50 mg/L). The water samples were kept at 4 °C in the laboratory until further analysis. Additionally, lake water was collected from Lake Mead Marina in 10 gallon cowboys and filtered using a 35 µm mesh filter to remove plankton, sediment, and large pieces of algae. The filtered water was stored in aerated, lightly covered five gallon buckets in the laboratory for further uses. Mussels collected from Lake Mead Marina were kept in an aquarium tank filled with the filtered lake water to acclimate to the laboratory conditions at room temperature for a week. The aquarium was aerated and fitted with sponge filters and exposed to 12 h of light and 12 h of darkness to maintain normal algae growth.

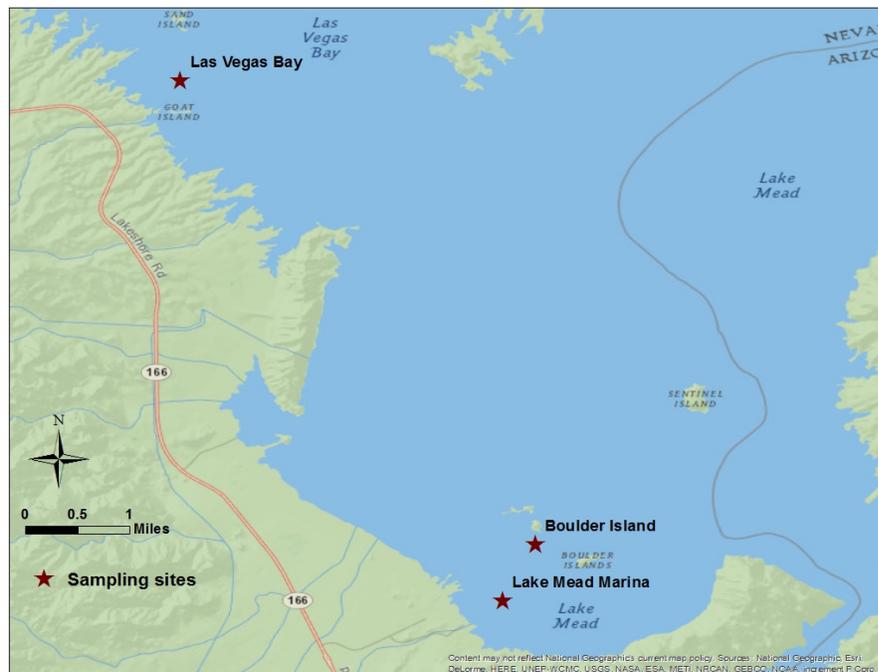


Figure 1. Map of sampling sites in Lake Mead, Nevada.

Table 1. Site description for water and quagga mussel sampling in Lake Mead.

Site	Latitude	Longitude	Sample Date	Depth (ft)
Lake Mead Marina	36.029306	-114.772056	Jan-9-2017	3
Boulder Island	36.037153	-114.767529	Feb-14-2017	40
Las Vegas Bay	36.101688	-114.816596	Feb-14-2017	40

2. Bench-scale exposure experiment

To evaluate the uptake of trace organic chemicals by quagga mussels, 30 adult mussels were selected from the aquarium tank and transferred in a 2 L beaker filled with filtered lake water and exposed to 12 h light and 12 h darkness at room temperature (~23 °C) for 7, 21, and 42 days. Each beaker was aerated throughout the experiment and lightly covered with foil. During the experimental period, two treatments were applied to evaluate two uptake pathways: direct water exposure and algae feeding. For direct water exposure, lake water was spiked with 50 µL of stock chemical solution to reach the desired initial concentrations (described later) before experiment. A freshwater green alga species, *Nannochloris*, was used as a food source to keep mussels alive and healthy. 10 mL of stock algal culture was centrifuged, and the supernatant was decanted. The remaining algal cells were kept frozen and used to feed mussels on a daily base. For the algae feeding treatment, each day before feeding mussel with algae, the algal cells were spiked with 5 µL of the stock solution with mixed target compounds. To keep water fresh and clean in the beakers, 1 L of water with mussel feces was withdrawal from each beaker twice a week, and fresh lake water (i.e., feed water) was added to refill the beaker afterwards. For direct water exposure, feed water was spiked with the trace organic chemicals to reach the initial doses before refill. Five replicates were used for each treatment and for each experimental duration. For each treatment, at day 7, 21, and 42, all mussels from each beaker were deshelled, and tissue was mixed together as one composite sample to reduce sample size. Each tissue sample (~ 10 g wet weight) was kept frozen at -20 °C in a glass jar until further analysis.

3. Chemical analysis

For field sampling, the collected water and mussel tissue samples were shipped overnight on ice to the Weck Laboratories Inc. (City of Industry, CA) for trace organic chemical analysis. Mussel tissue was first extracted using the QuEChERS extraction and cleanup procedure. The analytical method followed the EPA standard method for pharmaceuticals and personal care products (i.e., EPA 1694M ESI-) and hormones (i.e., EPA 1694M-APCI) using liquid chromatography tandem mass spectrometry (LC-MS/MS).

Only the compounds that were detected in the mussel tissue from field sampling were studied using laboratory-based experiments (Table 2 and 3). Standard chemicals of 17 α -ethinylestradiol, 17 β -estradiol, estrone, testosterone, bisphenol A, salicylic acid, and triclosan were purchase from Sigma-Aldrich (St. Louis, MO) with purity > 98% for the laboratory based experiments. The concentration of each chemical in the stock solution (in methanol) ranged from

3.7 to 86.5 mg/L (Table 4), and the actual applied dose in the feed water was determined by the Weck Laboratories Inc.

Principal findings and significance

1. Occurrence of trace organic chemicals in water and quagga mussel

The ambient concentrations of a list of trace organic chemicals were measured in both water and mussel samples collected at the three locations in Lake Mead. The reason of choosing these locations is that they can best represent the different sources of municipal waste-borne contaminants. The Las Vegas Bay is the receiving water body of municipal wastewater effluents from the Las Vegas Valley. Boulder Island and Lake Mead Marina are further downstream of the Las Vegas Bay and are expected to be less contaminated; however, these two locations are one of the most popular recreation areas in the lake, and recreational activities are considered the most important route for human exposure. The nearby fisheries may also be affected by the contaminants in the lake water. Monitoring the contaminants in quagga mussels at the selected locations may reflect the potential ecological risks in other aquatic organisms as well.

The measured concentrations of the contaminants are summarized in Table 2 and Table 3 for the water and mussel tissue samples, respectively. The results showed that hormones were not found in any water samples collected from the three locations (Table 2). All of the pharmaceutical and personal care products analyzed were detected in the water samples except iopromide, and they were found more abundant in the Las Vegas Bay compared with the other two locations. This is likely because the Las Vegas Bay receives wastewater effluents from the four municipal wastewater treatment facilities in the metropolitan area and the untreated contaminants are present in the Las Vegas Wash through the Las Vegas Bay. After entering Lake Mead, the contaminants can be diluted or naturally removed via biodegradation, photodegradation, and bioaccumulation. Another significant finding is that the pharmaceutical and personal care products were found in the water samples collected from 40 feet at the Las Vegas Bay and Boulder Island, indicating that they are mobile and persistent in the deeper horizon of the water column.

For the quagga mussels analyzed, testosterone was the only hormone that was detected, and bisphenol A, salicylic acid, and triclosan were also found at relatively high levels in the tissue. These chemicals are hydrophobic with great $\log K_{ow}$ values (i.e., 2.26-4.76; Table 4) so that they tend to be associated with biomass in the ecosystem. Testosterone was not found in the water samples but detected in the mussels, which demonstrates that bioaccumulation is a primary pathway for its fate and transport in the aquatic ecosystem. Although these compounds may not be detected in surface waters during traditional water quality monitoring, they can accumulate and transfer within the food web to cause ecological risks.

Table 2. Measured concentrations of trace organic chemicals in water samples (ng/L). MDL = method detection limit. MRL = method reporting limit. ND= not detected.

Compound	Lake Mead Marina	Boulder Island	Las Vegas Bay	MDL	MRL
<i>Hormones</i>					
17 α -Ethinylestradiol	ND	ND	ND	0.56	1.0
17 β -Estradiol	ND	ND	ND	0.31	1.0
Estrone	ND	ND	ND	0.20	1.0
Progesterone	ND	ND	ND	0.17	1.0
Testosterone	ND	ND	ND	0.14	1.0
<i>Pharmaceuticals and personal care products</i>					
Bisphenol A	1.2	30	22	0.27	1.0
Diclofenac	0.49	ND	1.5	0.26	1.0
Gemfibrozil	ND	ND	0.91	0.080	1.0
Ibuprofen	ND	0.55	1.5	0.39	1.0
Iopromide	ND	ND	ND	1.8	5.0
Naproxen	ND	ND	1.1	0.25	1.0
Salicylic Acid	17	28	36	0.86	20
Triclosan	ND	6.1	2.4	1.2	2.0

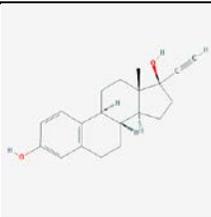
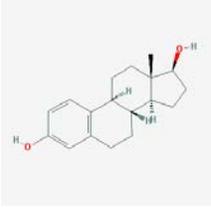
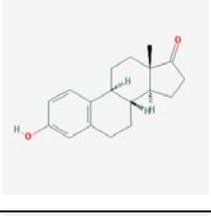
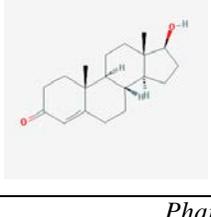
Table 3. Measured concentrations of target trace organic chemicals in mussel tissue ($\mu\text{g}/\text{kg}$ dry weight). MDL = method detection limit. MRL = method reporting limit. ND= not detected.

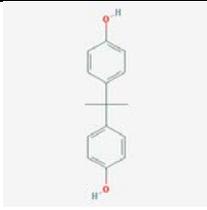
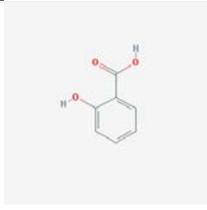
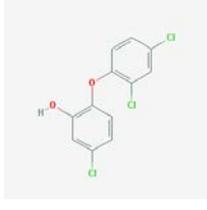
Compound	Lake Mead Marina	Boulder Island	Las Vegas Bay	MDL	MRL
<i>Hormones</i>					
17 α -Ethinylestradiol	ND	ND	ND	5.0	50
17 β -Estradiol	ND	ND	ND	5.0	50
Estrone	ND	ND	ND	5.0	50
Progesterone	ND	ND	ND	5.0	50
Testosterone	6.3	12	20	5.0	50
<i>Pharmaceuticals and personal care products</i>					
Bisphenol A	47	ND	ND	5.0	50
Diclofenac	ND	ND	ND	5.0	50
Gemfibrozil	ND	ND	ND	5.0	50
Ibuprofen	ND	ND	ND	5.0	50
Iopromide	ND	ND	ND	25	250
Naproxen	ND	ND	ND	5.0	50
Salicylic Acid	430	ND	ND	250	2500
Triclosan	24	28	ND	10	100

2. Mussel uptake of trace organic chemicals using bench-scale experiments

According to the findings from the field sampling, the compounds that were detected in the mussel tissue were studied using a series of bench-scale experiments. The physicochemical properties of the selected target compounds are summarized in Table 4. The initial concentrations were determined based on their reported levels in wastewater effluents and surface waters. The selected doses are approximately 5 to 10 times greater than the reported levels in surface waters to ensure the detection in this study. The experiments are finished and samples are being analyzed by the Weck Laboratories Inc. currently. The samples include mussel tissue from 7, 21, and 42 days of exposure to the target compounds and feed water to determine the actual applied dose of the compounds.

Table 4. Properties of selected target compounds.

Compound	Structure	Molecular Formula	Molecular Weight (g/mol)	Log <i>K</i> _{ow}	Sw (mg/L)	Dose in Stock Solution (mg/L)
<i>Hormones</i>						
17 α -Ethinylestradiol		C ₂₀ H ₂₄ O ₂	296.41	3.67	11.3	5.7
17 β -Estradiol		C ₁₈ H ₂₄ O ₂	272.39	4.01	3.6	3.7
Estrone		C ₁₈ H ₂₂ O ₂	270.37	3.13	30	5.7
Testosterone		C ₁₉ H ₂₈ O ₂	288.43	3.32	23.4	6.3
<i>Pharmaceuticals and personal care products</i>						

Bisphenol A		$C_{15}H_{16}O_2$	228.29	3.32	300	86.5
Salicylic Acid		$C_7H_6O_3$	138.12	2.26	2240	83.3
Triclosan		$C_{12}H_7Cl_3O_2$	289.54	4.76	10	5.1

Information Transfer Activities

The PIs have submitted an abstract to the American Chemistry Society National Meeting entitled “Uptake of hormones and pharmaceutical and personal care products by quagga mussels (*Dreissena bugensis*) in an aquatic ecosystem”, which will take place in Washington D.C. August 20-24, 2017. PI Bai will give an oral presentation at this meeting.

Student support

This project has supported two hourly students from undergraduate to Master’s level, Emily Kaminski and Yuzhen Feng, for nearly 6 months. This project also supported PI Bai for one month, who is currently a postdoctoral fellow at DRI.

An 8000-Year Paleoperspective of Hydroclimate Variability in the Southern Sierra Nevada

Basic Information

Title:	An 8000-Year Paleoperspective of Hydroclimate Variability in the Southern Sierra Nevada
Project Number:	2016NV213B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	NV-02
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Hydrology, Climatological Processes, Models
Descriptors:	None
Principal Investigators:	Steven Bacon, Rina Schumer

Publications

There are no publications.

An 8,000-year Paleoperspective of Hydroclimate Variability in the Southern Sierra Nevada

Steven N. Bacon

*Division of Earth and Ecosystem Sciences
Desert Research Institute*

Rina A. Schumer

*Division of Hydrologic Sciences
Desert Research Institute*

Introduction

Tree ring and other high-resolution paleoproxies that are resolved to annual time scales offer a means to extend the range of precipitation and temperature scenarios used in climate impact assessments. Deciphering patterns of background natural hydroclimate variability from underlying anthropogenic climate change is only possible from understanding the climate of the recent geologic past. The White Mountains within the Owens River Watershed in eastern California is the site of the ~8000-year long precipitation-sensitive Methuselah Walk bristlecone pine chronology (Hughes and Graumlich, 1996; Bale et al., 2011) and the ~5000-year long temperature-sensitive Sheep Mountain chronology (Salzer et al., 2014). It has been shown that the growth patterns of some annual tree-ring chronologies from moisture and temperature sensitive species show strong correlations with historical hydroclimate variability at watershed-to regional-scales (e.g., LaMarche, 1974). Depending on the type of tree species analyzed, tree-ring chronologies are commonly compared to a wide-range of instrumental records of the watershed's hydroclimatic system, such as precipitation, temperature, snow water equivalent (SWE), soil moisture, streamflow, lake water level, and drought indices. Ultimately, the goal of these analyses is to develop a hydroclimatic proxy dataset that could be used infer paleoclimatic change over the length of the tree-ring chronology studied. In turn the analyses could be used to provide an extended perspective on the range in magnitude and duration of potential hydroclimatic variability that could be experienced under future climate change in eastern California and western Nevada.

Research Objectives

The goal of this 2-year study is to evaluate the sensitivity of the longest tree-ring records in North America from the White Mountains to different components of the hydrologic system using a coupled watershed runoff and lake surface evaporation model for the Owens River-Lake system along the south-eastern Sierra Nevada in California. All previous studies of streamflow and lake-level reconstructions from tree-ring records in the Sierra Nevada, as well as with the rest of the western U.S. are limited to precipitation sensitive chronologies of less than ~2000 years. This study is using both temperature and precipitation sensitive tree-ring chronologies of less than ~5000 and ~8000 years, respectively, with a coupled watershed-lake water balance model to reconstruct past lake-level fluctuations of Owens Lake. The expected results will provide an annual resolved record of most of the Holocene (last ~8,000 years) hydroclimate

variability in the Sierra Nevada that could be used to refine regional to global Holocene paleoclimate models, as well as provide perspective on the potential magnitude and duration of hydroclimate variability under future climate change.

Methodology

The principal research activities during Year 1 research included the development of a calibrated watershed-lake water balance model and preliminary evaluation of the sensitivity of White Mountain tree-ring records using standard dendrochronological methods.

The watershed-lake water balance model developed consists of four simplified hydrologic model components: (1) watershed runoff modified after McCabe and Markstrom (2007), (2) energy-balance and snow melt, (3) glacial ice accumulation, and (4) open water evaporation based on the Priestley-Taylor (1972) equation. The model domain consists of 800 x 800 m grid cells, of which each grid cell is considered an independent modeling unit in terms of physiographic elements, hydroclimatic conditions, and hydrologic processes (e.g., Hatchett et al., 2015; Barth et al., 2016). The Owens River watershed model domain consists of 12,969 grid cells. The monthly water balance solution for each grid cell has been aggregated “lumped” at an annual time step in order to compare to Los Angeles Department of Water and Power measured runoff data for calibration. The climatic input variables of the model include 120-years of mean monthly minimum and maximum temperature, plus precipitation estimates for water years 1896–2015 from the 800-meter Parameter elevation Regression on Independent Slopes Model (PRISM) historical climate time-series dataset (Daly et al., 1994). Changes in solar insolation at each grid are also accounted for over the past ~8000 years using data in Berger and Loutre (1991).

Evaluation of the sensitivity of the White Mountain tree-ring chronologies to hydroclimate variability includes comparisons of raw tree-ring width data and published precipitation and temperature indices deduced from tree-ring records with historical modeled components of the hydrologic system in the watershed using linear regression analysis. The historical modeled components at the site of the tree-ring chronologies or throughout the watershed include: annual precipitation, temperature, evapotranspiration, SWE, soil moisture, streamflow, and simulated Owens Lake water levels.

Standard dendrochronological methods consisting of linear regression analysis were used to develop preliminary correlations between tree-ring records and specific components of the hydrologic model components during Year 1 research. A more comprehensive statistical analysis of tree-ring chronologies to the different hydrological components of the watershed will be performed during Year 2 research to reconstruct prehistorical runoff and resulting lake-level fluctuations. The accuracy of the modeled lake levels based on the tree-ring hydroclimatic reconstructions will be assessed by comparing to the Holocene shoreline record of Owens Lake (Bacon et al., 2006), in combination with the paleotemperature depression record developed in the Sierra Nevada from glacial deposits (Bowerman and Clark, 2011).

Year 1 Preliminary Results and Significance

The watershed-lake water balance model was calibrated to measured runoff, observed seasonal snowpack extent, surveyed glacial ice extent, and measured open water evaporation. Preliminary historical model watershed runoff and lake-level simulations are yielding interesting results that are providing insight to past hydroclimate variability of the region. In addition, preliminary analysis of tree-ring records with precipitation and temperature model results have confirmed previous research of the White Mountains bristlecone pine tree-ring chronologies that traditional statistical techniques used in dendrochronological studies yield problematic correlations to observed precipitation and temperature. The combined effects of asymmetric growth habits and steep and snow dominated terrain, which exposes the trees to dynamic and antecedent environmental conditions, adds a level of complexity to inferring climate from ring-width data for this particular tree-ring chronology (e.g., Salzer et al., 2009; Tolwinski-Ward et al., 2015; Tran et al., 2017). As a result, Year 2 research will be focused on investigating which component of the hydrologic system and at what geographical extent within the watershed the tree-rings are recording.

The watershed-scale modeling approach described above is similar in principle to the study of Saito et al. (2015) in the Sierra Nevada that also used a combined water balance and tree ring approach. Their study, however, did not include a lake evaporation element in the model and it simulated runoff over the last ~2000 years. If confident correlations of observed precipitation and temperature or other components of the hydrologic system (e.g., soil moisture, SWE, etc.) quantified by modeling of the Owens River-Lake system can be established, then up to 8000 year-long precipitation and temperature reconstruction estimates of the southern Sierra Nevada can be made. This approach could then be used to estimate the paleohydrologic surface conditions in closed basins of Nevada. With continued research, the results could possibly provide Holocene groundwater recharge estimates for these basins, which then could be used to provide a paleohydrologic context of groundwater recharge rates currently being used in groundwater modeling for water resources.

Information Transfer Activities

No conference presentations or publications resulted during Year 1 research activities. Discussion of the project and preliminary results were highlighted in *Nevada Water News* (NWN, 2017).

Student Support

The project is currently funding the research of one Ph.D. student (S. Bacon) in the Graduate Program of Hydrologic Sciences at the University of Nevada, Reno. The student's Year 1 research activities included what is summarized above.

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Assessing Tree to Grass Water Use Ratios; Significance to Urban Water Conservation

Basic Information

Title:	Assessing Tree to Grass Water Use Ratios; Significance to Urban Water Conservation
Project Number:	2016NV214B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	NV-01
Research Category:	Biological Sciences
Focus Categories:	Conservation, Water Use, Water Quality
Descriptors:	None
Principal Investigators:	Dale Devitt

Publications

There are no publications.

USGS Annual Research Report

Assessing Tree to Grass Water Use Ratios: Significance to the Golf Course Industry

Dr. Dale Devitt, School of Life Sciences, Univ. Nevada Las Vegas

Since receiving funding from the USGS in support of our USGA funded project entitled "Assessing Tree to Grass Water Use Ratios: Significance to the Golf Course Industry" we have made significant progress in initiating the research and addressing the research objectives stated in the proposal. First and foremost we selected a qualified student (Ms. Tamara Wynn) to undertake this project as part of her M.S degree in Biology at UNLV. We were fortunate to have a well- established tree research experimental orchard (10 species all planted approximately 20 years ago) that we could incorporate into the study and 12 non weighing lysimeters to use in estimating evapotranspiration of four turfgrass species.

Research Objectives

The main objective of the study is to quantify evapotranspiration of ornamental landscape trees and compare their water use to that of four different grasses grown in the arid southwest. The goal is to generate tree to grass water use ratios based on normalizing the water use of trees based on basal canopy area and canopy volume such that direct comparisons can be made with the turfgrass water use. We will make 40 different comparisons which will provide greater insight into tradeoffs that can occur in urban landscapes to attain aesthetically pleasing landscapes with low water use rates.

Site Development

Although we had an established orchard of landscape trees we had to trench to a depth of 120 cm in both a N-S and E-W direction to isolate each tree to make sure no roots from a given tree were accessing water from an area below a neighboring tree. Many roots were cut but very few were found below a depth of 30 cm. After the trenches were cut, a tractor was used to refill the trenches and smooth out the surface around the trees. Basins were then built up around each tree that could hold the weekly irrigation volumes. We cored into the soil of each basin and installed a theta probe access tube which would allow us the ability to lower a theta probe to a depth of 100 cm. In one of the three replicates of each species we also installed a deep time domain reflectometry probe at 150 cm to assess deep soil moisture that might reflect a drainage component. All trees received a single yearly application of mixed fertilizers during early spring and they will continue to receive this yearly amount throughout the duration of the study.

Sensor Installation

Each of the 30 trees selected for the study were equipped with 10 mm Granier probes to assess transpiration velocity within the xylem. Bark was gently removed with sand paper and holes were drilled for the combo sensors. All probes were then sealed with putty, surrounded with foam and insulated with a foil wrap. Cables from the 30 trees were run through flexible plastic tubing to protect the cables from rodents. All of the cables were routed to a data logger where they were wired into a multi-plexer. A program was written to collect and parse the data into a meaningful table. To convert the velocity measurements into a flux we conducted a dye experiment in which we drilled a ¼ inch hole to the center of selected trees, mounted a stopper funnel system that allowed red dye (sanfranin) to slowly move into the horizontal hole. We added additional dye on a daily basis and continued the dye application for a one week period. At the end of one week, we removed the stopper funnel system and cored a parallel hole 2 cm above where the dye entered. Intact cores were dried and mounted on wood and sanded to assess dye movement. We will measure the distance the dye penetrated and use this length to estimate the conductive tissue area in each tree, which will allow us to convert velocity to flux measurements.

Lysimeters

We have 44 non weighing lysimeters installed at our center for use in quantifying evapotranspiration. The lysimeters are 60 cm in diameter and 120 cm in depth with a theta probe access tube inserted at the center position. We selected 12 of these for use in quantifying evapotranspiration of turfgrass. In a large tall fescue plot we selected three lysimeters to remain as tall fescue. Three of the lysimeters in this area were converted to perennial ryegrass. In another research plot planted to bermudagrass we selected three lysimeters to remain as bermudagrass and three were converted to bentgrass. All grasses receive 0.5 pounds of Nitrogen per 1000 square feet on a monthly basis

Irrigations and water balance

We initiated the study in May of 2016 and began applying irrigations to the tree basins and lysimeters planted to turfgrass. The goal has been to irrigate in a way that does not contribute to a drainage component that would have to be included in the hydrologic balance. As such we irrigate based on the previous weeks evapotranspiration rate, where $ET = Input - Output - Change \text{ in Storage}$. In the tree basins we make weekly soil volumetric water content estimates at 10, 20, 30, 40, 60 and 100 cm, enabling a weekly soil water in storage estimate. We also take soil volumetric water content estimates at 150 cm to monitor any deep soil water movement (no movement has been observed as of this report). Irrigation water is applied to the tree basins from an irrigation hose that is equipped with an accurate flow meter to estimate irrigation volume in liters. Lysimeters containing turfgrass are hand watered by measuring irrigation volumes with a graduate cylinder and then transferring that water to a watering can where the water is applied in a uniform fashion to each lysimeter. In the case of the ryegrass and bentgrass we had difficulty establishing and maintaining 100 % cover in all of the lysimeters, especially during the heat of July in which temperatures remained above 115 F for a one week period. Because of these problems we had to abandon the standard water balance approach and give additional water to help maintain the two grass species. This led to over irrigation and drainage build up. We are currently evacuating drainage via a drainage system that is based on ceramic extraction cups placed at 110 cm depth that are hooked to a vacuum extraction system.

Evapotranspiration

We now have over 52 weeks of ET estimates for the 30 trees based on the hydrologic balance approach. We will begin to normalize the ET estimates based on canopy volumes, basal canopy areas, trunk diameters, tree heights and leaf area index measurements. The trees show an increase in ET from late spring to summer with higher values holding throughout the summer period, followed by a step down during the late fall period (Figure 1). Turfgrass ET has also revealed a similar temporal response (Figure 2). Once we normalize the tree ET values we will begin to compare the ET between the trees and turfgrass. The raw data suggests as much as a 30 fold difference in the weekly ET during the summer when comparing the trees (higher) with the turfgrass (lower). The basal canopy area of the trees is not 30 fold larger than the turfgrass area which would suggest tree to grass water use ratios that would clearly favor the trees during much of the active growing period. We will finalize the normalization process during the next few months, enabling us to report on actual tree to grass water use ratios for each tree grass combination. We will also finalize our estimates of conductive xylem tissue area to convert the transpiration velocities into flux estimates. This process will also allow us to compare the sap flow approach (Figure 3) with the hydrologic balance approach.

Information Transfer Activities

In October of 2017, Ms. Wynne will present a poster at the American Society of Agronomy, reporting on findings from this funded project.

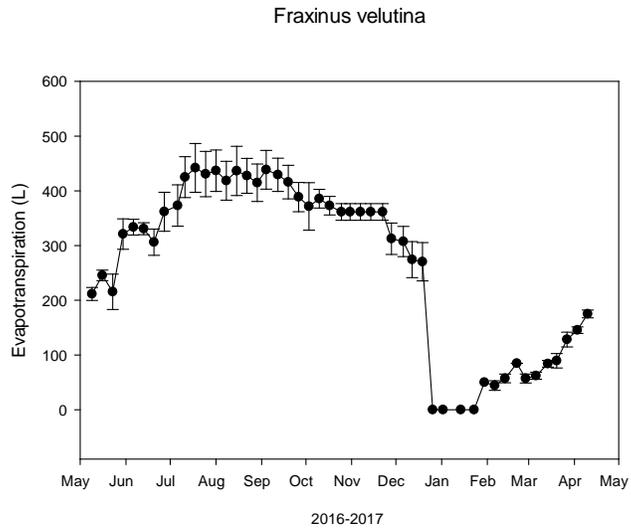


Figure 1. Evapotranspiration of Ash trees using the hydrologic balance technique during the 2016-2017 period.

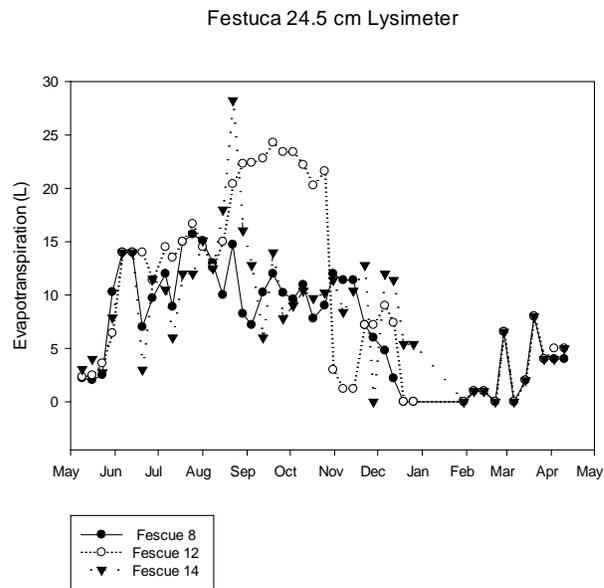


Figure 2. Evapotranspiration of tall fescue using the hydrologic balance technique during the 2016-2017 period.

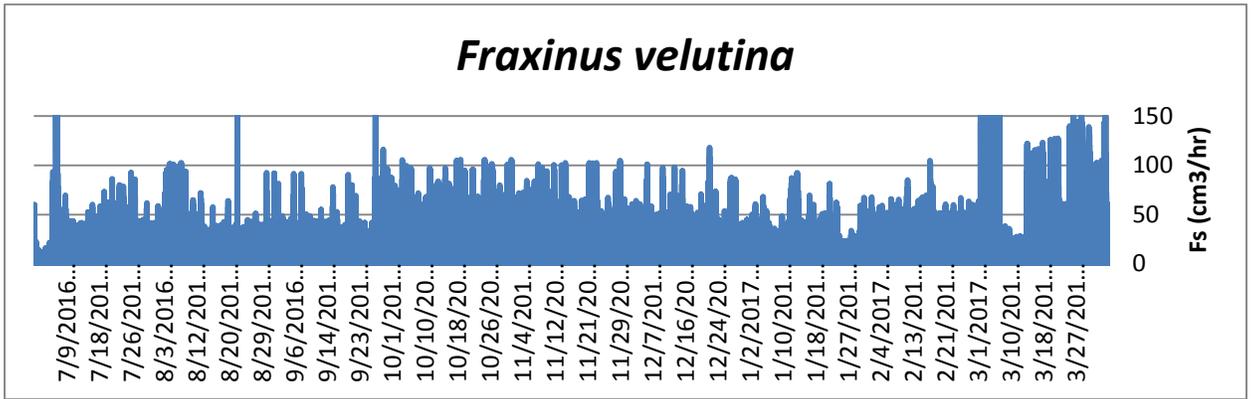


Figure 3. Granier probe transpiration estimates for a *Fraxinus velutina* tree over the 2016-2017 period.

Controls on Hydrologic Partitioning, Residence Time and Solute Export in a Snow-Dominated Watershed

Basic Information

Title:	Controls on Hydrologic Partitioning, Residence Time and Solute Export in a Snow-Dominated Watershed
Project Number:	2016NV217G
USGS Grant Number:	
Start Date:	9/1/2016
End Date:	8/31/2019
Funding Source:	104G
Congressional District:	NV-002
Research Category:	Climate and Hydrologic Processes
Focus Categories:	Models, Solute Transport, Hydrology
Descriptors:	None
Principal Investigators:	Rosemary Woods-Hart Carroll, Rina Schumer, Christopher T Green

Publications

There are no publications.

Controls on Hydrologic Partitioning, Residence Time and solute export from a snow-dominated watershed

Rosemary W.H. Carroll and Rina Schumer

Problems and Research Objectives

The Colorado River is a major water source and economic engine for seven Western U.S. states. The majority of its water originates in snow-dominated headwaters. These headwater basins are considered especially vulnerable to climate change with implications for water resources and environmental management. This study will be the first to apply new methods for developing streamflow time-varying travel time distributions (TTDs) to a snow-dominated watershed of the East River, CO and, in particular, at a scale relevant for water management decisions (>100 km²). Proposed work will develop TTDs describing the length of time water and solutes spend in the watershed under various hydrologic conditions using environmental tracers that capture a wide range of travel times. TTDs reflect integrated effects of watershed compartment connectivity and the degree of mixing of water of varying age since entering the watershed. These distributions affect water quality because many weathering processes and biogeochemical reactions are time-dependent. Time indicates catchment memory of past inputs and can be used as a proxy to understand hydrologic sensitivity to land use, climate change and other effects such as persistence of contamination. Implications of storage-dependence on water pathways and residence times in snow-dominated systems are not well understood, nor are the effects on both water delivery and water quality. We propose use of field observations with a combination of modeling approaches to quantify the principal controls on storage dependent thresholds and residence times as reflected by streamflow age distributions. Seasonal TTD moments will be compared to hydrograph characteristics (timing and volume) and export of principal ions, carbon, nutrients and heavy metals.

Methodology

Recent development of methods for computing time-variable TTDs incorporate multiple dynamics based on conservation equations for both mass and age (Botter *et al.*, 2011; Van Der Velde *et al.*, 2012; Harman 2015). Solving the conservation equation, requires an established relationship between the distribution of discharge ages and the distribution of stored water ages. This is captured in a so-called StorAge Selection (SaS) function that relates the way stored water of different ages is released to discharge. Separate SaS functions must be used for streamflow and ET outputs. We choose to use a method in which the SaS function relates the TTD to age ranked storage rather than absolute age (Harman 2015). This method does not contain *a priori* conceptual assumption, such as the number of “tanks” in a watershed and the degree of mixing, (Birkel *et al.*, 2010; McMillan *et al.*, 2012). While discharge age-ranked distributions can be estimated empirically using tracers, the functional form of the SaS function must be inferred. We will evaluate a variety of SaS functions simulating both invariant and transient storage conditions on stream flow output fluxes under a variety of hydrologic conditions. Functional responses will be developed for upper catchment tributaries and at the PH location where observed stream discharge and concentration data exist. The updated Python code written by (Harman 2015) has been obtained for hydrochemically-derived TTD development which contains an embedded

optimization routine for nonlinear parameter estimation to minimize the weighted difference between the reference age-tracer concentrations and the TTD model estimates of age tracer concentrations. Appropriateness of selected SaS will also rely on a comparison to the observed power spectral density (Harman 2015; Kirchner and Neal 2013) and modeled particle paths generated from SLIM-FAST in an integrated hydrologic model and will consider alternative conceptual models for snowmelt, monsoonal rain and dry, or baseflow conditions.

Quantifying ages of groundwater contributions to stream discharge from shallow and deeper groundwater systems is imperative to understanding memory in the system. Springs and seeps occur in the Mancos Shale and talus slopes. Mapping springs will be done and correlated to geologic and hydrologic characteristics of the basin. Selected springs will be sampled twice annually (spring and fall) for discharge and geochemistry. Samples will be analyzed for stable isotopes, chloride, sulfate, nitrate and atmospheric tracers of groundwater age (^3H , SF_6). Access to private boreholes in the Mancos shale will provide age constraints of deeper groundwater while selected piezometers in the upper and lower floodplain will provide ages of shallow, alluvial groundwater. Groundwater and spring samples will be compared to age of baseflow using the novel technique recently published by Sanford *et al.* (2015) in which SF_6 , Ar and N are collected hourly at a single location over a 12-hour period. The technique takes advantage of the temperature-dependence of Henry's Law constant of gases to estimate the mean gas residence time, and hence apparent age, of groundwater contribution to baseflow. This experiment will occur in the late summer within proximity of the PH sampling site. Data will help calibrate/verify TTD estimated mean travel times during baseflow conditions.

Principal Findings and Significance

Work by Dr. Rosemary Carroll (PI) in joint effort with the Lawrence Berkeley National Laboratory Science Focus Area (SFA) performed end-member mixing analysis (EMMA) for the East River, CO using a suite of natural chemical and isotopic observations. EMMA is an initial step to elucidate source contributions to streamflow, associated flow paths and residence time. EMMA relies on principal component analysis to reduce the number of dimensions of variability (U-space) for use in hydrograph separation. The mixing model was developed for the furthest downstream and most heavily characterized stream gauge in the study site (PH). Potential tracers were identified from PH discharge as near linear (Mg, Ca, Sr, U, SO_4 , DIC, $\delta^2\text{H}$ and $\delta^{18}\text{O}$) with alternative groupings evaluated. The best model was able to describe 97% of the tracer variance in 2-dimensions with low error and lack of residual structure. U-space positioning resulted in seasonal stream water source contributions of rain (9-16%), snow (48-74%) and groundwater (18-34%). EMMA developed for PH did not scale across 10 nested sub-catchments. Differences in mixing ratios are attributable to, (1) biogeochemical processes of sulfate reduction in the floodplain sediments; (2) source rock contributions from Mancos Shale and Morrison Fm; (3) hydrologic partitioning induced by feedbacks within the critical zone; and (4) associated subsurface flow paths.

Information Transfer

Presentation of EMMA results at the Department of Energy PI meeting and to the SFA Watershed Function meeting occurred outside the reporting time period.

Student support

Work was funded in the fall of 2016. Work to date has focused on an international search to hire a Post-Doctoral Fellow. Dr. Zhufeng Fang began his contract on March 15, 2017 at the Desert Research Institute.

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Information Transfer Program Introduction

GreenPower Mission Statement: To support Nevada's preK-12 educators in science-based, environmental education by providing the tools, resources, and knowledge they need.

What is a Green box? Developed for K-12 educators, Green Boxes introduce environmentally focused topics that emphasize sustainable practices and natural resource conservation. Each Green Box is centered around a "green" topic written for either a particular grade or range of grade levels. Every box contains the material and curriculum needed to engage students in hands-on activities with real-life applications that are both informative and fun! Best of all, our program is completely free for educators to use. We have a large list of titles available and more coming online all the time.

Who Creates Green boxes? Green Boxes are made by educators for educators. Once created, each box is then vetted through our Advisory Green Box Committee, which is comprised of education and environmental experts. Upon committee approval, the Green Boxes then make their way to GreenPower schools.

What Does a Greenbox Contain? Curriculum aligned to Nevada State, Common Core, and Next Generation Science Standards. Enough content for 1 to 2 weeks of instruction, complete with hands-on-activities and projects. Most materials needed for activities (both consumables and non-consumables). A flash drive with curriculum and supplemental materials.

In addition to the Greenpower/GreenBox program, DRI maintains a current website and publishes a quarterly newsletter.

Greenbox

Basic Information

Title:	Greenbox
Project Number:	2016NV215B
Start Date:	3/1/2016
End Date:	2/28/2018
Funding Source:	104B
Congressional District:	NV-03
Research Category:	Not Applicable
Focus Categories:	Education, None, None
Descriptors:	None
Principal Investigators:	Amelia Gulling

Publications

There are no publications.

NIWR and Maki Reporting 2015

DHS Water Green Boxes

Problem and research objectives:

In collaboration with the Division of Hydrologic Systems (DHS) faculty develop two K-12 Maki Water Green Box that highlight southern Nevada water as well as use funds were used to replicate four existing water related Green Boxes that were high in demand, creating a total of nine additional Green Boxes.

Methodology:

An internal RFP was solicited to DRI DHS faculty for a southern Nevada water-focused Green Box for specific water related topics aligned to the Next Generation Science Standards from elementary school through high school grades. Once proposals were selected DRI's GreenPower staff worked on pairing the faculty member as the science-content expert of the Green Box with an educator as the education expert. The boxes are designed to include 4-8 lessons that are based on the learning cycle 5E model and that are aligned the Next Generation Science Standards.

In addition to the creation of two new Green Box topics on water, the DRI K-12 team had identified four additional existing topics that were high in demand from teachers across the state. Based on this demand, they replicated an additional nine boxes.

Water Basics, Grade 2 – replicated three additional

This Water Basics Green Box is composed of seven lessons; Water Use Song, Handprint Evaporation, Bodies Lose Water, Water in our Foods, Plants Need Water, Desert Heat, and Keeping Water Clean. At completion of this Watershed Green Box students will be able to understand:

- The role of water everyday lives.
- The concept of evaporation and the process by which water changes from liquid to a gas or vapor.
- Understand needs of different plants and animals and the places they live and patterns of what plants and animals need to survive.
- Solutions that will reduce the impact of humans on water.

Water in the natural and built environment, Grade 3- replicated three more

The Water in the Natural and Built Environment Green Box has eight lessons; Tasty Water, Water around the World, Water Pipes, Down the Drain, Water Through Earth Materials, Bugged by Litter, Desert Habitat, and Undercover Plants. At completion of this Green Box students will be able to understand:

- Data in tables and graphical displays that describe typical weather conditions expected during different season.
- Different climates in different parts of the world.
- How water moves through our environment.
- Understand human impacts on the environment and our watersheds.
- Understand watershed health and water quality.

Introduction into the Hydrologic Cycle, Grade 4- replicate one additional

The Introduction into the Hydrologic Cycle Green Box has ten lessons; Water in the News, Junior Hydrologists, Where's the Water, Water Works, Where Does Water Go?, Condensing Water, Floating and Sinking, Walking on Water, Water Where it is Needed, and Raining Cats and Dogs. At completion of this Green Box students will be able to understand:

- Information to describe that energy and fuels are derived from natural resources and their uses affect the environment (Dams).
- Water functions in different ecosystems.
- Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.
- Local water issues
- Ways in which humans change their environments to meet their needs.

Water Resources and Conservation, Grade 5- replicate one additional

The Water Resources and Conservation Green Box has nine lessons; Down the Drain, Drinking It Up, Water Maps, A Drop in the Bucket, Salt, Soap. . or Not?, Seedy Environments. Dirty Water, Water Wars, and Washoe Worries. At completion of this Green Box students will be able to understand:

- Describe and graph the amounts and percentages of water and fresh water in various reservoirs.
- Water quality and quantity issues around the globe and locally.
- Where southern Nevada gets its water from.
- Water efficiency and conservation measures that local businesses and residential homes use.
- Infrastructure of how water is delivered in our community.

Development of New Content Green Boxes

Drought in the Southwest, Grade MS

The Drought in the Southwest Green Box will include four to six lessons on what a drought is, why the southwest is prone to drought, how we monitor drought and how the drought change in the future in the southwest. At completion of the Green Boxes students will be able to understand:

- Define different types of droughts; meteorological, agricultural, hydrologic, and regional.
- Explain Hadley circulation and rain shadow effect.
- Learn how to analyze and interpret data
- Evaluate and communicate scientific information

Soil Erosion in Southern Nevada, Grade 2-3

The Soil Erosion in Southern Nevada Green Box will include four lessons on what soil erosion is, different factors that can cause soil erosion, how soil erosions have an impact on southern Nevada, and ways to prevent soil erosion. At completion of the Green Box students will be able to understand:

- Soil erosion and different causes by water
- Impacts of soil erosion especially focused on southern Nevada
- Modeling soil erosion and practicing mitigation practices

Principal Findings and Significance

The completion of this project was developing this Green Box content that will strengthen student's understanding of watersheds and water quality in southern Nevada. Students also increased their scientific knowledge in alignment with the Next Generation Science Standards for their grade levels. With the addition of two new Green Box topics and the replication of nine more existing Green Boxes, the expected reach 1,500 students per school year.

Information Transfer Activities

These Green Boxes will be available for online check out on our www.greenpower.dri.edu web site and free for any Nevada teacher to use in their classrooms.

Student Support

There was no student support paid through this funding.

NWRRI Website & Newsletter

Basic Information

Title:	NWRRI Website & Newsletter
Project Number:	2016NV216B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	NV-03
Research Category:	Not Applicable
Focus Categories:	None, None, None
Descriptors:	None
Principal Investigators:	James Thomas

Publications

There are no publications.



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RFPs

If you have questions about submitting a NWRRRI proposal, e-mail Amy Russell (Amy.Russell@dri.edu).

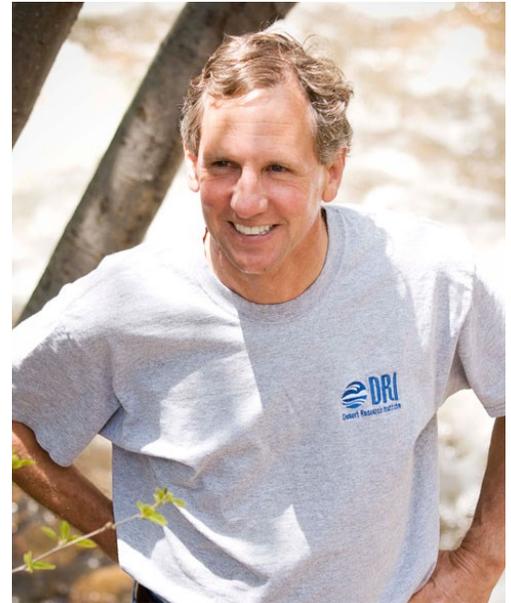
For current RFP information, visit the NWRRRI website (www.dri.edu/nwrrri).

Director's Letter

Greetings! We've had a great year of Nevada Water Resources Research Institute projects and the new grants that have been awarded will continue to take our water research projects in exciting new directions.

Drs. Xuelian Bai and Kumud Acharya's project "Uptake of Pharmaceutical and Steroidal Compounds by Quagga Mussels in Lake Mead" will explore the effects of wastewater contaminants on aquatic species in Lake Mead. The project will evaluate the uptake rates of selected trace contaminants from pharmaceutical and personal care products in quagga mussels to understand the exposure of aquatic organisms to these contaminants. The project will also provide insight into the exposure pathways of these chemicals and their effects on nontarget species to help develop ecological risk assessments.

Dr. Dale Devitt's project "Assessing Tree to Grass Water-use Ratios: Significance to Urban Water Conservation" will measure tree and grass water-use rates to evaluate the two landscape coverings. With extended droughts and potential climate changes, meeting water demands in the arid West is challenging. Research into these



water-use rates will allow water managers, landscape architects, horticulturists, and golf course managers to find tree and grass combinations that create attractive, water-saving landscapes.

Dr. Clay Cooper's project "Theoretical Analysis of Optimal Groundwater Basin Development" will develop a scaling analysis to estimate water table conditions for potential basin-wide water development. Natural recharge and discharge are often not sufficient assessments of the hydrologic budget of a groundwater basin. This project will determine the conditions under which drastic drops in the water table can occur.

(Continued on following page)

(Director's Letter continued)

Drs. Steven Bacon and Rina Schumer's project "An 8,000-Year Paleo Perspective of Hydroclimate Variability in the Southern Sierra Nevada" will develop an 8,000-year record of hydroclimate data for the southern Sierra Nevada region. The region's hydrologic budget will then be estimated and used to model historical monthly temperature and precipitation data using PRISM.

This data will be used to reconstruct the hydrologic system, which can then be applied to snowmelt-dominated watersheds in Nevada and California that do not have gaged streamflow records.

We will also continue to develop Green Boxes with activities that teach PreK-12 students about different aspects for water science,

such as the activities highlighted in this issue. I look forward to sharing more about all of our new projects in the upcoming issues of *Nevada Water News!*

Sincerely,

Jim Thomas ■

Upcoming Events

112th GSA Annual Meeting, Cordilleran Section
April 4-6
Ontario, CA
www.geosociety.org/sections/cord/2016mtg/

UNR/NWRA Spring Dinner Forum
April 5
Reno, NV
www.nvwra.org/2016unr-nwrainnerforum

2016 NGWA Groundwater Summit
April 24-27
Denver, CO
www.groundwatersummit.org/

2016 AWRA Spring Conference: Water, Energy, Environment
April 25-27
Anchorage, AK
www.awra.org/meetings/Anchorage2016/

14th Annual Truckee River Field Study Course
May 5-6
Reno, NV
www.nvwra.org/truckee-river-tour

AGU Chapman Conference: Emerging Issues in Tropical Ecohydrology
June 5-9
Cuenca, Ecuador
chapman.agu.org/ecohydrology/



Groundwater from the Mountains to the Sea in the Central Atlantic Region
June 6-7
Virginia Beach, VA
www.ngwa.org/Events-Education/conferences/Pages/5056jun16.aspx

2016 UCOWR/NIWR Annual Conference
June 21-23
Pensacola Beach, FL
ucowr.org/conferences/2016-ucowr-conference

2016 AWRA Summer Conference: GIS and Water Resources IX
July 11-13
Sacramento, CA
www.awra.org/meetings/Sacramento2016/

(Continued on page 5)

Project Spotlight: NIWR/Maki Green Boxes

The new NIWR/Maki Water Green Boxes were developed by the GreenPower program, Desert Research Institute's (DRI) educational outreach program, and the Division of Hydrologic Sciences (DHS), which houses the Nevada Water Resources Research Institute. Green Boxes are self-contained science education kits that cover a variety of environmental science curricula for PreK-12 students. "Green Boxes are customized to encompass a wide range of STEM (science, technology, engineering, and math) topics that highlight applied science and twenty-first century technology," says Mackenzie Peterson, the Green Box administrator for GreenPower. "All of our curricula is designed to be hands-on, inquiry based, and student driven."



Students at Sandy Searles Miller Elementary School in Las Vegas, Nevada, conducting a Green Box experiment in their classroom.

The NIWR/Maki Water Green Boxes focus on projects that teach middle and high school students about water resources in southern Nevada. The Water Quality Green Box is tailored to middle school students and it includes activities such as measuring the salinity of multiple water samples and mapping changes in water quality as water travels through the Colorado

River system. The students also evaluate how differing levels of salinity affect the humans and biota that rely on the river for survival.

The Watersheds Green Box is tailored to high school students and it includes activities such as creating a model of local watersheds, simulating streamflow, and measuring the turbidity and dissolved oxygen content of various water samples. The box primarily focuses on water resources in southern Nevada, specifically the Colorado River watershed. Students learn about the effects of channel morphology on flow and sediment transport and how topographic features affect runoff and ponding. The students also learn how to measure nutrients in water and how nutrient levels affect algae growth.



The projects in each Green Box, such as the Water in the Natural & Built Environment box above, require students to use critical thinking and problem solving skills. This box is geared toward Grade 3 students and the activities focus on how water is used and transported.

(Continued on following page)

(Project Spotlight continued)

The NIWR/Maki Water Green Boxes give students a chance to learn first-hand about the different scientific disciplines that are used in water resources research. “Each box includes active learning materials, which engage students in hands-on projects that foster critical thinking and problem solving skills,” Peterson says. “The kits are designed to encourage student inquiry and excitement for STEM by exposing them to content and specialized equipment they might not have access to otherwise. And the best part is that the activities are fun!”

GreenPower makes sure that all Green Boxes are aligned with Nevada State, Common Core, and Next Generation Science Standards. The program also gives DRI faculty the opportunity to directly contribute to enhancing science literacy in Nevada. “Our Green Boxes allow faculty to translate complex subject matter into tangible resources that educators can use in the classroom,” Peterson says. “Dr. Alex Lutz and Brian Fitzgerald have each integrated their research into a cohesive series of labs and activities that nearly 200 students are projected to use over the next year.”

In addition to curriculum development, GreenPower also provides other opportunities for faculty to participate in the



Each Green Box, such as the Properties of Water box above, is a self-contained science education kit. The curriculum in this box is geared toward high school students and allows them to examine water throughout the hydrologic cycle.

program, such as showcasing an existing Green Box activity in classrooms or at teacher-training workshops. “Brian Fitzgerald will be giving a keynote presentation at the summer installment of our professional development series, which is a three-day teaching intensive that will focus on the water/energy/climate nexus,” Peterson adds. “This training will allow teachers to deepen their own understanding of watershed and water quality issues in Nevada and, in turn, confidently share what they have learned with their students.”

The NIWR/Maki Water Green Boxes are a valuable addition to the Green Box program because they expand students’ understanding of regional water resource issues. “Students are the next generation of decision makers and community leaders,” Peterson says. “Establishing a foundational understanding of Nevada’s water resources is key to accurately evaluating place-based issues, such as drought and the pervasiveness of invasive aquatic species.” ■

“Establishing a foundational understanding of Nevada’s water resources is key to accurately evaluating place-based issues, such as drought and the pervasiveness of invasive aquatic species.” – Mackenzie Peterson

NIWR/Maki Green Box Highlights

The NIWR/Maki Water Green Boxes are activity-based instruction units that allow students to learn the fundamentals of water science. Desert Research Institute faculty help develop the activities in the boxes, which are approved by the Green Box Advisory Committee to ensure that they meet Nevada State, Common Core, and Next Generation Science Standards. Green Boxes can be checked out online and are delivered to schools with the necessary supplies to teach the unit.

NIWR/Maki Water Quality Green Box (Middle School)

The Water Quality box outlines a sequence of labs devised to highlight how the salinity of the Colorado River system acts as an indicator of water quality. Throughout the unit, students will learn how to test water samples using an electrical conductivity (EC) meter and evaluate the effects that various point/nonpoint pollution sources have on water quality.

Learning Objectives

- Identify, graph, and map changes in salinity as water is diverted and returned to the river by various users.
- Determine how varying levels of salinity affect the life forms that rely on the river (people, plants, and animals).

NIWR/Maki Watersheds Green Box (High School)

The Watersheds unit provides a series of broad-based experiments designed to help students understand the relationships between human impacts and local hydrology. Covering a range of disciplines—including geology, chemistry, Earth science, botany, and biology—these lessons are intended to provide a thorough snapshot of the Colorado River watershed.

Learning Objectives

- Identify trees and common plant species found in the watershed using a dichotomous key.
- Determine how the shape of a river channel affects the flow of water and the transportation of sediment.
- Classify common macroinvertebrates that live in the Clark County Wetlands and learn how these species can be indicators of water quality. ■

Events continued

USGS Technical Conference – Groundwater and Surface Water: A Single Resource
August 29-September 2
Reno, NV
www.nvwra.org/2016-usgs-conference

Connecting the Dots: Groundwater, Surface Water, and Climate Connections
September 8-9
Portland, OR
www.ngwa.org/Events-Education/conferences/Pages/5029sep16.aspx

2016 GSA Annual Meeting
September 25-28
Denver, CO
www.geosociety.org/meetings/2016/

ASA, CSSA, and SSSA: Resilience Emerging from Scarcity and Abundance
November 6-9
Phoenix, AZ
www.acsmeetings.org/meetings

Emerging Leaders Alliance Conference
November 9-12
Falls Church, VA
www.ngwa.org/Events-Education/conferences/Pages/elanov16.aspx

2016 AWRA Annual Conference
November 13-17
Orlando, FL
www.awra.org/meetings/Orlando2016/

Groundwater Week
December 6-8
Las Vegas, NV
groundwaterweek.com/

AGU Fall Meeting 2016
December 12-16
San Francisco, CA
sites.agu.org/meetings-events/#meeting

Postdoc Interview: Peng Jiang

We asked Maki Postdoctoral Fellow Dr. Peng Jiang about his current research and his continuing research plans. Here's what he had to say:

1) What sparked your interest in water resources research?

I chose hydrology for my undergraduate major and I became even more interested in water resources research when I worked on a reservoir project, which taught me that good water management is important for maintaining this important resource.

2) What do you find most interesting about water resources research, particularly working in an arid/semiarid environment such as Nevada?

What most fascinates me is how climate change could affect the redistribution of water. Whether there are changes in total precipitation or the precipitation pattern, the effects are critical to the hydrological cycle of arid environments such as Nevada.

3) What kinds of research are you currently working on and what have you learned so far from this research?

One focus of my research is to investigate how precipitation, particularly at the event scale, could be affected by anthropogenic activities and natural oscillations and how these changes could further affect water redistribution (such as changes in the soil moisture

component, snow pack, and surface runoff) in the arid Southwest. The study indicates that precipitation in the Las Vegas Valley will exhibit changes in precipitation patterns with shorter storm durations, longer interstorm periods, and higher storm intensities even if total precipitation decreases. These

changes in storm properties may have profound effects on surface water fluxes and solute transport.

4) What do you hope to learn more about from the research you are doing?

I would like to gain a better understanding of the physical theories of hydrology and be able to reduce the uncertainties of hydrological evaluations based on these theories.

5) Do you have a preference for lab work or field work, and if so, why?

I like field work, but most of my research is done in the lab because my work centers on program writing and modeling. I would prefer a good combination of both field and lab work.

6) What are some of your other research interests? Do you have any goals for incorporating those interests into your work as you continue in your career?



Changes in environment, ecology, and hydrology are connected, so one of my future research interests is to see how changes in hydrological processes could affect the ecology of our surrounding environment.

7) What is one of your favorite movies and why?

My favorite movie is *Forest Gump*: "Life is like a box of chocolates. You never know what you're gonna get." So, stick to what you want to do and try to do your best.

8) If you had six months with no obligations or financial constraints, what would you do with the time?

I would travel around the world and just enjoy new and beautiful natural environments without anything else on my mind. ■

"Changes in environment, ecology, and hydrology are connected, so one of my future research interests is to see how changes in hydrological processes could affect the ecology of our surrounding environment."

– Peng Jiang

NWRRI - Desert Research Institute

Success and the dedication to quality research have established the Division of Hydrologic Sciences (DHS) as the Nevada Water Resources Research Institute (NWRRI) under the Water Resources Research Act of 1984 (as amended). As the NWRRI, the continuing goals of DHS are to develop the water sciences knowledge and expertise that support Nevada's water needs, encourage our nation to manage water more responsibly, and train students to become productive professionals.

Desert Research Institute, the nonprofit research campus of the Nevada System of Higher Education, strives to be the world leader in environmental sciences through the application of knowledge and technologies to improve people's lives throughout Nevada and the world.



www.dri.edu/nwrri

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Banner photo: Wildflowers in Copper Basin, Nevada, by Famartin (Own work) [CC BY-SA 3.0 (<http://creativecommons.org/licenses/by-sa/3.0/>)], via Wikimedia Commons

Events, page 2: Paradise Valley wildflowers, Nevada, by Zack Sheppard from San Francisco, USA (Flickr Uploaded by PDTillman) [CC BY-SA 2.0 (<http://creativecommons.org/licenses/by-sa/2.0/>)], via Wikimedia Commons

Newsletter written and compiled by Nicole Damon



Project Spotlight: Theoretical Analysis of Optimal Groundwater Basin Development

Inside this issue:

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<i>Postdoc Interview</i>	4
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Responsible aquifer management requires an understanding of the interrelationships among inputs and outputs of water in the aquifer. The goal of this project is to develop a scaling analysis to estimate water table conditions for potential basin-wide water development. The results of the project will determine the conditions under which drastic drops in the water table can occur.

The main misconception about groundwater pumping is that as long as the amount of water pumped from a basin doesn't

exceed recharge from precipitation, the basin can be sustainably managed. "It would seem to make sense because the amount of water in the aquifer will increase over time if annual pumping is less than what is added through recharge," says Dr. Clay Cooper, who is the principal investigator for the project. "However, increasing the amount of water that is withdrawn can actually increase the amount of water available if recharge is induced from other sources of water on the land surface." Induced recharge pulls water from

RFPs

If you have questions about submitting a NWRRRI proposal, e-mail Amy Russell (Amy.Russell@dri.edu).

For current RFP information, visit the NWRRRI website (www.dri.edu/nwrrri).

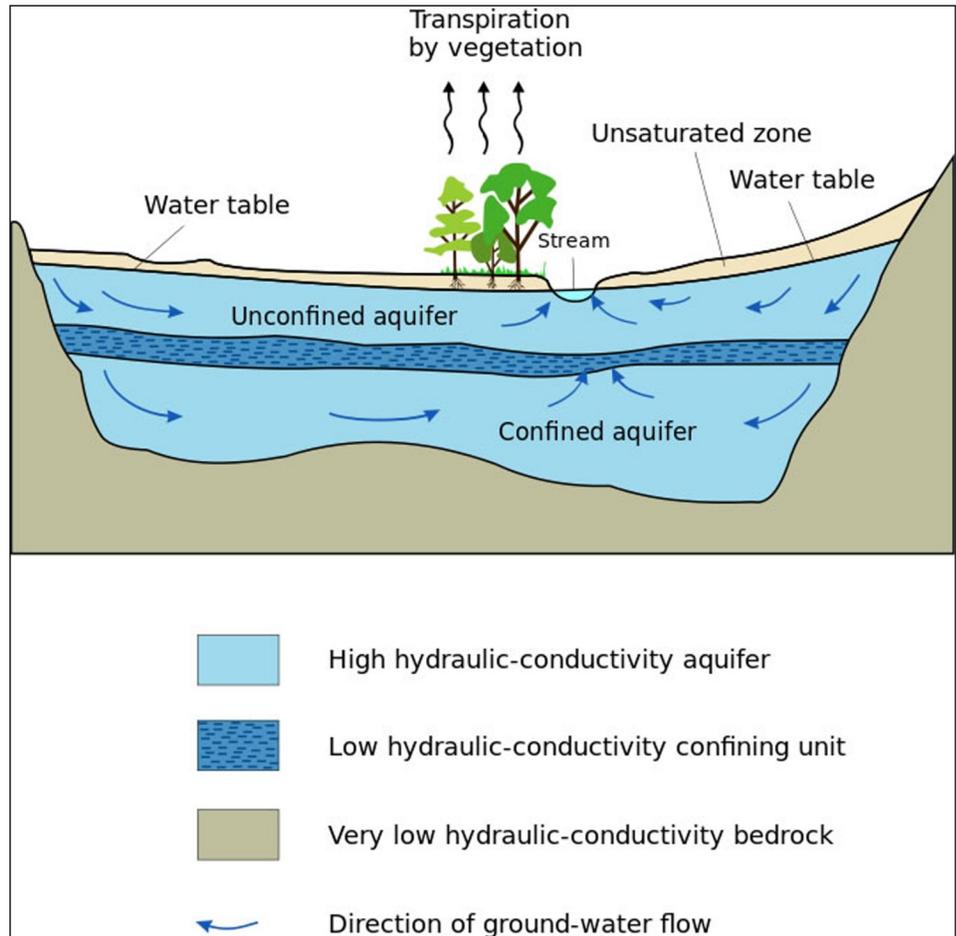


Because hydrologic systems connect groundwater and surface water, groundwater pumping can also affect available water in rivers, streams, and springs.

(Project Spotlight continued)

surrounding surface water resources. This means that even though it refills the aquifer, the surface water sources from which the water is withdrawn suffer. “Some aquifers can be pumped so much that water is eventually withdrawn from distant rivers, streams, and springs,” Cooper adds, “which can significantly affect valuable surface water resources, particularly in arid and semiarid regions.”

This project will evaluate what happens during groundwater withdrawal and how it affects the stability of groundwater basins. “Groundwater pumping lowers the water table in unconfined aquifers and drops the pressure in confined aquifers until a new steady state is reached, which stabilizes the water level or pressure in the aquifer,” Cooper explains. “This is how aquifers are supposed to function. However, my hypothesis is that under certain scenarios, excessive pumping can result in a drastic water table decline in unconfined aquifers, and this bifurcation in water level could result in groundwater mining.” Cooper developed the idea for this project based on papers by USGS hydrologists Charles Theis, John Bredehoeft, Leonard Konikow, and William Alley, as well as Allan Freeze from the University of British Columbia. The research conducted for this project will help determine the conditions



Cross section of a typical aquifer.

that might lead to significant bifurcating behavior or unstable groundwater levels.

This research is important for managing groundwater resources in Nevada because it will help water managers understand the available water in aquifers and how it interacts with surface water resources. “Overall, groundwater in Nevada is managed far better than

many other states and has been for over one hundred years,” Cooper explains. “However, the competing water needs for mining and irrigation, as well as municipal, industrial, and recreational uses make managing water resources a complex issue. I hope that this work results in an easy-to-use tool that can help with basin management.” ■

“Groundwater pumping lowers the water table in unconfined aquifers and drops the pressure in confined aquifers until a new steady state is reached, which stabilizes the water level or pressure in the aquifer. This is how aquifers are supposed to function.

However, my hypothesis is that under certain scenarios, excessive pumping can result in a drastic water table decline in unconfined aquifers, and this bifurcation in water level could result in groundwater mining.” – Clay Cooper

PI Spotlight: Dr. Clay Cooper

Dr. Clay Cooper first became interested in water resources research when he was studying geology for his bachelor's degree at Northern Arizona University in the 1970s. "At that time, geology was largely a descriptive science, with little understanding of the coupling and feedbacks of the different chemical, physical, and biological processes of an observed phenomenon," Cooper says. "For example, a geological engineer could estimate a rate of erosion from a hillslope, but that would have been largely intuitive or based on crude measurements. Hydrology seemed more quantitative and because I enjoyed math and physics, that's the field I decided to pursue in graduate school."

The interaction of time scales of different hydrologic processes in arid environments is one of the aspects of water resources research that Cooper finds particularly interesting. "Water residency times vary greatly. In the atmosphere, it is on the order of a few weeks and in streams it is days to months," Cooper explains. "In arid environments, the mean residence time of groundwater can be several tens of thousands of years compared with several thousand

years in oceans, which contain over 95 percent of Earth's water. So groundwater is a choke in the hydrologic cycle, but it is balanced out by the fluxes in and out of different reservoirs."

What Cooper finds most interesting about the research he is doing for the NIWR project "Theoretical Analysis of Optimal Groundwater Basin Development" is the qualitative study of differential equations. "I think this research is important and I will be interested to see what the peer response is so that I can improve on the methods I'm developing," he says. "I'm learning a lot as I make progress on this project." Another aspect of groundwater research that Cooper finds particularly fascinating is thermal and solute convection in porous media. "Our understanding of the processes controlling groundwater



convection in fractured, heterogeneous geothermal reservoirs is largely known through analytical and numerical studies," he says. "Very few laboratory experiments have been conducted and they have been mostly in uniform porous media."

When it comes to working in the lab or in the field, Cooper prefers lab work. "I have done quite a bit of field work in the past, but I like laboratory studies because they are largely underutilized in hydrology, especially in some of the areas in which I work," he says. "I believe pretty strongly that advances are

"I like laboratory studies because they are largely underutilized in hydrology, especially in some of the areas in which I work. I believe pretty strongly that advances are made through a combination of careful laboratory experiments, mathematical and numerical analysis, and field observations and measurements." – Clay Cooper

(PI Spotlight continued)

made through a combination of careful laboratory experiments, mathematical and numerical analysis, and field observations and measurements.”

In his spare time, Cooper likes to read popular science books and research monographs and

textbooks. “The book I’m currently reading is *Flow in Porous Rocks* by Andrew W. Woods,” he says. “I’m also reading *Barbarian Days: A Surfing Life* by William Finnegan. I’m not a surfer, but it’s a great read.” Outside of his research interests, Cooper is also a jazz drummer and enjoys making

chile relleno casserole, which is one of his favorite dishes to make. And for dessert, if he has a choice between cake or pie, there’s only one answer: “Warm strawberry rhubarb pie with ice cream,” he says. “Every time.” ■

Postdoc Interview: Xuelian Bai

We asked Maki Postdoctoral Fellow Dr. Xuelian Bai about her current research and her continuing research plans. Here’s what she had to say:

1) What sparked your interest in water resources research?

Environmental pollution is an important issue for both researchers and the public. Although many known and regulated contaminants have been widely studied, there are increasing concerns regarding emerging contaminants because their presence, transport, life cycles, and effects on humans and wildlife are largely unknown. I am interested in this type of research because I want to understand how emerging contaminants affect the environment. Human activities affect ecosystems and we are exposed to chemicals through water, air, soil, and food. The production and consumption of numerous chemicals might cause ecological risks and the continuous release and ubiquitous distribution of these chemicals could potentially affect human and wildlife health.

2) What do you find most interesting about water resources

research, particularly working in an arid/semiarid environment such as Nevada?

In an arid/semiarid area such as Nevada, water scarcity and water quality are significant issues. In southern Nevada, Lake Mead is both our major drinking water source and a reservoir for receiving wastewater discharge. The water quality in Lake Mead is a critical issue because we rely on it as a water source. Because Lake Mead is a receiving water body for treated wastewater, we want to ensure that the nutrients and regulated pollutants have been removed from the wastewater. We also need to evaluate untreated chemicals that could affect the water quality of the lake. This unique situation means

that the performance of wastewater treatment plants, the types and concentrations of untreated chemicals in wastewater discharge, and the life cycles of those chemicals in the ecosystem and their potential adverse effects on humans and wildlife are important research topics. These topics are also the ones I find most interesting.



(Continued on page 5)

(Postdoc Interview continued)

3) What research projects are you currently working on and what have you learned so far from your research?

I am currently working on the uptake of pharmaceutical and personal care products (PPCPs) by freshwater algae and quagga mussels from Lake Mead. Algae can play a major role in removing PPCPs in aquatic ecosystems. The advantage of this process is that algae can remove PPCPs or other organic chemicals from water bodies. The disadvantage of this process is that algae are the major food source for higher-trophic-level organisms, such as mussels and fish. Therefore, contaminants can be transferred through the food web and accumulate in aquatic organisms, which may cause adverse effects. Quagga mussels are a dominant invasive species in Lake Mead and my current research evaluates the role quagga mussels play in removing and accumulating PPCPs. Understanding these processes will help us evaluate the potential exposure routes and ecological effects associated with PPCPs so that we can make recommendations to regulators and agencies to mitigate the risks.

4) What do you hope to learn more about from the research you are doing?

My current research focuses on the uptake process of PPCPs by algae and mussels, including

sorption and degradation. I am interested in studying sources of emerging contaminants for the entire southern Nevada water system, including wastewater treatment facilities, urban runoff, the Las Vegas Wash, and Lake Mead. I am also interested in studying antibiotic resistance in the Las Vegas Wash and Lake Mead. Many types of antibiotics have been detected in the lake and wash, which makes potential antibiotic resistance in this aquatic ecosystem an important research topic.

5) Do you have a preference for lab work or field work, and if so, why?

The majority of my research is laboratory based, but it also includes some minor field work. We do field sampling for water and mussels from Lake Mead, and then we analyze the samples in the lab to find out the ambient concentrations of the contaminants in the environmental samples. Laboratory-based experiments under controlled conditions are preferable for understanding the mechanisms of fate and transport and the ecological impacts associated with the contaminants.

6) What are some of your other research interests? Do you have any goals for incorporating those interests into your work as you continue in your career?

My other research interests include industrial water quality

issues, such as cooling towers, as well as advanced water treatment technologies. I also have a background in soil science, so I'm interested in research topics related with soil quality and health. My long-term research interests are to understand fate and transport and the risks of contaminants in both aquatic and agroecosystems.

7) If you were shipwrecked on a deserted island, but all of your human needs (food, water, etc.) were taken care of, what two items would you want to have with you?

I'd want to have my Kindle with lots of books and a painting kit. I'd really enjoy having the time to read the books I have on my Kindle that I haven't had a chance to finish. I'd also want to have the time to learn how to paint. I bought a painting kit years ago, but haven't opened it yet.

8) If you had six months with no obligations or financial constraints, what would you do with the time?

I would learn how to scuba dive and surf. ■

“My other research interests include industrial water quality issues, such as cooling towers, as well as advanced water treatment technologies. I also have a background in soil science, so I'm interested in research topics related with soil quality and health. My long-term research interests are to understand fate and transport and the risks of contaminants in both aquatic and agroecosystems.” – Xuelian Bai

Upcoming Events

2016 AWRA Summer Conference:
GIS and Water Resources IX
July 11-13
Sacramento, CA
www.awra.org/meetings/Sacramento2016/

2016 Water Rights in Nevada
Seminar
July 12
Lovelock, NV
www.nvwra.org/2016-july-water-rights-seminar

2016 Advanced Water Rights in
Nevada Seminar
July 13
Lovelock, NV
www.nvwra.org/2016-july-advanced-water-rights-seminar

10th International Rangeland
Congress
July 16-22
Saskatoon, Saskatchewan, Canada
2016canada.rangelandcongress.org/#sthash.PsffxtKs.dpbs

8th International Acid Sulfate Soils
Conference
July 17-23
College Park, MD
www.midatlanticsoilscientists.org/acid-sulfate-soils-conference

3rd International Conference on
Hydropedology
August 16-19
Beijing, China
hydropedology2016.csp.escience.cn/dct/page/1

Marlette Lake Water System Tour
August 24
Marlette Lake, NV
www.nvwra.org/marllettelaketour2016

Connecting the Dots: Groundwater,
Surface Water, and Climate
Connections
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2016 GSA Annual Meeting
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Fall 2016 History of Water in
Nevada Event
October 24-25
Reno, NV
<http://www.nvwra.org/2016-water-history-event>

2016 Borehole Geophysical Logging
Workshop
October 26
Reno, NV
www.nvwra.org/2016borehole-geophysical-logging-workshop

Lithium Workshop
October 27
Reno, NV
www.nvwra.org/2016lithium-workshop

2016 Nevada Well Drilling
Regulations & Forms Class and
Water Well Drilling Exam Tutorial
October 27
www.nvwra.org/2016wellregs

ASA, CSSA, and SSSA: Resilience
Emerging from Scarcity and
Abundance
November 6-9
Phoenix, AZ
www.acsmeetings.org/about

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www.dri.edu/nwrri

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Page 1: Reese River near Austin, NV, by Famartin - Own work, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=34556137>

Page 2: Aquifer cross section by © Hans Hillewaert /, Public Domain, <https://commons.wikimedia.org/w/index.php?curid=2152154>

Events listing: Big Bend of the Colorado River courtesy of Nevada State Parks, parks.nv.gov

Newsletter written and compiled by Nicole Damon



Uptake of Pharmaceutical and Steroidal Compounds by Quagga Mussels in Lake Mead

Inside this issue:

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<i>Grad Student Interview</i>	5
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Lake Mead is the primary water source for the Las Vegas metropolitan area and a habitat for diverse wildlife, including endangered species such as the razorback sucker. Because Lake Mead continuously receives treated wastewater from the Las Vegas Wash, it's important to understand the prevalence of untreated emerging contaminants—such as pharmaceutical and personal care products and steroidal hormones—in the lake and their effects on wildlife.

This project will evaluate the uptake rates of select contaminants from pharmaceutical and personal care products in quagga mussels (*Dreissena bugensis*) to understand the effects of these contaminants on aquatic species in Lake Mead. Quagga mussels are an invasive species that have been spreading rapidly in the lake since they were first detected in 2007. The researchers will study a group of trace organic chemicals that includes antibiotics (azithromycin, ciprofloxacin, and sulfamethoxazole),

RFPs

If you have questions about submitting a NWRRRI proposal, e-mail Amy Russell (Amy.Russell@dri.edu).

For current RFP information, visit the NWRRRI website (www.dri.edu/nwrrri).



The Las Vegas Wash receives reclaimed water, shallow ground water, urban runoff, and storm water that then drain into Lake Mead.

(Project Spotlight continued)

antidepressants (fluoxetine, temazepam, and venlafaxine), an anticonvulsant (carbamazepine), and a steroidal hormone (estrone). “These trace organic chemicals represent highly prescribed and widely used pharmaceutical compounds and personal care products that are present in municipal wastewater, and many of them have been detected in fresh water and drinking water,” explains Dr. Xuelian Bai, one of the principal investigators of the project that also includes Dr. Kumud Acharya. “The target antidepressants have been reported at high accumulation rates in fish tissues, and carbamazepine and estrone have been found to cause adverse effects in aquatic species, even at trace levels.”

Concerns regarding pharmaceutical and steroidal compounds are increasing because of their ubiquitous presence in aquatic environments and the ecological risks they present for aquatic ecosystems such as Lake Mead. This project will provide insight into the exposure pathways of these chemicals and their effects on nontarget species to help develop ecological risk assessments. The researchers will evaluate the ambient concentrations and quagga mussel uptake rates of trace organics. Understanding the bioaccumulation of trace organic chemicals in quagga mussels will



Assessing the bioaccumulation of trace organics in quagga mussels will allow researchers to understand contaminant exposure routes in Lake Mead.

clarify their exposure routes in the Lake Mead ecosystem, either directly from water or by feeding on algae. “In an aquatic environment, mussels release pseudofeces that can be consumed by fish or other organisms in the benthic zone,” Bai says. “During this process, trace organic chemicals can be transferred via the food web and accumulate in higher-trophic-level organisms.”

The researchers will collect water and quagga mussels from Las Vegas Bay in Lake Mead, where treated wastewater enters the lake and is likely affected by the discharge, and the Lake Mead Marina, which is closer to Hoover dam and perhaps less affected by wastewater

discharge because of dilution and natural attenuation. They will then use liquid chromatography-tandem mass spectrometry to analyze the water and mussel samples for the target contaminants and assess the doses that the mussels are exposed to in Lake Mead. A series of bench-scale experiments will also be conducted to evaluate the bioaccumulation of the contaminants in the mussels to understand if they uptake contaminants directly from the water or by consuming algae. “To date, most research has been focused on the uptake of trace organic chemicals by aquatic organisms at higher trophic levels, such as fish,” Bai explains. “Currently, there is little information about the uptake

“This research will provide vital information about the bioaccumulation of trace organic chemicals in the food web of the Lake Mead ecosystem and the effects of trace organic chemicals on nontarget species.” – Xuelian Bai

(Project Spotlight continued)

of trace organics by lower-trophic-level organisms, such as phytoplankton and zooplankton, which are food for higher-trophic level organisms. The role that quagga mussels play in the fate and persistence of trace organic chemicals in the aquatic environment is also still unclear. This research will provide vital information about the bioaccumulation of trace organic chemicals in the food web of the

Lake Mead ecosystem and the effects of trace organic chemicals on nontarget species.”

Lake Mead is not only the primary water supply reservoir for the Las Vegas metropolitan area, but it is also a receiving water body for four major wastewater treatment plants. Because southern Nevada is an arid/semiarid region, water quality is a significant issue. Understanding the presence and effects of emerging contaminants

in this water source is a critical issue for both regulators and the public. Bai adds, “This project will also provide useful information for ecological risk assessments and recommendations for improving wastewater treatment technology, such as advanced treatments to reduce or eliminate trace organic chemicals in treated wastewater to protect aquatic ecosystems.” ■

Postdoc Interview: Hai Pham

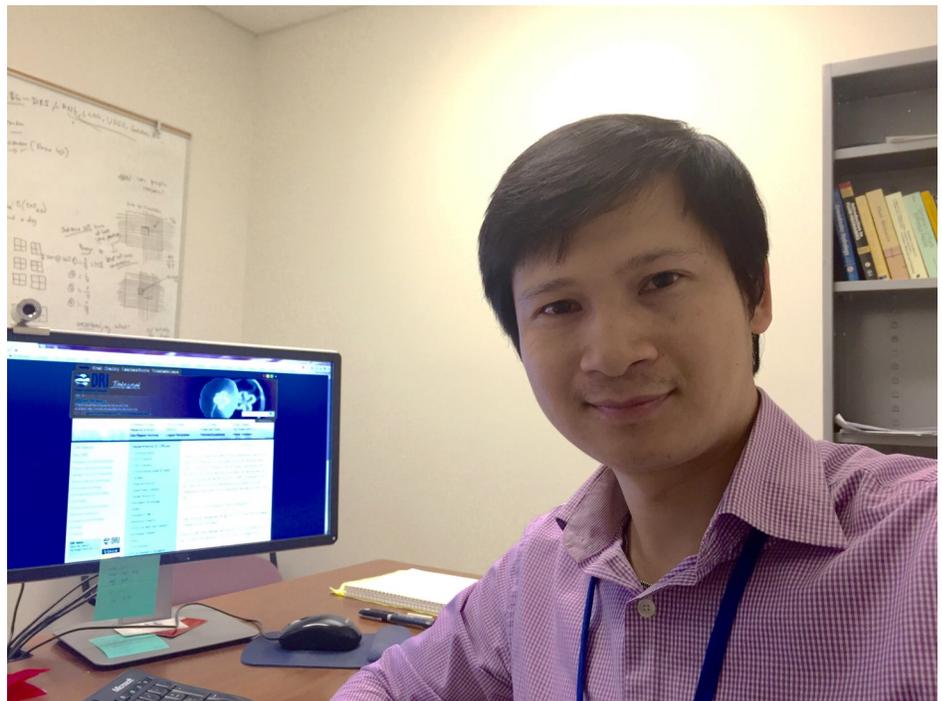
We asked Postdoctoral Fellow Dr. Hai Pham about his current research and his continuing research plans. Here’s what he had to say:

1) What do you find most interesting about water resources research, particularly working in an arid/semiarid environment such as Nevada?

In arid/semiarid regions such as Nevada—where rainfall is scarce and surface water is not available and/or of poor quality—groundwater plays an important role in socioeconomic development. Nevada is facing major groundwater issues, such as groundwater availability, natural and artificial groundwater recharge, and underground storage of hazardous wastes. My research goal is to find new ways to model the Nevada groundwater systems to protect, restore, and promote sustainable groundwater use.

2) What kinds of research are you currently working on and what have you learned so far from this research?

One of my primary focuses is to study fluid flow and contaminant characteristics in fractured rock.



This is a crucial part of long-term storage of radioactive waste in subsurface repositories. In fractured rock, fracture networks are typically the main pathways for flow and contaminant transport. Discrete fracture network (DFN) modeling is one of the most powerful numerical modeling approaches, but 3-D DFN model simulations are challenging because

fractured rocks are difficult to characterize and these simulations create a high computational burden. I am working to construct 3-D DFN models and run them in a high-performance system. The ultimate goal of this study is to investigate transport characteristics in the 3-D DFN under various uncertainties.

(Continued on next page)

(Postdoc Interview continued)

3) What do you hope to learn more about from the research you are doing?

I would like to gain a better understanding of fluid flow and contaminant characteristics using 3-D DFN models. This is different from previous studies that use 2-D DFN models or different modeling approaches (e.g., the equivalent continuum model or dual-continuum model). The flow and transport characteristics of 3-D stochastic DFN models could also help develop upscaling methods for fractured systems and incorporate upscaling methods into studies of flow and contaminant characteristics.

4) Do you have a preference for lab work or fieldwork, and if so, why?

I prefer fieldwork because I like to be outside. Unfortunately, the majority of my research is laboratory based. I spend most of my time developing and configuring numerical models, writing computer programs and scripts, conceptualizing and developing research proposals, and preparing technical reports and peer-reviewed journal articles. If possible, I would prefer a good balance of fieldwork and lab work.

5) What are some of your other research interests? Do you have any goals for incorporating those interests into your work as you continue in your career?

A lack of hydrogeological data leads to uncertainty in numerical modeling, and many conceptualizations have been proposed to represent uncertainty in model components. Once I've constructed the 3-D DFN models, I will use them to study how conceptual and parametric uncertainties influence transport behavior in 3-D DFNs. I will conduct spatial and temporal analyses of the contaminant plumes to compute the influence of uncertainty on transport behavior. The flow and transport characteristics of 3-D stochastic DFNs under uncertainty will help lay the groundwork for model development and analysis of field-scale fractured rock systems.

6) If you could go on vacation anywhere in the world, where would you want to go, why would you want to go there, and what would you want to do there?

If I could take a vacation anywhere, I would want to take a trip that would allow me to visit

most of the countries in Europe. I'd really enjoy discovering famous architectural and historical areas, and sampling the delicious cuisine and beer. I'd also like to watch a Chelsea game, which is my favorite soccer team.

7) If you were shipwrecked on a deserted island, but all of your human needs (food, water, etc.) were taken care of, what two items would you want to have with you?

A laptop connected to the internet and a solar-powered generator.

8) If you had six months with no obligations or financial constraints, what would you do with the time?

I would love to spend time playing with my two sons and travel around the world with my family.

9) Cake or Pie?

Neither of them; I don't like sweets. ■

“Nevada is facing major groundwater issues, such as groundwater availability, natural and artificial groundwater recharge, and underground storage of hazardous wastes. My research goal is to find new ways to model the Nevada groundwater systems to protect, restore, and promote sustainable groundwater use.” – Hai Pham

Grad Student Interview: Crystal DuBose

We asked graduate student Crystal DuBose about her current studies and her plans for the future. Here's what she had to say:

1) What field are you currently studying and what sparked your interest in that field?

I am currently studying hydrogeology for my master's degree. The extreme nature of floods, hurricanes, and droughts and the processes that generate such environmental hazards sparked my curiosity in hydrology. I chose hydrogeology for my master's because I like that it provides a more mathematical approach for solving water related issues.

2) What research project are you currently working on and what research are you doing?

The research project I'm working on is titled "Estimating Future Flood Frequency for Regions in the Southwest." The goal of this project is to try to predict how often it will flood in the future (i.e., for the time period 2041-2070) because of climate change. To accomplish this task, we are developing a simple yet effective statistical model that correlates extreme precipitation events with flood frequency events. Currently,

we are looking at the Virgin River watershed, but we hope to apply this model to other Southwestern locations—such as the Colorado River Basin and southern Nevada—where flash flooding is a recurring issue.

3) What have you learned from working on this project?

I have learned more about the statistical methods used when developing a design storm and performing a regional frequency analysis, such as distribution type, exceedance probability, return periods, and hypothesis testing. Furthermore, analyzing hydrological time series in a high temporal resolution required me to learn programming languages such as C++ and Python.

4) What have you enjoyed most about working on this project?

Working as a team to solve future flooding issues is what



makes this project most enjoyable. It's gratifying to know our research will potentially be beneficial to the hydrologic community and possibly affect the decisions agencies and water managers make to properly prepare for future flooding events.

5) What are your goals for the next step in your career?

I hope that eventually I will get a job with the Southern Nevada Water Authority, National Water Resources Association, or USGS. ■

"Working as a team to solve future flooding issues is what makes this project most enjoyable. It's gratifying to know our research will potentially be beneficial to the hydrologic community and possibly affect the decisions agencies and water managers make to properly prepare for future flooding events." – Crystal DuBose

Upcoming Events

2016 GSA Annual Meeting
September 25-28
Denver, CO
community.geosociety.org/gsa2016/home

Fall 2016 History of Water in Nevada Event
October 24-25
Reno, NV
www.nvwra.org/2016-water-history-event

2016 Borehole Geophysical Logging
Workshop
October 26
Reno, NV
www.nvwra.org/2016borehole-geophysical-logging-workshop

Lithium Workshop
October 27
Reno, NV
www.nvwra.org/2016lithium-workshop

2016 Nevada Well Drilling Regulations &
Forms Class and Water Well Drilling Exam
Tutorial
October 27
Reno, NV
www.nvwra.org/2016wellregs

ASA, CSSA, and SSSA: Resilience Emerging
from Scarcity and Abundance
November 6-9
Phoenix, AZ
www.acsmeetings.org/

Desert Terminus Lakes Symposium
November 9-10
Reno, NV
greatbasinresearch.com/walker/symposium/

2016 AWRA Annual Conference
November 13-17
Orlando, FL
www.awra.org/meetings/Orlando2016/

Groundwater Week
December 6-8
Las Vegas, NV
groundwaterweek.com/



AGU Fall Meeting 2016
December 12-16
San Francisco, CA
fallmeeting.agu.org/2016/

AGU Chapman Conference: Extreme Climate Event
Impacts on Aquatic Biogeochemical Cycles and
Fluxes
January 22-27, 2017
San Juan, Puerto Rico
chapman.agu.org/extremeclimate/

Water Rights in Nevada Class
February 13, 2017
Reno, NV
www.nvwra.org/2017-water-rights-seminar

2017 Mine Water Management Symposium
February 13-14, 2017
Reno, NV
www.nvwra.org/2017-symposium

Advanced Water Rights in Nevada Class
February 14, 2017
Reno, NV
www.nvwra.org/2017-adv-water-rights-seminar

2017 NWRA Annual Conference
February 14-16, 2017
Reno, NV
www.nvwra.org/2017-annual-conference-program

NWRRI - Desert Research Institute

Success and the dedication to quality research have established the Division of Hydrologic Sciences (DHS) as the Nevada Water Resources Research Institute (NWRRI) under the Water Resources Research Act of 1984 (as amended). As the NWRRI, the continuing goals of DHS are to develop the water sciences knowledge and expertise that support Nevada's water needs, encourage our nation to manage water more responsibly, and train students to become productive professionals.

Desert Research Institute, the nonprofit research campus of the Nevada System of Higher Education, strives to be the world leader in environmental sciences through the application of knowledge and technologies to improve people's lives throughout Nevada and the world.



www.dri.edu/nwrri

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Banner photo: Aspens during autumn in Lamoille Canyon, Nevada, by Famartin - Own work, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=28885229>

Page 1: Lower Las Vegas Wash near its drainage into Lake Mead by Stan Shebs, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=6310546>

Page 2: *Dreissena bugensis*, courtesy of the U.S. Geological Survey, http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/quagga_gallery.aspx

Events listing: Petroglyphs in Valley of Fire State Park, Nevada, by Clément Bardot - Own work, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=25863791>

Newsletter written and compiled by Nicole Damon



Assessing Tree-to-grass Water-use Ratios: Significance to Urban Water Conservation

Inside this issue:

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The effects of climate change and the increase of extended droughts make meeting water demands in the arid West a challenge. Because of these factors and rapidly growing populations, understanding water use in urban environments is critical for water conservations efforts. In particular, being able to estimate the amount of water used

specifically for landscaping is crucial for understanding urban water use. “Urban landscapes in Las Vegas use approximately 40 percent of the total water used annually,” says Dr. Dale Devitt, the principal investigator for the project that also includes graduate researcher Tamara Wynne. “Although turfgrass has been demonstrated to be a high water user, many trees can also

RFPs

If you have questions about submitting a NWRRRI proposal, e-mail Amy Russell (Amy.Russell@dri.edu).

For current RFP information, visit the NWRRRI website (www.dri.edu/nwrrri).



The Acacia Demonstration Gardens in Henderson, Nevada, shows examples of water-efficient landscaping combinations for the arid Nevada climate.

(Project Spotlight continued)

use significant amounts of water. In fact, trees use larger amounts under more favorable conditions, such as irrigated landscapes.”

Quantifying tree and turfgrass water-use rates for landscaping in urban environments is vital for conserving Nevada’s precious water resources. All plants require water, but it’s important to know the water usage of different landscaping covers to make sure that water resources are being allocated correctly. Even xeric landscape designs can use more water as the trees mature, and therefore their water-saving benefits could decrease over time. The researchers of this project will evaluate the water-use rates of mature landscape trees growing in an arid environment, the water-use rates of these trees relative to the morphological parameters to scale the data to other locations, the trade-offs between different tree species, tree-to-grass water-use ratio estimates for younger and mature trees, water-use rates under experimental and field conditions, and the effects of water use by trees on turfgrass.

This project will quantify tree-to-grass water-use rates to show the trade-offs between using turfgrass and trees. “Natural



The water-use rates of trees can change as they mature, so it is important to understand those changes to create the most water-efficient tree and grass landscape combinations.

trade-offs exist between vegetation types in terms of water use,” explains Devitt. “Low-water-use landscapes can be comprised of a mix of grass and tree species, such as high-water-use turfgrass and low-water-use trees or low-water-use turfgrass and high-water-use trees.” Understanding the water-use rates of turfgrass and maturing trees will provide insight into these trade-offs that landscape architects, golf course and park superintendents, homeowners, horticulturalists, and water managers can then use to design and maintain water-efficient landscapes. “We will

use a hydrologic balance approach by estimating soil water storage using soil moisture sensors and irrigation based on evapotranspiration feedback to minimize drainage,” continues Devitt. “Simultaneously, we will also use Granier’s thermal dissipation probes to assess transpiration velocity within the trees by relying on a dye injection system to assess the conductive tissue.”

An experimental plot of landscape trees planted in 1998 at the Center for Urban Horticulture and Water Conservation at the University of Nevada, Las Vegas, will be

“Natural trade-offs exist between vegetation types in terms of water use. Low-water-use landscapes can be comprised of a mix of grass and tree species, such as high-water-use turfgrass and low-water-use trees or low-water-use turfgrass and high-water-use trees.” – Dale Devitt

(Project Spotlight continued)

used to assess the water-use rates of mature tree species that are commonly planted in the arid Southwest. The researchers have also planted turfgrass in nonweighing lysimeters to estimate the water-use rates of commonly planted turfgrass

species. “We selected ten urban landscape tree species and four turfgrass species,” says Devitt. “This will allow us to make 40 different tree-to-grass water-use comparisons over the two-year experimental period.” The results of this study will benefit

Nevada and other arid regions in the Southwest by providing solutions for beautiful, water-saving landscape combinations that use diverse plant species. ■

PI Spotlight: Dr. Dale Devitt



Dr. Dale Devitt’s career at University of Nevada, Las Vegas, has given him an in-depth understanding of the critical water issues that affect southern Nevada. “I have been at the university for over 30 years and have watched the population in the Las Vegas community increase fourfold,” says Devitt. “We are 90 percent dependent on

the Colorado River and many models suggest that flow reductions associated with climate change may be significant over the next 20 to 30 years.”

Because a significant amount of the water used in the Las Vegas metropolitan area is used outdoors to irrigate urban landscapes, finding solutions for water-efficient landscaping is important for conserving valuable water resources and meeting increasing water demands over the long term. It is the fact that water resources research is directly applicable to daily life, especially in arid and semiarid environments such as Nevada, that Devitt appreciates most about his work for NIWR. “The research I’m doing for NIWR has real applied significance that can be easily translated into water savings in the urban landscape,” he

explains, “and the results directly benefit end users.”

In addition to his NIWR research, Devitt is also researching the effects of climate change, such as the hydrologic and ecological connectivity in mountain valley systems, the response of phreatophytes (deep-rooted shrubs) to groundwater oscillations, the environmental impacts of large utility-scale solar facilities on desert ecosystems, and the use of treated sewage effluent as an alternative irrigation source.

When asked what he would want to have with him if he was stranded on a desert island, Devitt answered that he’d want to have a telescope and a surfboard. And when it comes to dessert, if he had to pick between cake or pie, his choice would be: “Loganberry pie straight from the oven with a scoop of vanilla ice cream.” ■

“The research I’m doing for NIWR has real applied significance that can be easily translated into water savings in the urban landscape and the results directly benefit end users.” – Dale Devitt

Grad Student Interview: Tamara Wynne

We asked graduate student Tamara Wynne about her current studies and her plans for the future. Here's what she had to say:

1) What field are you currently studying and what sparked your interest in that field?

I am currently studying botany. I've always loved nature and the outdoors. I took a botany class in high school here in Las Vegas, and that's what sparked my interest. I graduated from Cornell University in New York with my bachelor's degree in plant science, which is what fueled my passion for plants.

2) What research project are you currently working on and what research are you doing?

I am currently working on the project "Assessing Tree-to-grass Water-use Ratios: Significance to Urban Water Conservation." Professor Dale Devitt of the University of Nevada, Las Vegas, and I are studying the amount of water that is used by landscape trees versus landscape grasses. We have ten different species of trees and four different species of grasses that I carefully monitor. Fortunately, we were able to purchase Granier probes to measure the amount of sap flow in the trunk of the trees and a three-foot-long moisture probe to

measure the soil moisture at six depths.

3) What have you learned from working on this project?

I am continually learning something new as I work on this project. Currently, we are studying how the xylem tissue exhibits active and inactive functions that are intermingled in the wood of the tree. Measuring the soil moisture around the trees has taught me about the relationship between evapotranspiration and soil water content. I have also observed interesting water-use trends by studying the grasses. So far, I have seen how some grasses, such as fescue, use much more water than Bermuda grass.

4) What have you enjoyed most about working on this project?

My dad volunteers at the orchard where I do my research, so it's great being able to work



with him almost every day. I really value our time together learning about the trees, and life. I also enjoy working with Dr. Devitt, particularly because of his kindness and what he teaches me about the value of research and hard work. And lastly, I love being outside working with plants, so that's another great aspect of working on this project.

5) What are your goals for the next step in your career?

I hope to continue teaching and researching. I love the idea of doing experiments and leading

"Caring for the environment and working to conserve our natural resources ranks very high on my priority list." – Tamara Wynne

(Grad Student Interview continued)

classes, especially because I enjoy doing both. Also, caring for the environment and working to conserve our natural resources ranks very high on my priority list.

6) If you could go on vacation anywhere in the world, where would you want to go, why would you want to go there,

and what would you want to do there?

A vacation to Israel would be so cool! Israel has so many cool things related with water resources research, such as desert soil research and desert fruit orchards. It's also the Holy Land, so there would be a lot of neat places to see. I would love to

collaborate with the scientists there and see all the landmarks.

7) Cake or Pie?

Pie, especially my mom's apple pie. ■

Upcoming Events

AGU Chapman Conference: Extreme Climate Event Impacts on Aquatic Biogeochemical Cycles and Fluxes
January 22-27, 2017
San Juan, Puerto Rico
chapman.agu.org/extremeclimate/

Water Rights in Nevada Workshops
February 13-14, 2017
Reno, NV
www.nvwra.org/2017-water-rights-seminar

2017 Mine Water Management Symposium
February 13-14, 2017
Reno, NV
www.nvwra.org/2017-symposium

2017 NWRRA Annual Conference
February 14-16, 2017
Reno, NV
www.nvwra.org/2017-annual-conference-program

Geotechnical Frontiers
March 12-15, 2017
Orlando, FL
geotechnicalfrontiers.com

2017 AWRA Spring Specialty Conference
Connecting the Dots: The Emerging Science of Aquatic System Connectivity
April 30-May 3, 2017
Snowbird, UT
www.awra.org/meetings/Snowbird2017/

2017 GSA Cordilleran Section: 113th Annual Meeting
May 23-25, 2017
Honolulu, Hawai'i
www.geosociety.org/Sections/cord/2017mtg/

3rd North American Symposium on Landslides
June 4-8, 2017
Roanoke, VA
www.aegweb.org/mpage/nasl17m

2017 AWRA Summer Specialty Conference
Climate Change Solutions: Collaborative Science, Policy, and Management for Sustainable Water Management
June 25-28, 2017
Tysons, VA
www.awra.org/meetings/Tysons2017/

GSA 2017
October 22-25
Seattle, WA
www.geosociety.org/meetings/2017/

2017 Annual AWRA Conference
November 5-9, 2017
Portland, OR
www.awra.org/meetings/Portland2017/

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Banner photo: Wheeler Peak in Nevada (looking east-southeast) by DrunkDriver - Own work, Public Domain, <https://commons.wikimedia.org/w/index.php?curid=9879374>

Page 1: Plants at the Acacia Demonstration Gardens by DavidGrayson (Own work) [Public domain], via Wikimedia Commons

Page 2: Trees and grass in Las Vegas, Nevada, area by Rmvisuals (Own work) [CC BY-SA 4.0 (<http://creativecommons.org/licenses/by-sa/4.0>)], via Wikimedia Commons

Newsletter written and compiled by Nicole Damon

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	1	0	0	0	1
Masters	2	0	0	0	2
Ph.D.	1	0	0	0	1
Post-Doc.	1	0	0	0	1
Total	5	0	0	0	5

Notable Awards and Achievements

None to report.