Conference Proceedings

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Water is Not for Gambling: Utilizing Science to Reduce Uncertainty



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Covered agriculture for coping with climate and water availability uncertainty: A broad-brush assessment

C. Robert Taylor, Auburn University
(co-authors: R. Rodriguez-Kabana, R. Lacewell)

Production of high value vegetable crops and some fruit crops in greenhouses and hoop houses is expanding rapidly in many parts of the world, particularly where extensive acreage of high quality land is not available. World acreage of covered vegetable production now exceeds a million acres, with over 300,000 acres in Europe. Over 900 acres of hydroponic (without soil) tomatoes are grown in the U.S. Some of these covered production systems are nothing more that industrial farming on an intense, horizontal scale. Some covered systems may be sustainable. Most are located on the fringe of urban areas and are high value fruits and vegetables. This production system can be expected to increase dramatically with the projections of increases in the population of the earth and emphasis on addressing the food, energy and water nexus. A broad-brush assessment of the potential for covered agriculture to cope with climate and weather uncertainty, and water consumption will be discussed.

Bio: Dr. Taylor is ALFA Eminent Scholar (Distinguished University Professor) in Agricultural and Public Policy since 1988. He is also Senior Economics Fellow, Organization for Competitive Markets (OCM), Past Co-recipient of the Award for the Outstanding Article in the Journal of Agricultural and Applied Economics and Co-recipient of American Agricultural Economics Association Award for Quality of Research Communication. His research has focussed on policy issues ranging from competition, bioenergy, water and other. Dr. Taylor has a long list of awards and recognition, publications and presentations.

The impact of the feed grains industry in the Southern Ogallala Region

Bridget Guerrero, West Texas A&M University
(co-authors: S. Amosson, H. Graham)

Feed grain production has been a part of agricultural operations since the first pioneers settled the Southern Ogallala Region. Production increased substantially in the 1940s with the discovery of groundwater supplies and the development of irrigation equipment, allowing cropland to be irrigated in the semiarid region. The availability of feed grains, in turn, led to the development of confined livestock feeding operations. There are approximately 6.3 million acres of feed grains and 510,000 acres of silage production in the region. The primary water source is the Ogallala Aquifer, which is declining as withdrawals largely exceed recharge. Irrigated feed grain production on approximately 3.5 million acres has led to this industry being the largest single user of water from the region. The industry's demand for water has local leaders concerned about whether feed grain production in the region is an appropriate use of scarce water resources. This study evaluates the feed grain industry in terms of water use and its contribution to the regional economy. Results indicate that total water use for the feed grain industry was approximately 3.9 million acre-feet. The feed grain industry, including production and processing sectors, generates $9.4 billion in annual economic output and 47,500 jobs. Feed grain production accounts for $5.3 billion of the total, supporting 31,000 jobs. Feed grains generate $1,225 per acre-foot of water when considering only the impacts of production, or $2,201 per acre-foot of water use with both the production and processing sectors included. Producers continue to adopt conservation tillage methods, more efficient delivery systems, irrigation scheduling to optimize water application, and better varieties to improve water-use efficiency. While it is expected that irrigated feed grain acreage will gradually shift to dryland as a result of aquifer depletion, production may be stable to increasing as productivity per acre-inch of water improves.

Bio: Bridget Guerrero received a Bachelor of Science in Agribusiness in 2002 and a Master of Business Administration in 2003 from West Texas A&M University. She earned her doctoral degree in Agricultural and Applied Economics from Texas Tech University in 2010. Dr. Guerrero worked with the Texas A&M AgriLife Extension Service for 10 years before taking a position as an Assistant Professor with West Texas A&M University.

Optimal regional regulation of animal waste

Antti Iho, MTT Economic Research
(co-authors: *D. Parker, D. Zilberman)
*Presenter - Doug Parker, California Institute for Water Resources, University of California

Large animal facilities generate more manure than needed on their own feed production areas. Excessive nutrient applications deteriorate groundwater (nitrogen) and surface water quality (nitrogen and/or phosphorus). Livestock production is the main source of man-made nutrient loads to environment. Due to differences in environmental and economic characteristics, adjacent regions may have differing objectives for nitrogen and phosphorus abatement. Environmental regulation of animal agriculture is focused on nutrient surpluses, though typically on either nitrogen or phosphorus. We postulate an analytical model of upstream agricultural and downstream recreational regions and analyze optimal policies from the perspectives of agricultural region and of both regions. We show that, depending on the environmental and economic characteristics, tightening upstream regulation with respect to the loading of one nutrient might increase the downstream loading of the other. Our model contributes to the literature by (1) differentiating the impacts of manure regulation between the livestock farms and the adjacent crop production farms, (2) showing how this differentiation impacts the relative and absolute amounts of nitrogen and phosphorus loading due to changes in nutrient application and uptake as well as changes in application areas, (3) allowing for regional differences in abatement objectives, and (4) identifying policies that are optimal locally and globally.

Bio: Doug Parker is the Director of the California Institute for Water Resources and Strategic Initiative Leader for UC Agriculture and Natural Resources' Water Quality, Quantity, and Security Strategic Initiative. He coordinates water-related research, extension, and education efforts across the 10 UC campuses, the UC ANR system, and other academic institutions within California. Prior to joining the University of California, Doug worked on water quality issues related to the Chesapeake Bay as an Associate Professor and Extension Specialist in the Department of Agricultural and Resource Economics at the University of Maryland. He has also worked on issues related to California water as a Cooperative Extension Economist at UC Berkeley. Doug obtained his Ph.D. in Agricultural and Resource Economics at UC Berkeley and Bachelor's Degrees in Economics and Environmental Studies at UC Santa Barbara.

The Central Arizona Groundwater Replenishment District/Yuma Mesa Irrigation and Drainage District Pilot Rotational Fallowing Program

Perri Benemelis, Central Arizona Groundwater Replenishment District

The Central Arizona Groundwater Replenishment District ("CAGRD") and Yuma Mesa Irrigation and Drainage District ("YMIDD") have developed a Pilot Rotational Fallowing Program ("Pilot Program"). Implementation began in January 2014 and the program will continue at least through 2016. Participating landowners within YMIDD have fallowed "Qualified Land." YMIDD does not divert Colorado River water that otherwise would have been used to irrigate the fallowed land, and the "conserved" Colorado River water remains in Lake Mead to help minimize or avoid shortages to water users in Arizona and the Lower Basin. The purpose of the Pilot Program is to 1) generate data that will be used to quantify the water savings associated with the forgone irrigation water use and 2) provide information about how to best structure a program of this type. Information from the Pilot Program will inform future decisions regarding a longer-term rotational fallowing program to generate a water supply for CAGRD. Only Qualified Land may be enrolled in the Pilot Program, which means the land produced crops in four out of the last five years (2009 through 2013) is at least five contiguous acres in size and would have been irrigated for the production of crops if it weren't enrolled in the Pilot Program. Total Pilot Program acreage is approximately 1,400 acres; less than 10% of the current irrigated acreage within YMIDD. The Pilot Program provides a stable revenue stream for YMIDD farmers, has a limited impact on current farming operations, avoids permanent loss of productive agricultural land, minimizes any adverse local economic impacts and serves an agronomic benefit by allowing a longer rest-rotation for some lands.

Bio: Perri Benemelis is the manager of the Central Arizona Groundwater Replenishment District Water Supply Program. The Water Supply Program is responsible for acquiring water supplies to replenish groundwater pumping by its member lands and service areas. Ms. Benemelis has over 20 years of water resources experience with a focus on Colorado River operations.

The Center for Great Lakes Literacy: promoting informed community engagement in Great Lakes issues

Marti Martz, Pennsylvania Sea Grant

The Center for Great Lakes Literacy, (CGLL), is a partnership of seven Great Lakes Sea Grant programs and EPA's Great Lakes Network Program Office (GLNPO). Its mission is to provide hands-on experiences, professional development, educational resources, and networking opportunities that promote Great Lakes literacy among an engaged community of educators, scientists, students and citizens to foster informed and responsible decisions that advance basin-wide stewardship. By working with these audiences from around the Great Lakes basin, CGLL acts as a conduit of science-based information on Great Lakes issues between the lab and the classroom or meeting room. It engages people in service-learning and stewardship efforts, fostering a sense of place and Great Lakes Literacy in participating educators, citizens, and students in grades 5-12 who will become future leaders in science, business, government, education and other fields. Coordinating Great Lakes educational efforts among 5 Great Lakes, 7 Sea Grant programs, and 8 states bordering 10,000 miles of shoreline that is home to more than 25% of the U.S. population takes teamwork. In NOAA's 2013 Education Partnership Portfolio Review, CGLL was recognized as a "high return partnership" in which "benefits to NOAA outweighed the investment and involvement for all parties involved". This presentation will share examples of best practices for developing a community of practice among educators and researchers and will highlight the benefits of place-based education in developing a stewardship ethic in students and citizens.

Bio: Marti Martz, Senior Coastal Outreach Specialist, joined PASG in 2005. She develops and implements education and outreach programming on a variety of topics including professional development for Great Lakes basin educators; student-driven watershed focused service learning projects; impacts of Pharmaceuticals and Personal Care Product chemicals on water quality; Harmful Algal Blooms; shoreline bluff erosion; terrestrial invasive species removal; and propagation of rare, threatened and endangered plant species. Martz has twice been awarded the Outstanding Program Award from the Great Lakes Sea Grant Network, in 2012 and 2014.

Lawn to Lake

Adrienne Gulley, Illinois-Indiana Sea Grant College Program

The Great Lakes are a globally important natural resource. They represent approximately 20 percent of the world's fresh surface water and provide habitat for over 100 species of globally rare plants and animals. Lawn to Lake is a collaborative program promoting healthy lawn and landscape practices to protect water resources in the Great Lakes region. Lawn to Lake is an outreach and training program delivered in the Lake Michigan Basin to protect water in the Great lakes by facilitating a switch to landscape practices that reduce pollution. With funding from the Great Lakes Restoration Initiative, the partners coordinate a prevention campaign that addresses the needs of landscapers, municipalities, and homeowners. Programs include: Natural Lawn Care 101 – Information and guidelines for homeowners on how to care for their lawns without compromising water quality. Retailers: Growing Naturally – Directory of stores that carry natural lawn care products. Professional Workshops – Lawn to Lake training opportunities including natural lawn care workshops for schools, childcare centers and professional landscapers. Master Gardeners and Teachers – Lawn to Lake has joined with University of Illinois Extension's Master Gardener and Master Naturalist programs to provide sustainable lawn and landscape information as part of the continuing training requirement for Master Gardener/Naturalist certification. Lawn to Lake has provided training on water smart landscaping and sustainable lawn care practices to almost 300 Master Gardeners. The recent transition of Lawn to Lake to the pollution prevention program enables the program to expand to a greater area than in previous years.

Bio: Adrienne Gulley is the Illinois-Indiana Sea Grant pollution prevention outreach specialist located on the campus of the University of Illinois at Urbana-Champaign. She manages the Lawn to Lake program and also collaborates with communities and police departments to educate and coordinate single-day and permanent medicine take-back programs. Adrienne creates video segments to assist communities in learning about PPCPs. Adrienne has a bachelor's degree in English and a master's degree in agricultural communications from Southern Illinois University Carbondale. She joined Sea Grant in the summer of 2014 from an academic advising position at her alma mater, Southern Illinois University Carbondale.

Protecting water resources through education and outreach about pharmaceuticals, personal care products, and other emerging contaminants

Laura Kammin, Illinois-Indiana Sea Grant College Program

Illinois-Indiana Sea Grant's (IISG) pollution prevention program works to increase knowledge of emerging contaminants in the environment, specifically pharmaceuticals and personal care products (PPCPs). To adequately manage water resources, people need to understand the sources, transport, fate, and potential impacts of PPCPs on human, animal, and environmental health. IISG takes a multi-pronged approach to reducing the load of PPCPs reaching waterways through: 1) funding and conducting research, 2) developing education and outreach programs, 3) communicating through social media, and 4) building partnerships. IISG has developed a series of toolkits and regional and national initiatives to help communities and individuals properly use, store, and dispose of PPCPs. Part of that effort focuses on microbeads found in many personal care products, such as facial and body washes and toothpastes. While the effects of plastic contamination in the oceans are well documented, researchers only began searching for microplastics in the Great Lakes in 2012, sampling lakes Huron, Superior, and Erie. In August 2013, IISG conducted a survey of southern Lake Michigan to document the abundance of microplastics. Microbeads from personal care products were clearly visible in several of the samples. Microbeads are known to adsorb toxins such as polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), and are often inadvertently consumed by fish and other aquatic wildlife. The potential food web impacts of microbeads and PPCPs in the Great Lakes are not yet fully understood. The goal of the IISG pollution prevention program is to use the latest available science to empower people to solve water resources problems in sustainable ways.

Bio: Laura Kammin is a pollution prevention program specialist at Illinois-Indiana Sea Grant. Her work focuses on pharmaceuticals and personal care products, polycyclic aromatic hydrocarbons (PAHs), plastic marine debris as well as other pollution prevention efforts. Laura's work is directed at improving water and air quality, conserving natural resources, and protecting human health. Prior to joining IISG, Laura held positions at Prairie Rivers Network, University of Illinois Office of Sustainability, University of Illinois Extension, and the Illinois Natural History Survey. Laura received a B.S. in Natural Resources and Environmental Sciences and an M.S. in Wildlife Ecology from the University of Illinois at Urbana-Champaign.

Purdue Rainscaping Education Program

Kara Salazar, Purdue University
(co-author: J. Orick)

Rainscaping includes the use of sustainable landscape design and management practices at household and community scales to prevent polluted runoff from reaching water bodies by directing stormwater to be absorbed by plants and soils. The Purdue Rainscaping Education Program provides training and resources on practices that can be installed in a residential setting or small scale public spaces project. The 2013-2016 program focus includes community awareness and education for bioretention/ rain garden planning, installation, and maintenance using an advanced training model for Purdue Master Gardeners, conservation agencies and organizations, stormwater professionals, and landscape companies and consultants. Participants are encouraged to attend as community teams to support implementation of public education programs and provide technical assistance to homeowners upon completion of the training. The model consists of four, three-hour training modules in a workshop setting and educational service opportunities for Purdue Master Gardener volunteers. The workshops include flipped classroom instruction, online learning, experiential training activities, field techniques, and field trips to community examples of rainscaping projects. Participants receive hands-on experience through creation of a demonstration bioretention /rain garden project with community partners in a public space. A customized website and associated database tracks state-wide rain garden installation projects and calculates related ecological benefits such as reduction in stormwater runoff. This presentation will provide a program overview, results from the spring 2015 workshops, and discuss next steps.

Bio: Kara Salazar is Sustainable Communities Extension Specialist for the Purdue University Department of Forestry and Natural Resources and Illinois-Indiana Sea Grant. Working with multidisciplinary teams throughout Purdue University, Extension, and the Sea Grant College network, Kara develops programs and resources that engage decision makers in evaluating, prioritizing, and implementing sustainability strategies for their communities. Kara serves as the outreach team lead for Tipping Points and Indicators, a research and extension program for Great Lakes coastal communities. She has developed state-wide Extension programs for public spaces and rainscaping education and is a member of the Purdue Land Use Team. Kara has a B.S. in public affairs and environmental science and a M.P.A. in natural resources management and nonprofit management from the Indiana University School of Public and Environmental Affairs. She received a M.S.Ed. degree from the IU School of Education at Indiana University-Purdue University Indianapolis with concentrations in community building and science education, holds a Certificate in Fundraising Management from IU, and the LEED Green Associate credential.

The need for a sustainable water infrastructure planning and engagement system (SWIPES)

Anish Jantrania, Texas A&M University
(co-author: J. Wolfe)

Extended Abstract

Sustainable water infrastructure requires careful and reliable assessments of water sources, water processing systems, and water distribution systems. Stakeholders' input representing municipal, industrial, and agricultural sectors is critical to development of state-of-the-art water treatment, delivery, and re-use systems capable of meeting demands from increased population (future expansion) for dwindling water supplies due to climate-change (drought), at an affordable price. A computer system that can evaluate infrastructure options based on user input of the existing water infrastructure conditions or proposed new options, and determines sustainability index and sustainability grade could be a powerful tool for decision makers to use at the planning stage. Such a computer system must combine multiple input data sources and must facilitate examination of the data from multiple perspectives. A sustainability index from 1 to 100 and a sustainability grade from A to D, assigned to different options along with economic data, could allow decision makers to better evaluate the proposed options. Sustainable Water Infrastructure Planning and Evaluation System (SWIPES) is conceptualized to offer that level of service to planners and decision makers. Water reuse and conservation are important elements along with desalination of saline groundwater or sea water to supplement depleted surface water sources. Distributed or decentralized water infrastructure offers an alternative to a conventional centralized water infrastructure with potentially better sustainability grade. These three concepts (conservation and re- or multi-use of water, on-demand desalination to augment fresh water supply, and a decentralized or distributed infrastructure approach) need to be carefully assessed at the planning phase to determine if they offer improved sustainability and if so the cost to attain that sustainability. SWIPES is conceptualized to be the tool for evaluating infrastructure options to answer "how to" questions for incorporating the concepts of re-use, desalination, and decentralizing into current or future water infrastructure.

Problem Statement

Water infrastructure plays an important role in protecting public health and economic development. The slogan "Water is Life" is universally accepted. Water infrastructure for this research proposal includes both drinking water infrastructure and wastewater infrastructure.

At present, our drinking water infrastructure removes water from the environment, treats it, and distributes it to households and other customers, and our wastewater infrastructure collects, treats, and returns water back into the environment, most of the time after a single use. Despite the importance and funding given to water infrastructure in our nation, the American Society of Civil Engineers (ASCE) infrastructure report card grade assigned to both water and wastewater infrastructure is D (ASCE 2013).

The ASCE report defines grade D as "Poor: At Risk" and is explained as *"The infrastructure is in poor to fair condition and mostly below standard, with many elements approaching the end of their service life. A large portion of the system exhibits significant deterioration. Condition and capacity are of significant concern with strong risk of failure."*

Table 1 summarizes the ASCE infrastructure grades from 1988 to 2013. Note that while the grade for solid waste improved steadily from C- in 1988 to B- in 2013, the grades for both drinking water and wastewater infrastructure declined overall. The drinking water grade declined significantly from B- in 1988 to D- in year 2005 and 2009. The grades for both the drinking water and wastewater improved slightly to D in 2013 from D- in 2009.

The ASCE report offers three key solutions to begin raising these grades. One key solution is to "promote sustainability and resilience" to meet the ongoing needs for natural resources like water while protecting and improving the environmental quality. While the current water and wastewater infrastructure has met our water demand during the 20th century, we need to rethink how we plan to upgrade the existing infrastructure or to build new infrastructure to meet the demand in 21st century in a sustainable manner.

Water supply scarcity is another growing problem recognized in several states, including Texas. Global climate change along with increased demand on source water are the two major factors contributing to water shortage. The 2012 Water for Texas report indicates that the state population is expected to increase 82% between the years 2010 and 2060, but the water demand is projected to increase by only 22% (Texas Water Development Board 2012). The report suggests that *"if the state does not implement new water supply projects or management strategies, then homes, businesses, and*

Table 1: ASCE Grade Report Card for America's Infrastructure. (http://www.infrastructurereportcard.org. Accessed May 8, 2015.)

Category	1988	1998	2001	2005	2009	2013
Aviation	B-	C-	D	D+	D	D
Bridges	-	C-	C	C	C	C+
Bridges	-	C-	C	C	C	C+
Dams	-	D	D	D+	D	D
Drinking Water	**B-**	**D**	**D**	**D-**	**D-**	**D**
Energy	-	-	D+	D	D+	D+
Hazardous Waste	D	D-	D+	D	D	D
Inland Waterways	B-	-	D+	D-	D-	D-
Levees	-	-	-	-	D-	D-
Public Parks and Recreation	-	-	-	C-	C-	C-
Rail	-	-	-	C-	C-	C+
Roads	C+	D-	D+	D	D-	D
Schools	D	F	D-	D	D	D
Solid Waste	C-	C-	C+	C+	C+	B-
Transit	C-	C-	C-	D+	D	D
Wastewater	**C**	**D+**	**D**	**D-**	**D-**	**D**
Ports	-	-	-	-	-	C
America's Infrastructure GPA	C	D	D+	D	D	D+

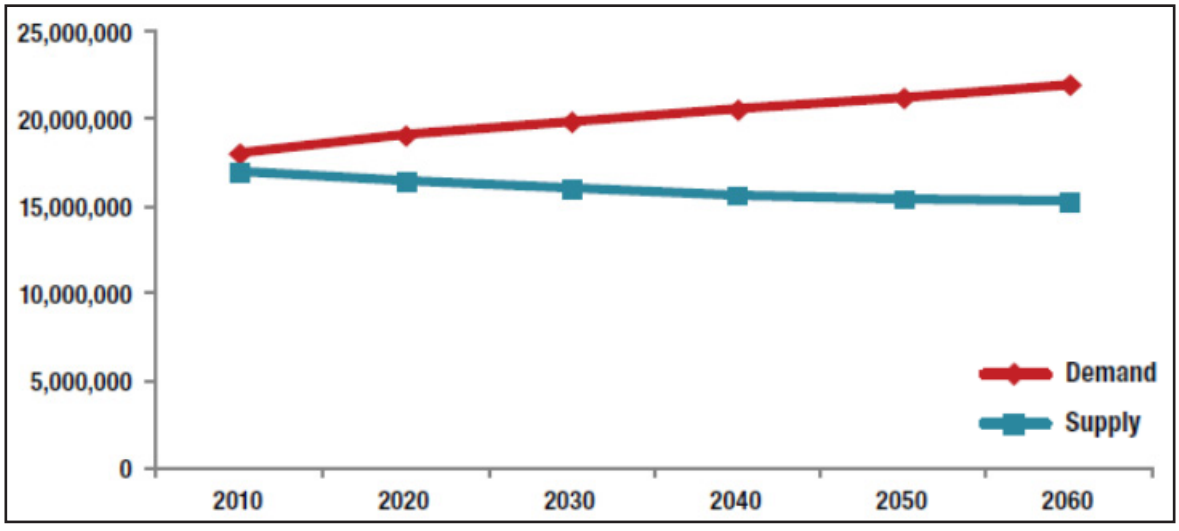

Figure 1. Projected water demands and existing supplies (acre-feet per year) during six decades (Texas Water Development Board 2012)

agriculture enterprises throughout the state are projected to need 8.3 million acre-feet of additional water supplies by 2060." Figure 1 shows the gap between the projected water demand and the existing supplies in Texas.

Infrastructure at risk and water supply that does not meet the demand are the two aspects that need careful evaluation to build a sustainable 21st century water infrastructure. Tools and concepts developed during the late 20th century can offer valuable solutions to current problems. Our research initiative at Texas A&M AgriLife plans to further develop the current knowledge to promote stainable water infrastructure in Texas and beyond.

Water Infrastructure Evolution

During most of the 20th century, a centralized water infrastructure was considered the preferred approach for providing drinking water to, and collecting wastewater from, homes and businesses (also called occupied structures in the Census reports). The 1990 Census reported that centralized water infrastructure delivered drinking water to approximately 84% and collected wastewater from approximately 75% of the occupied structures (U.S. Census Bureau 1990). The remaining structures were reported to be served by individual wells and septic systems, also known as onsite or decentralized water and wastewater infrastructure.

At the national level, the centralized water infrastructure trend has grown during the last 20 plus years. The 2011 American Housing Survey for the United States reported that centralized water infrastructure delivered drinking water to 88% (about 4% increase) and collected wastewater from about 81% of the occupied structures (about 6% increase) (U.S. Census Bureau 2011). Despite the perceived advantages of centralized water infrastructure, the infrastructure grades for both the water and wastewater has not improved in the past 20 plus years (Table 1). As a matter of fact, the water infrastructure grade decreased from B- (GOOD: ADEQUATE FOR NOW) in 1988 to D (POOR: AT RISK) in 2013. This is a strong indicator that increase in centralization of water infrastructure may not be as beneficial as previously thought.

Resistance to changing the use of conventional approaches and thinking is a significant problem in the water infrastructure industry. For example, technological innovation and knowledge gained in small-scale wastewater treatment and effluent reuse systems during the '80s and '90s are still not fully recognized or integrated in water infrastructure planning or rehabilitation processes. In 1997, the US Environmental Protection Agency (EPA) prepared a Response to Congress on Use of Decentralized Wastewater Treatment Systems (U.S. EPA 1997). The response identified benefits of decentralized systems and offered suggestions for overcoming barriers to implementing decentralized systems. Managing water at or near the location where it is needed (decentralized system) and using water more than once (reuse system) represent a paradigm shift from the current approach of "centralized" single-use water management system. The current approach is based on the 2000 year old Roman model.

Since water plays such a vital role in our lives, we cannot afford to rely on infrastructure that is crumbling or projections that show gaps between supply and demand. Fortunately we don't have to. Empowering decision makers and end-users with "tools" necessary to make informed choices based on the contemporary information will result in development of a Sustainable and Integrated Water Infrastructure (Si-Wi). Note that Si-Wi is pronounced "sigh-Y" and the term is coined to get attention to the subject matter in a manner similar to the term Wi-Fi that was coined towards the end of twentieth century to bring attention to the concept of wireless communication.

Both concepts, sustainability and integration, are complex and are thus not adequately considered during water infrastructure planning process. Advanced computer modeling tools can be helpful in assessing infrastructure sustainability. Researchers have developed a model to simulate sustainability of water resources while considering decentralization of urban water infrastructure (Giacomoni et. al 2013). If the qualitative parameters that represent the crux of sustainability and integration values can be quantified and used to compare various infrastructure options along with life-cycle costs in a manner that is accepted by both the decision-makers and the end-users, then we believe the needed paradigm shift could occur within the water industry.

Reuse of wastewater for both direct and indirect potable usage has been demonstrated at both large municipal and small on-site scales during the last two decades. However, a slogan such as *"Toilet-to-Tap"* is still commonly used by demonstrators specifically when direct potable reuse (DPR) system is considered to address water deficits. The water gap shown in Figure 1 is based on the fact that reuse water is less than 5% of the water demand. What if the reuse is increased to more than 25%? City of Wichita Falls, Texas is successfully using 50% of treated wastewater to augment dwindling water supplies since July 2014. The Si-Wi program is developed to encourage communities to consider reuse, decentralization, and desalination.

Research Objectives

1. Develop a frame work to calculate a sustainability index (from 1 to 100) and a sustainability grade (from A to D) for water infrastructure.
2. Modify currently used computer models (APEX, SWAT, and HAWQS[1]) to develop a dynamic computer system SWIPES[2] that presents water infrastructure options to decision makers with a sustainability index and a grade for each option at the planning stage.
3. Test and demonstrate effectiveness of SWIPES in communities that are facing water infrastructure challenges.
4. Develop education and promotion strategies to stimulate interest in Si-Wi, and integrate use of SWIPES into Extension Education Program to promote Si-Wi in Texas.

Research Approach

Over the last 40 years, a team of researchers at the Blackland Research and Extension Center (BREC) have successfully developed and applied several computer simulation models to *examine the impacts of changes in technologies and climate on the resilience and sustainability of agriculture and natural resources*. The team is comprised of scientists and engineers from three agencies: Texas A&M AgriLife Research, USDA Agricultural Research Service (ARS), and USDA Natural Resources Conservation Service (NRCS). The computer models (APEX, SWAT, and HAWQS) operate on spatial scales ranging from individual fields to river basins with a primary goal of assisting farmers to determine soil productivity and to predict the impacts of land management practices on water, sediment, and agricultural yields.

The overall approach of our research project is to (1) develop a new dynamic computer model SWIPES by modifying the current models (APEX, SWAT, and HAWQS) supported at BREC, (2) test and refine the new model based on input from communities in Texas, (3) demonstrate effectiveness of the model by documenting its effect on water infrastructure performance, and (4) integrate research results into extension program to educate water industry professionals about Si-Wi and application of SWIPES at local and regional levels.

The sustainable life style mantra is being promoted by many in all aspects of our lives. Sustainable Infrastructure is not an exception. There is an Institute for Sustainable Infrastructure (ISI), a nonprofit organization that has developed a sustainable rating system for civil infrastructure called Envision™ (http://www.sustainableinfrastructure.org. Accessed May 8, 2015.). There are a few other similar rating concepts proposed by researchers (Ariaratnam et al. 2013) and organizations (http://sanitationandwaterforall.org/. Accessed May 8, 2015.) that offer current approaches for quantifying Sustainability. The BREC research team will thoroughly review existing literature and prepare a summary of knowledge and concepts. The ASCE Grade Report Card presents a list of eight grading criteria and a grading process for assigning grade to an infrastructure. Using this, and other available information, the research team will develop a comprehensive criteria list and a scheme to calculate a Sustainability Index and a Grade for proposed water infrastructure projects.

SWIPES will be a "dynamic" model such that it will allow for efficient and timely upgrade of its data and knowledgebase to incorporate new scientific and technical information related to water infrastructure. The goal is to allow the planners and decision-makers to have access to the latest information available in the water industry. SWIPES is also envisioned as a tool to educate end-users of water infrastructure (the constituents) by offering them information on developing trends in water industry such as water conservation, rain water harvesting, water reuse and desalination as alternative water sources, and decentralized water infrastructure. Thus, the knowledge base developed for SWIPES will have an interactive educational module that would allow end-users to gain comprehensive understanding of the Si-Wi approach and how it may benefit their community. It is expected to take additional years after completion of the first objective to complete the development of SWIPES. The goal is develop SWIPES in three years.

[1]APEX: Agricultural Policy / Environmental eXtender; SWAT: Soil and Water Assessment Tool; HAWQS: Hydrologic and Water Quality System.
[2]SWIPES: Sustainable Water Infrastructure Planning and Engagement System.

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Bio: Dr. Anish Jantrania is an Associate Professor/Extension Specialist in the Biological & Agricultural Engineering Department at Texas A&M University. He is based at he Blackland Research & Extension Center in Temple, Texas. Dr. Jantrania has over 25 years of experience working in the wastewater industry, in the public and private sectors, with a focus on On-Site Sewage Facilities (OSSF/septic systems), and decentralized wastewater systems used in areas not served by public sewer. His research and extension interests focus on sustainable infrastructure to ensure the availability of clean water to meet society's water demands, and to ensure safe sanitation to protect public health and environmental quality. Before coming to Texas, Anish has worked in Virginia, Massachusetts, and West Virginia, and has studied in West Virginia, South Carolina, Ohio, and India. His work in Texas will focus on developing a statewide extension education and research program related to surface and groundwater quality protection with specific emphasis on non-point sources, OSSF, and other environmental issues. His work will also focus on education and research needs in water treatment technologies (such as desalination), water capture and multiuse, and conservation technologies that address identified needs in both agricultural and urban sectors.

Photovoltaic-powered wastewater electrolysis cell as a sustainable sanitation technology for developing countries

Kangwoo Cho, Korea Institute of Science and Technology
(co-author M. Hoffmann)

This study seeks a technically and economically feasible solution for world challenges for water, sanitation and energy, based on highly practical strategy. The Photovoltaic-powered Wastewater Electrolysis Cell (PWEC) starts from the conventional electrolysis for water splitting to oxygen and hydrogen with employing wastewater as an electrolyte. In this situation, the chloride in the wastewater is oxidized to the reactive chlorine species, which can degrade environmental pollutants including fine particles, dissolved organics and other aqueous pollutants. This green chemistry without external chemicals can be totally driven by photovoltaic panels, which makes PWEC to be a traditional infrastructure-free approach. The hydrogen can be an energy source for domestic living by proper energy conversion practices. Reliable energy efficiency and cost reduction are achieved by using inexpensive but highly active electrodes based on bismuth oxides doped titanium dioxide (BiOx/TiO2). This presentation will cover the chemical reaction engineering for process optimization in laboratory-scale and field-scale wastewater electrolysis cell (WEC). The BiO_x/TiO_2 anode shows excellent indirect oxidation efficacy by reactive chlorine species generation, with an external chloride higher than 10 mM. Urine can be a potential source of chloride, while the existence of refractory organics in urine required an anaerobic biological reaction as a pretreatment. Under an optimal condition, the chemical oxygen demand, measurable protein, and color in human waste were almost completely removed within 6 hr of electrolysis, allowing the treated water suitable for unrestricted urban reuse (toilet flushing and irrigation). Hydrogen was produced almost proportionally with the response current, and the energy conversion efficiency was around 25%. The loss during the energy conversion in adulterated solution can be compensated by saving energy for water treatment.

Bio: Kangwoo Cho received his B.S. and M.S. in Civil, Urban, and Geosystem Engineering from Seoul National University in Korea. He finished Ph.D degree in Environmental Science and Engineering at California Institute of Technology (CalTech) in 2014. He has served as a research scientist at Korea Institute of Science and Technology (KIST) from 2006. He has been working with physical, chemical and biological water treatment systems. His current research interests include advanced oxidation process using electrochemical approaches for water reuse and energy harvesting. His recent research work with Prof. Michael Hoffmann in CalTech received the grand prize in the 1st Reinvent the Toilet Fair issued by Bill and Melinda Gates Foundation.

Evaluating sustainability tradeoffs of integrated urban water resources management alternatives

Erfan Goharian, University of Utah
(co-authors: S.J. Burian, T. Bardsley, C. Strong, J. Niermeyer, T. Kirkham, L. Briefer)

Future sustainable uses of earth's resources and the concern about fate of them have been increased over past years. The way of human living is interconnected with future existence of not only non-renewable resources, but also renewable resource like water resources. Changes in climate (like precipitation phase - rain versus snow), combined with population growth and urbanization, can also exert stress on water management, particularly in mountainous terrain where the water supply is largely stored as snowpack. Sustainable integrated water resource management needs not only existence of a detail integrated water system model, but it needs a model which shows relationships between different parts of sustainability framework including the social and economic modulus. In this study, system dynamics (SD) approach is used to build the evaluation framework for sustainability as it is more flexible and capable to present the nature of water systems. This paper describes the use of integrated modeling to study the relative sustainability benefits of incorporating decentralized infrastructure elements in combination with centralized systems for the Salt Lake City, UT, water supply system. The results show that adding decentralized elements to the urban water system can increase the overall sustainability, a clear improvement if not noted in individual categories of the three strands of sustainability, economic, environment, or social.

Bio: Erfan Goharian is currently a PhD Candidate at the University of Utah.

"All In" Together: The role and influence of environmental programs in Colorado River water management and resource conservation

Jason Thiriot, Colorado River Commission of Nevada
John Swett, Lower Colorado River Multi-Species Conservation Program - Bureau of Reclamation, Lower Colorado Region
Sharon Whitmore, San Juan River Recovery Implementation Program - U.S. Fish and Wildlife Service
Thomas Czapla, Upper Colorado River Endangered Fish Recovery Program - U.S. Fish and Wildlife Service
Beverley Heffernan, Adaptive Management Group - Bureau of Reclamation, Upper Colorado Region
Scott VanderKooi, Grand Canyon Monitoring and Research Center - U.S. Geological Survey

The Colorado River Basin contains four major environmental programs that are recognized for conservation and restoration objectives: Glen Canyon Dam Adaptive Management Program, Upper Colorado River Endangered Fish Recovery Program, San Juan River Basin Recovery Implementation Program, and Lower Colorado River Multi-Species Conservation Program. Collectively, the stewardship and scope of these four environmental programs spans the headwaters in the Colorado River Basin to the international boundary with Mexico. Each of the four programs is unique in purpose, goals, and organizational structure. The common thread between these science-based programs is the influence and improvement of native species and habitat in compliance with the Endangered Species Act. Both unique and similar, these programs integrate the collective efforts of hundreds of diverse stakeholder representatives that include: state, federal, Native American tribes, environmental/conservation groups, water/hydropower users, and local agencies and communities. The panel discussion will highlight some of the common challenges facing the Colorado River Basin as a whole, while promoting the exchange of information on research and management activities related to species and habitat restoration and conservation in the Colorado River and its major tributaries. Topics will include: 1) Program Overview - How the programs provide for ESA compliance (recover, conserve, restore, and mitigate impacts of existing and new water and hydropower projects). 2) Stakeholder Involvement - Stakeholder participation (advantages/disadvantages) and stakeholders' critical role in finding solutions to legal and funding challenges. 3) Assessing Program Effectiveness - How adaptive management is implemented in each program; how program goals are measured; determining near term and long term expectations. 4) Future Challenges - How the programs address climate change, drought, invasive species, fire, etc. 5) Long Range Planning - How far out to plan; how expansive should the scope be (regional vs. site specific); how to incorporate watershed coordination (goal setting/cost sharing/data base sharing across programs).

Bios:

John Swett has been the Program Manager for the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) since September 2008. Prior to becoming Program Manager, he was the Wildlife Group Manager for the LCR MSCP and was responsible for conducting monitoring and research projects for 27 threatened, endangered, and sensitive species and their habitats within the MSCP planning area. John has worked in the natural resources field since 1979, including 11 years with the US Forest Service, prior to accepting a position with the Bureau of Reclamation in 1992. He has a BS in Wildlife Management from the University of Maine and a MS in Forestry from the University of Massachusetts.

Sharon Whitmore received her college education from New Mexico State University in the late 70s and early 80s. She has spent over 25 years in federal service working in large river native and endangered species management and coordination of river basin, multidisciplinary efforts to preserve, conserve, and restore native ecosystems. Her current position is Assistant Program Director for the San Juan River Recovery Implementation Program based out of Albuquerque, New Mexico. The recovery program was established in 1992 and is a collaborative partnership of American Indian Tribes; local, state and federal agencies; water organizations; power customers and environmental groups. The recovery program has two goals: to recover populations of two endangered fish species, the Colorado pikeminnow and razorback sucker, in the San Juan River and its tributaries in Colorado, New Mexico, and Utah, and to allow for continued water development in the basin in accordance with federal and state laws and interstate compacts.

Thomas E. Czapla is a program coordinator for the Upper Colorado River Endangered Fish Recovery Program (Recovery Program). He received a B.A. in Biology from Canisius College, an M.S. in Aquatic Biology from Buffalo State College, and a Ph.D. in Zoology from Texas A&M University. Dr. Czapla coordinates all projects and activities under two of the five Recovery Program elements: 1) Propagation and Genetics Management and 2) Research and Monitoring. He assesses the four endangered fish data to follow progress toward downlisting and recovery. His interests include population dynamics and aquatic ecology.

Session 4, Colorado River I - Panel Discussion

Beverley Heffernan has been Manager of the Environmental Resources Division in the Bureau of Reclamation's Upper Colorado Region since October 2010. Prior to that, she served as Chief of the Environmental Group in the Provo Area Office from November 2002 until moving to the regional office. She began working for Reclamation as the project manager for the Operation of Flaming Gorge Environmental Impact Statement in July 2001. Beverley began her federal career in 1975 at the Federal Energy Administration, which became part of the new Department of Energy in 1977. She held a number of different positions over the years at the Energy Department, including staff assistant to an Assistant Secretary during the Carter Administration and staff assistant to the Under Secretary in the Reagan Administration. She held several different environmental compliance positions dealing with the National Environmental Policy Act, the Endangered Species Act, the Clean Water Act, the Clean Air Act, and a multitude of other environmental and cultural resource protection laws. She also held public outreach and speechwriting positions at the Energy Department during the Bush and Clinton Administrations. Beverley was born and raised in Houston, Texas, earned a bachelor's degree in history at Sweet Briar College in Virginia, and spent 20 years working 'inside the beltway' before she and her husband came to their senses and moved to Utah in 1995. She has been married for 38 years, and has two sons, two horses, two dogs, and a rescued Utah tarantula.

Scott VanderKooi is a Supervisory Biologist with the U.S. Geological Survey's Grand Canyon Monitoring and Research Center. He received a B.S. in Marine Biology from Oregon State University and an M.S. in Fishery Science also from Oregon State University. Mr. VanderKooi oversees biological monitoring and research efforts at the Center which are focused on native fishes of the Colorado River Basin, particularly the endangered humpback chub, as well as nonnative fishes, aquatic ecology, and riparian vegetation.

The effect of topographic position on soil properties and erosion within agricultural fields in central Illinois

Andrew Mellinger, Southern Illinois University Carbondale
(co-authors: J.E. Schoonover, J. Groninger, R. Cook)

Much of the Mississippi River watershed is characterized by highly productive, flat landscapes that are under intensive row crop production. Waterways within these watersheds are often impaired by sediment-borne and soluble nutrient runoff. While principles of topography and erosion dynamics are commonly discussed within steeper agricultural landscapes, these have not been explored in level landscapes where erosion-deposition impacts appear to be minimal. The objective of this study was to delineate field topography, relate delineated topography to soil properties over four years and also observe soil behavior during an in-situ erosion simulation. Topographic positions on the soil surface were delineated by shape, (i.e. convex, concave, and linear) to characterize potential zones that may accumulate or lose soil. Soil samples for chemical analysis were taken on a per acre basis over the entire field in the fall of 2011 through 2014. Nine controlled rainfall simulations were completed to determine total suspended solids (TSS) and turbidity of runoff water at each of the positions. Soil samples for percentage of water stable aggregates (WSA) and earthworm biomass were also collected to relate to TSS. Results suggest concave topographic positions had highly significant increase of all nutrients except for sodium and nitrate, higher soil organic matter, higher total exchange capacity, and higher water stable aggregates compared to the convex positions. Linear soil surfaces were typically intermediate but occasionally were also significantly higher than a convex soil surface. WSA had a significant negative correlation with TSS and turbidity. Earthworm biomass, however, had a highly significant positive correlation with TSS and significant negative correlation with WSA. Quantifying soil quality and observing soil movement within these positions would allow for better optimization of agricultural inputs in regards to crop yield and watershed protection.

Bio: Andrew Mellinger graduated with a B.S. in International Agriculture and Rural Development from Cornell University with a minor in soil science. Currently, he is completing a masters in the Forestry Department at Southern Illinois University studying soil dynamics in agriculture landscapes in central Illinois.

Indicators of soil quality in forest buffers and row-crop agriculture: Restoration of riparian function

Karl W.J. Williard, Southern Illinois University Carbondale
(co-authors: N. Rahe, J.E. Schoonover)

Riparian zones, the transitional areas between terrestrial and aquatic environments, support a number of critical ecosystem functions such as nutrient cycling, carbon storage, sediment trapping, aquatic food chain support, and wildlife habitat. These small areas on the landscape largely control the flow of water, nutrients, and sediment from adjacent terrestrial areas to surface waters. Reclaimed mine areas offer a unique opportunity to study the restoration of riparian function without the confounding influence of past land use, since soils were reconstructed in a similar fashion. Between 1980 and 2000 in southern Illinois, forest buffers were established along three restored stream reaches adjacent to reclaimed agricultural land. Our research objective was to compare indicators of soil quality (infiltration, soil C and N, bulk density, and soil moisture) between forest and cultivated riparian zones to determine if riparian function was being restored. Soil bulk density was significantly lower in the forest buffers compared to the agricultural fields. The forest buffers had greater soil total C, total N, and moisture levels than agricultural fields likely due to greater organic matter inputs. Soil total C and N levels in the forest buffers were positively related to age of restoration, indicating that soil quality is gradually being restored in the buffers. Restoration success of riparian buffers should not be estimated by the return of structure (vegetation) alone. It also includes the re-establishment of functions such as nutrient cycling and water retention that largely determine water quality benefits. Watershed planning efforts can expect a lag time on the order of decades between the completion of riparian restoration and surface water quality improvement.

Bio: Karl W.J. Williard is a Professor of Forest Hydrology and Watershed Management in the Department of Forestry at Southern Illinois University Carbondale. He received a B.A. in Biology from Lehigh University, an M.S. in Environmental Pollution Control from Penn State University, and a Ph.D. in Forest Hydrology from Penn State University. Dr. Williard teaches undergraduate and graduate courses in Watershed Management and Hydrology. He serves as Executive Director for the Universities Council on Water Resources. His current research interests include agricultural land management impacts on soil and water quality and quantifying the water quality benefits of riparian buffers.

Bio-economic farm-level analysis of growing Brassica as a biodiesel crop in the west side of the San Joaquin Valley of California

Lucia Levers, University of California, Riverside
(co-author: K. Schwabe)

Brassica1, a salt-tolerant, phytoremediative, biofuel crop, provides higher profits and greenhouse gas benefits than either land retirement or the growth of wheat when grown with saline drainage water on marginal land of the San Joaquin Valley of California (SJV) as part of an Integrated on-Farm Drainage Management (IFDM) system. A bio-economic mathematical programming model of irrigated agricultural production with a nonlinear optimization framework is used to examine Brassica in a farm-level analysis modeled on a SJV farm of 1500 hectares of nonmarginal land and 500 hectares of marginal land. Four scenarios of marginal land production utilizing drainage water are used: 1) land retirement, 2) Brassica production, 3) wheat production, and 4) efficiency. In all scenarios, nonmarginal land is used to grow tomatoes and almonds, two higher-valued, low salt tolerance crops with fresh water. Yield equations that are functions of irrigation scheme, water, nitrogen, season, and salinity are generated using Hydrus-1D.

Bio: Lucia Levers is a doctoral candidate in the Environmental Sciences Department at UCR. She earned her bachelor's degree in Human Biology at Stanford University and her master's degree in Environmental Sciences at UCR. She is particularly interested in the research nexus of natural sciences and economics.

Drivers of the reduction in agricultural wetland loss rates in the United States 1955-2009

Christopher Lant, Utah State University
(co-author: R. Wiebusch)

While non-agricultural wetland conversions have persisted, the five U.S. national wetland inventory reports spanning 1955-2009 show a large decline in the rate of conversion of wetlands to agricultural purposes, especially from the mid-1970s to the mid-1990s. Through correlation, regression, and principal components analysis, this study identifies primary drivers of this decline in wetland losses. Crop prices for corn, wheat, and soybeans are positively related to wetland losses, while the Clean Water Act §404 and Swampbuster programs are negatively related to loss rates. The Conservation Reserve and Wetland Reserve programs are secondary brakes on wetland loss. In combination, these factors, in addition to the percentage of 1955 wetland area remaining, explain 96 percent of the variance in all annual wetland losses and 94 percent of the variance in agricultural losses nationally, though, due to multicollinearity, it is difficult to isolate the individual effect of each driver. A model of the process of agricultural wetland conversion founded in agricultural economics is proposed that is very effective in explaining both emergent and forested wetland losses and losses in seven heavily agricultural strata, but is less effective in strata where agriculture is less dominant. This analysis suggests that forces that increase the demand for major crops, the scaling back of the agricultural conservation programs Swampbuster, CRP or WRP, or of the Clean Water Act §404 program will likely result in a renewal of drainage where convertible wetlands are still available.

Bio: Dr. Lant is currently a Professor and Head of the Department of Environment and Society, Quinney College of Natural Resources, at Utah State University. He is the former Executive Director of UCOWR.

Pushing the refresh button: How Project WET is innovating through expanded content, new partners and enhanced delivery strategies

Dennis Nelson, Project Water Education for Teachers (WET) Foundation

Project WET (Water Education for Teachers) has been active in water resources education for more than 30 years. From its roots in the North Dakota State Water Commission through incubation and development on the Montana State University campus and the establishment of Project WET as the U.S. 501(c)(3) nonprofit Project WET Foundation in 2005, Project WET has constantly sought to innovate to serve the broadest possible swathe of the water sector. This presentation will highlight Project WET's commitment to ActionEducation™ (awareness and education that leads to action) through public-private partnerships with some of the world's largest corporations and organizations, including Nestlé, Ecolab and Levi Strauss & Company, as well as government agencies and NGOs in more than 66 countries. Geographic case studies from Africa, China, Brazil and India will demonstrate how Project WET helps water managers and educators address local hydrologic conditions in the context of unique and diverse water management capabilities, wide-ranging issues, challenges and opportunities. Partnership case studies will highlight WaterStar, a new Ecolab-Project WET program that aims to identify, recognize and award students, educators and local partners for taking action related to water conservation and hygiene, as well as the WaterAction App that Intel volunteers are helping Project WET create to document local actions for water. Throughout this atmosphere of innovation, Project WET's commitment remains to providing educators of all kinds, most with limited science backgrounds, with best-in-class water-science instructional methods and materials focused on student learning. Participants in this workshop will be given tools to join Project WET in new and creative water education programs that prepare today's youth to be tomorrow's water scientists, managers and water stewards.

Bio: Dennis Nelson founded Project WET (Water Education for Teachers) in 1984 while working at the North Dakota State Water Commission. Through extensive partnerships and successful fundraising efforts, he has developed the program into the Project WET Foundation, a global leader in water resources education around the world. The Project WET Foundation helps people of all ages and nationalities understand water resources through engaging, action-oriented water education. By promoting water literacy and awareness, the Project WET Foundation gives people tools to address both current and future water issues. With a strong network of public and private partners in more than 66 countries around the world, the Project WET Foundation has been recognized with a U.S. Water Prize, and its materials are recommended by the National Science Teachers Association (NSTA). Some of the largest corporations in the world—including Nestlé, Ecolab and Levi Strauss—are working with the Project WET Foundation to develop customized employee training and community engagement programs. The Project WET Foundation's educational materials cover the entire spectrum of water, including water quality, wetlands, water conservation, watersheds, WASH (water, sanitation and hygiene), oceans, water and natural disasters, water history, groundwater, storm water and more. These materials have been created under Project WET's numerous brands, which include not only Project WET but also the Kids In Discovery Series (KIDS), WOW! The Wonders of Wetlands, Discover a Watershed Series, Healthy Water/Healthy People, Conserve Water and Native Waters.

Educating today; innovative solutions tomorrow

Kerry Schwartz, Water Resources Research Center at the University of Arizona

A reliable, safe, quality water supply is central to life, production and the economy. Yet in a 2011 poll, 77% of Americans (not on a private well) were unable to identify the source of their water (TNC and FMMM & Associates). Many people are disconnected from their own rivers and watersheds even in the Colorado River Watershed, where headlines regularly warn of drought, shortage, and climate change. Arizona Project WET (APW) engages people in learning about this over-allocated system that provides water to 30 million people using Project WET Foundation's extraordinary, Discover a Watershed: The Colorado educators' guide. For Arizonans this understanding is critical. According to Cronkite News (1-2015), "Arizona draws 40 to 50 percent of its water from the Colorado and would see some of the sharpest impacts in job losses and declines in gross state product if a shortage occurred." Arizona agencies, sponsors, partners, the University of Arizona and Cooperative Extension invest in the APW program. APW builds STEM-literate citizenry and inspires an ethic of water stewardship through a three-pronged approach; by providing teacher professional development that assists teachers in evolving their instructional practices, direct student outreach that delivers or extends classroom learning, and purposeful community engagement that benefits student learning. This session will demonstrate: 1) how to teach about interrelated earth systems by building understanding from a strong foundation and 2) how to develop problem solving skills. Tomorrow's answers will come from people with a strong understanding of interrelated earth systems; a grasp of complex, competing needs and multidisciplinary issues; and the ability to think. APW's education programs build thinking skills through relevant and real-world instruction. Critical, creative, interdisciplinary, scientific, systems-oriented and prosocial thinking will all be needed to ensure a secure water future.

Bio: Kerry Schwartz is Faculty with Arizona Cooperative Extension and the Water Resources Research Center at the University of Arizona and the Director of the Arizona Project WET (APW) water education program, transferring knowledge focused on hydro-literacy and 21st Century learning to educators, K-12 students and community members. She directs a team of education coordinators working out of three extension offices. Her degree in geohydrology and 8 years of experience in environmental consulting enable her to deepen content knowledge about water resources with real world examples and relevancy. She has raised over 3 million dollars over her 15 year tenure at the UA and has sustained partnerships with corporations, foundations and governmental agencies, even as economic realities became challenging. Currently, Kerry is working to develop and evaluate STEM focused education programs that integrate science and engineering practices in to environmental education and foster critical and creative thinking skill development. In the last four years, she has received awards for Merit in Environmental Education, a Long Publication, APW's Outstanding Team, Individual Program Leadership, and the Most Innovative Program. She co-authored the Arizona Conserve Water Educators' Guide which was a finalist for the 2008 Association of Educational Publishers Distinguished Achievement Award.

Developing soil & water science curriculum for informal youth education

Natalie Carroll, Purdue University

Extended Abstract

Many major funding agencies now require outreach efforts so that new knowledge can be shared with the appropriate client groups. These efforts often result in new educational materials written for dissemination to non-formal audiences. The goal of non-formal curriculum development is to write with clarity to communicate science effectively to those who are often learning outside the formal classroom, although they can also be used in classrooms for enrichment, particularly when explaining new research, technology, or special applications. In-service training helps assure that the goals and objectives of the educational materials are understood by teachers and other knowledgeable educators or volunteers and the materials are used as designed.

Science is most effectively communicated in non-formal settings when the learners are interested in the topic, can understand why it matters, and is taught by a knowledgeable educator in an age-appropriate manner. Experiential learning techniques and using the scientific method are two "tried and true" methods that 4-H [Cooperative Extension Service (CES) youth program] uses to engage youth in non-formal learning and develop skills and attitudes that foster life-long learning.

The major components of curriculum development for non-formal youth audiences include assembling a team, writing, reviewing, pilot testing, editing, design & layout, printing and/or posting online, evaluation, and updates. While the progression is largely linear, some steps require multiple iterations and some can happen simultaneously. These steps are describe below as they were used for the creation of a new curriculum (posted online in February, 2015): 4-H Soil and Water Science.

Curriculum Development Steps

Create a Team:

The first step in curriculum development is to assemble a team representing both content and youth development expertise. The team is responsible for planning, delegating, coordination, and oversight. The team must have a leader who takes responsibility for setting up meetings, follow-up, and generally assuring each step is completed.

Example:

The author was the team leader in the development of the new 4-H Soil and Water Science curriculum. Team members included faculty from a research university, CES educators, a senior resource planner from an engineering firm, a representative from the state department of environmental management, a representative from the local soil and water conservation district, teachers, and a representative from a local river enhancement corporation. The bulk of the work done by the committee was in the planning stages (described below). During the initial meeting(s) it is beneficial for all team members to learn what expertise that each person brings to the table. This helps in the determination of the delegation of assignments and tasks. Face-to-face meetings were held monthly during the planning stages which allowed the team to get to know each other and learn to work together. Not all team members were able to attend each meeting but the team leader and a small core (3 others) were at all the planning meetings. This created a cohesive working group. Meetings were less frequent and sometimes via phone and/or web-based, once the actual curriculum writing began. The development team provided support, advice, and reviews throughout the curriculum development process. They also greatly assisted with the promotion of the new materials.

Planning:

The initial planning discussion should focus on the curriculum audience, goals, and objectives determined.

Example:

Since the curriculum was being written for a 4-H audience, the target audience was predetermined to be youth in grades 3 – 12. The team chose to follow the traditional format in their state of writing a separate manual for youth in grades 3-5 (Level 1); grades 6-8 (Level 2), and grades 9-12 (Level 3) with a Facilitator's Guide for the adult assisting with the non-formal education. This division works well as there tends to be a natural break between elementary, middle, and high school ages and allows basic information to be introduced in Level 1 and topic interactions and more complex topics to be introduced in Level 2. The final manual, Level 3, has some new information but also encourages youth to find their own resources; use the scientific method to test their own hypothesis; and teach, mentor, and share their knowledge and findings.

The development team determined the general goal for each level. The following overview is printed on the

inside front cover of each manual: "Level 1 introduces basic terms and concepts. Activities focus on understanding important soil and water processes. Level 2 activities help you put the basic concepts into action to understand more advanced soil and water concepts and interactions with the environment. Level 3 activities are divided into chapters based on how you might use the information you have learned — as a homeowner, resident of a watershed, food and fiber producer (farmer), mayor, teacher, or legislator. Level 3 delves deeper into soil and water science concepts, and can prepare you to be well informed and to study these topics at a college or university. Youth are encouraged to supplement their learning by consulting knowledgeable people and current written materials in Level 3 with references from governmental and/or university sources (online extensions *.gov and *.edu)."

The next phase of planning new curriculum is to complete a Logic Model (Severs et al. 2007, pg. 101) to assure that the necessary inputs are available and to outline the activities, desired outputs, and desired impacts. The goals, inputs, specific activities, outputs, outcomes, outcome measures, and impacts should be defined for the entire curriculum.

Example:

The Soil and Water Science team determined the specific outcomes and activities to be developed to achieve the stated outcomes. They chose to start with the high school manual (Level 3) and asked the question, "What do we feel that youth should know about soil and water to be knowledgeable citizens and prepared for post-secondary work?" Once these topics were determined, they worked on the middle school level (Level 2) and then the upper-elementary level (Level 1) asking, "What will the youth need to know about soil and water to proceed to the next level?" These deliberations led to the activity titles used in the 3 manuals as shown below:

Level 1 (grades 3-5)	**Level 2 (grades 6-8)**	**Level 3 (grades 9-12)**	
Erosion	Careers	You are a Homeowner	You are the Mayor
Splash	Clean Water	City Dwellers/Country Dwellers	Conservation Planning
Water	Color Clues	Conservation at Home	Explore Your Wastewater Treatment Plant
Wind	Conservation Practices	Soil Moisture	Planning for Growth
Floods!	Floodplains	Why Should I Care About My Soil?	Wetlands
Life in the Soil	The Kankakee Marsh	You Live in a Watershed	You are a Teacher
Properties of Water	Municipal Water Treatment	Stream Water Quality Monitoring	Interactive Demonstration
Soil and Water	Onsite Wastewater Treatment	Water as a Resource	Lights, Camera, Learn-by-Doing!
Soil Needs Space	Soil Erosion	Water Information Online	Mentor a 4-H Member
Soil Origins	Soil Formation	Water Pollution	Share Your Knowledge
Soil Profiles	Soil Health	You are a Food and Fiber Producer	You are a Legislator
Soil Textures	Soil Texture	Agricultural Soils	Challenges
The Water Cycle	Storm Water Runoff	Agricultural Water	Current Events
What is a Watershed?	Surface Water and Groundwater	Soil Erosion	
	Water Testing	Water and CAFOs	
	Wetlands		

Writing:

Once the planning steps are complete, the actual content writing can begin. 4-H manuals are generally "activity-based," meaning that they are a collection of "learn by doing" (the 4-H motto) lessons that encourage youth to learn through their own investigations. While it is not always possible to teach each concept in this manner, the authors strived to use active learning and hands-on methods as much as possible. A lesson plan template should be used to provide consistency across the curriculum and to simplify development. This also helps youth by having a consistent format for all lessons.

Example:

The components of the template used in the Soil and Water Science curriculum were:

- The title
- A question to engage the learner
- Introduction intended to help the learner understand any background information and why the topic is important
- A list of supplies needed (tool kit –the supplies, equipment needed to perform the activity)
- Instructions for what must be done by the learner (Make It, if the youth constructs something, Do It, if the youth doesn't make a product)
- Talk it Over - experiential learning prompts (to encourage youth to think about what they learned and how it applies to them and to life in general)

- Glossary words (new words introduced or used and their definitions)

The template should also include the items needed for the Facilitator's Guide because it is much easier to develop this content when developing the original activities than to go back and create it later. The Facilitator's Guide includes:

- Big Picture, background section - the core understanding underlying the activity)
- Answers to any questions in the youth manual
- Essential questions – important concepts to discuss with youth
- Suggestions for facilitating the activity
- Connections to other topics or idea (when available)
- Life skills that youth are expected to gain by completing the activity
- Academic standards (the Next Generation Science Standards were used, www.nextgenscience.org/next-generation-science-standards)
- Success Indicator - how the learner demonstrates that they learned

The Facilitator's Guide also includes general information about the learning goals and the importance of youth learning life skills, an introduction to the Experiential Learning Model, and a discussion of youth development stages.

A writer was hired to focus on writing, using the activity template, and worked closely with the author (team leader). The writer became a member of the curriculum development team once they were hired. One team member also contributed a couple of activities.

4-H manuals are not used in a linear fashion, rather youth are free to skim through the entire manual and choose the activities that appeal most to them. Because the manuals are generally used for multiple years, most 4-H programs encourage youth to pick from 3 to 5 activities to complete each year. This allows youth to enroll in multiple 4-H projects without any one project becoming overly burdensome.

Each learning activity is intended to be taught in a single session. Learning sessions are sometimes led by a parent, sometimes by a volunteer 4-H leader, and sometimes completed by the youth themselves. The manuals are written with the intent that youth in Level 1 receive adult assistance to complete the activities but youth progressively take more responsibility for self-learning as they advance to Levels 2 & 3.

Reviews:

The curriculum design team reviews the activities as they are being written. The work is generally shared so that each activity is reviewed by one or two people. It is also important to have the completed curriculum reviewed by youth development professionals and scientists who were not involved in the curriculum development. They may find omissions, inaccuracies, or have suggestions for improvement. Errors are corrected and suggestions incorporated, when possible.

Pilot Test:

Once the review and corrections are completed a pilot test with the target audience, high school aged youth, is initiated. The pilot test allows an important check to determine youth interest, usability, and level of difficulty. Evaluations (IRB certified) should be completed by youth, volunteer leaders, and parents involved in the pilot test phase.

Changes:

Any additions, deletions and changes suggested by the pilot test must be addressed. Some recommendations can be handled easily by the writers, but others may need a discussion with the design team to determine how to best address the concern.

Edits:

A professional editor is hired to assure proper language usage and organization. The author has found professional editing to be an invaluable tool in presenting an accurate and consistent work.

Design & Layout:

Professional design and layout of the curriculum publication is completed after the final edits have been made. As with editing, professional design is critical, particularly when presenting an attractive and appealing product to youth (see Figure 1).

Printing or Online Posting:

Once the publication is designed it is finally time for publication.

Example:

We chose to print the Level 1 manual so that youth in upper elementary school could have a full color manual

that they become accustomed to, and for ease of teaching to multiple youth. In our experience the 4-H club work is often done in groups for the younger aged youth but more individually for middle and high school aged youth. All the manuals (including Level 1) are posted online at The Education Store, www.edustore.purdue.edu (enter "soil and water science" in the Search Box). Making the online publications web accessible turned out to be more time consuming than planned so the author highly recommends discussing web accessibility with the designer before they begin. It is much easier to do this "up front" than later on.

Revisions:

Although the materials are reviewed, pilot tested, and edited, errors still occur, inevitably. The online materials can be updated fairly easily but printed manuals generally must be used before being reprinted due to costs.

Inclusion

It is important, particularly when writing for audiences served by CES (a government entity), to understand social, economic, cultural, and political realities that can affect youth learning; to incorporate a variety of cultures, values, ethical principles, and points of view; and to develop civic and service responsibilities within these contexts when possible and appropriate. While discussion of these topics was not included in this paper, sensitivity to these issues must be involved in the choice of language and graphics used in curriculum.

Summary

Curriculum development is a process that can take from 3 to 5 years to complete. However, smaller projects that do not span multiple age-groups and are targeted to a more specific topic can be completed much more quickly. The steps outlined should be followed, however, to assure an accurate, attractive, and useful product.

References

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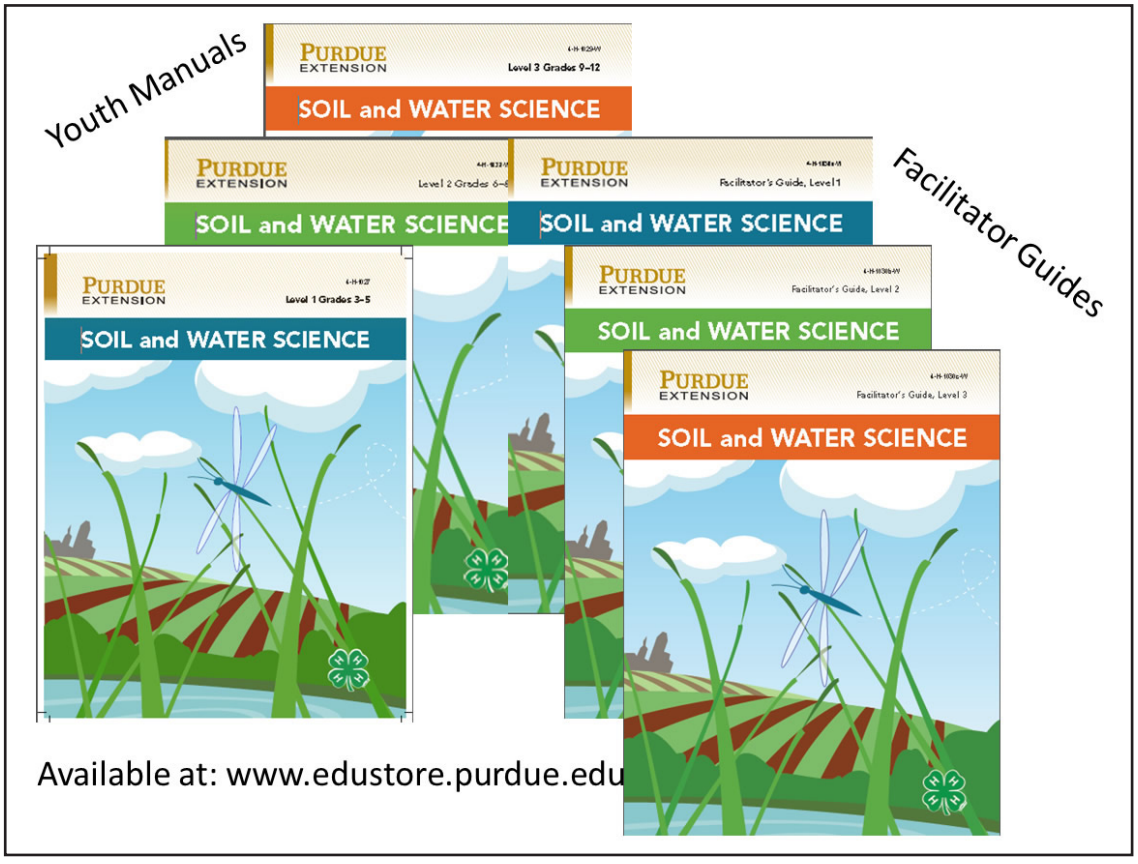

Figure 1. 4-H Soil and Water Science Covers

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Bio: Natalie specializes in developing resources for informal youth education in natural resources and the environment. She has written or collaborated on 50 new publications for youth and adults and maintains (updates and/or revises) 75 paper publications. Paper publication sales average 13,000 each year. She works extensively with faculty and staff from many disciplines to develop curriculum and other resources and learning opportunities to youth using natural resource education in informal settings. She has served as committee chair for seven students, and committee member for 26 students from 12 departments. She has served as an investigator, co-investigator, or collaborator on grants totaling more than $27 million, primarily as the outreach coordinator and/or curriculum developer. Dr. Carroll holds a joint appointment in Agricultural and Biological Engineering where she teaches Environmental Systems Management in the Ag Systems Management undergraduate program. She has provided sessions at 402 Extension conferences, schools, workshops, short courses, and other organized educational activities for 11,800 youth and 8,600 adults since 1995.

Developing and integrating a four-legged water curriculum in architecture education in Arid Regions

Nader Chalfoun, University of Arizona
(co-author: *O. Youssef)
*Presenter - Omar Youssef, University of Arizona

The earth holds about eight million cubic miles of freshwater, most of it is stored in underground reservoirs, permanent ice, snow covers, lakes, and rivers. Although this statement implies availability of large quantities of water sources, many current desert communities are in jeopardy from lack or diminishing of water supplies for survivorship. Water and energy are fundamental components of our 21st century life, but they can no longer be considered separated. Just as the fact of producing energy consumes water, the pumping, treating and distributing of water in turn requires energy. In other words, water is an energy issue and energy is a water issue. Until today, in Architecture Education water efficiency principles have not been taught in tandem with energy conservation though strongly related. This paper describes the development of an innovative Architecture education curricula that focuses on the effective use of water in desert communities and its impact on energy consumption and building performance. The education curriculum approaches the issue of water/energy nexus through a proposed four-legged body of knowledge addressing 1) Water Harvesting, 2) Water Reduction, 3) Water Reuse, and 4) Water Energy Generation technologies. Although water harvesting and water reduction have recently become common methods in building design, water reuse and water energy generation are relatively newer technologies that demonstrates greater promise to contribute to the affordability of water and its use as alternative energy sources. The curriculum includes the environmental benefits from integrating water saving strategies to modify thermal conditions inside spaces. The modified environments would otherwise use energy to be achieved while the saved water will facilitate techniques for exterior landscape development. All technologies will include calculative methods, use of computer simulation, design monographs, and hands on inquiry based learning through laboratory sessions.

Bio: Dr. Nader Chalfoun is a Professor of Architecture and Environmental Sciences at the University of Arizona. He is regionally and internationally recognized for his work on building energy efficiency and energy performance modeling. He and his colleagues developed MRT an outdoor thermal comfort simulation model. He directs the House Energy Doctor program at the University and teaches a course sequence to architects on building energy efficiency as well as bringing these technical issues into the graduate and undergraduate curriculum. He is a prime contributor to Tucson's Sustainable Energy Standard, and a member of the Institute on Health and Wellbeing at the Arizona Center for Integrative Medicine, University of Arizona. Co-author, Omar Youssef, recently graduated with a Masters of Science in Architecture focusing on design and energy conservation. He was awarded with Best Masters Thesis for his research "Creating a Design Index for Therapeutic Architecture", and Best-in-Studio for designing the new Engineering Innovation Building. Youssef is undergoing his Ph.D. at the Arid Lands Resource Sciences as a Research Associate with a full scholarship and also the Harvill Fellowship.

One World One Water Center for Urban Water Education and Stewardship

Sandra Haynes, Metropolitan State University of Denver
(co-author: T. Cech)

Extended Abstract

Metropolitan State University of Denver (MSU Denver) is the home of an exciting new water institution – the One World One Water Center for Urban Water Education and Stewardship, or the OWOW Center (Oh, Wow, as it is fondly known). It was created in 2011 with a $1 million donation to help in the development of an educated, empowered, solution-oriented, Colorado citizenry that protects and preserves our precious water resources. In short, OWOW was created to develop "urban water stewards" from diverse backgrounds and a wide range of disciplines.

In Denver's urban environment, water stewardship and sustainability is an especially important and responsible education topic. Metropolitan State University of Denver is uniquely positioned to offer a water curriculum that promotes water stewardship and sustainability for our region because MSU Denver:

- is a large (23,000 students), urban campus adjacent to a major headwater river, the South Platte;
- has a focus on educating underserved/disadvantaged populations and has the largest number of students of color of any institution in the state;
- has alumni who largely stay in Colorado and the Denver Metro area, thereby empowering and affecting change in our region; and
- has as part of its mission as an urban institution to help the community solve community-related issues and there is no denying that water is a huge issue in the West.

The Center has three major functions designed to deepen students' understanding of water as a critical resource that must be sustained and conserved for all:

1. To offer an interdisciplinary Water Studies minor to complement a wide variety of majors;
2. To provide enriching co-curricular activities; and
3. To enhance water stewardship on and beyond campus by promoting effective use of water resources.

The current 18 credit hour minor curriculum consists of courses that cover important water topics such as hydrology, history, politics, water law, conflict resolution and negotiation. Students are guided toward experiential learning opportunities to help shape new solutions for local and statewide water issues. These experiential learning opportunities – be they internships, service learning, or volunteer contributions – focus on such issues as urban waterway restoration, education, hydro-philanthropy efforts, water law, conflict resolution, stream reclamation, conservation, etc. The Water Studies minor has attracted students from all majors on campus – including art, music, industrial design, nutrition, earth and atmospheric science, theater, teacher education, engineering technology, and many more.

Many enriching co-curricular activities have been offered for students and the general public. These events have exposed enrolled students to "real life" impacts of water resources in Colorado via conversations with those stakeholders directly affected by and involved with water policy. Leaders in the field have also been guest speakers for highly successful public events. These include Ken & Ruth Wright of Wright Water Engineers; John Echohawk, Native American Rights Foundation; Nicole Seltzer, Colorado Foundation for Water Education; David Little and Matt Bond, Denver Water; Kevin Fedarko, Author; Jorge Figueroa, Western Resource Advocates; Mike King, Colorado Department of Natural Resources; Peter Ornstein, USEPA, Region 8; Casey Davenhill, Cherry Creek Stewards; Dan Luecke, Resource Consultant; Gary Herman, irrigator; Jennifer Riley-Chetwynd, Denver Botanic Gardens; and many others.



The One World, One Water sculpture by Rik Sargent and pictured here was installed at MSU Denver in 2012. The sculpture's location is a focal point for water education and awareness-raising activities and is a symbolic representation of our vision for this curriculum.

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Bio: Dr. Sandra Haynes has served in the Dean's position in the School of Professional Studies of Metropolitan State College of Denver since 2003. Haynes's collaborative approach helped her to obtain approval for a new Hotel and Hotel Learning Center for the School's growing Hospitality, Tourism and Events Department, and she has also been involved with the planning of a new Student Success Building and redevelopment of existing space, the development of the new athletics complex, and the Aerospace Engineering Sciences Building. Other accomplishments include helping to secure a $9.5 million Teacher Quality Enhancement Grant, a $3.8 million Title III Grant to improve advising college-wide and establish a School of Education, assisting in the establishment of the regional headquarters for Teaching with Primary Sources, a venture born out of the Library of Congress's, Adventures of the American Mind project, the establishment of the accelerated nursing program, and one of the first master's degree programs in the institution, Master of Arts in Teaching. Haynes was the primary person responsible for obtaining public art, a bronze entitled, "One world, One Water", and $1 million in funding to create a progressive educational program using the sculpture as inspiration. She lead the college wide effort to establish the Center for Faculty Development, and actively participated in the revision of the college's general education program, reorganization plans, and strategic planning efforts. Haynes's dedication to diversity has led her to establish best practices in the recruitment and retention of diverse faculty. She has developed a strategic plan dedicated to ensuring inclusive excellence by instituting best practices in the recruitment and retention of diverse faculty such as strategic and pro-active advertising and creating welcoming and sustained faculty communities. In 2014, Haynes was awarded an honorary doctorate and professorship by the University of Pecs in Hungary for her work in developing international partnerships. She was a 2010-11 American Council on Education Fellow. This fellowship complements other leadership development efforts including HERS and the Harvard MDP program. She was the 2009 recipient of Metro State's President's Award for Distinguished Service and 2004 Outstanding Woman's Award for the Advancement of Education for Woman.

Quantifying the uncertainty of precipitation partitioning from soil to trees to the atmosphere: An application of Bayesian hierarchical modeling

Heather Speckman, University of Wyoming
(co-authors: D. Beverly, K. Hyde, B. Ewers)

Understanding the partitioning of precipitation into soil storage, evapotranspiration, overland and later flow and groundwater is crucial to predicting streamflow from mountainous watershed. Observational methods to quantify the movement of water through soil, air and vegetation have advanced rapidly in recent years. In the past soil moisture was measured only in one fixed point. Now it can be observed on an entire hillslope over time by utilizing permanently installed electroresitivity equipment. Sapflux measures water flow through vegetation. Eddy covariance quantifies the entire water vapor leaving the system. Past studies have used these techniques to estimate water budgets but no systematic error propagation has been applied. This study aims to unite these techniques into a model to describe water flow through the whole system. Utilizing Bayesian statistics, we can test whether prior knowledge from disparate datasets across a hierarchy of scales improves our understanding of the water budget compared to not having each dataset. Such knowledge can then be used to determine where new measurements can be focused and the level of uncertainty in resulting water out of the system. We apply these techniques to a hillslope within a subalpine forest watershed in Southeast Wyoming. Preliminary analyses show that the uncertainty of groundwater recharge, evapotranspiration and soil moisture spatial dynamics along the slope are large sources of error.

Bio: Heather Speckman is a PhD student in Ecology at the University of Wyoming under Brent Ewers. She's a native of Colorado, and earned both her Bachelors and Masters from Colorado State University before moving to Wyoming in 2013.

Estimating uncertainties in streamflow forecasts using a Bayesian multi-model and multi-product approach

Tirthankar Roy, The University of Arizona
(co-authors: A. Serrat-Capdevila, H. Gupta, J. Valdes)

Real-time monitoring and forecasting of streamflow are important applications to support an efficient management of available water resources and alleviating water-related problems. A tool that can serve these purposes, therefore, needs to have accuracy, precision and reliability levels that fall within the needs of the specific management goals it aims to support. It should take advantage of the available cutting-edge data resources as well as the benefits of advanced modeling techniques. There are several sources of uncertainty within these types of monitoring and forecasting systems, arising from model forcings, model parameters, model structure, etc. In order to make the platform efficient, these uncertainties must be quantified and reduced to the best extent possible, and the remaining uncertainties must be appropriately presented in a probabilistic forecast. This can then help decision makers gauge the amount of risk involved in their management decisions. We follow a multi-model and multi-product approach to develop a real-time streamflow monitoring and forecasting platform in African basins, which effectively accounts for different sources of uncertainty. We use multiple satellite precipitation products (TMPA, CMORPH, PERSIANN-CCS, and CHIRPHS) and multiple hydrological models (HyMod, HBV-EDU, VIC, ANNs, and ARMA models), and combine different forecasts by Bayesian Model Averaging (BMA) techniques to produce more reliable forecasts with the associated uncertainty estimates. Along this journey, we explore scientific aspects ranging from the importance of bias correction, the multi-model multi-product approach, data assimilation issues, calibration and validation, as well as fault tolerance (i.e., robustness) and reliability of the system.

Bio: Tirthankar Roy is a Ph.D. student with a major in Hydrology in the Department of Hydrology and Water Resources, The University of Arizona.

Simulating the uncertainty in surface water and ocean topography (SWOT) observations of global reservoirs

Kurt C. Solander, University of California, Irvine
(co-authors: J. Famiglietti, J.T. Reager, C.H. David, K. Andreadis)

Reservoirs represent a critical component of water resource management systems worldwide. Thus, an accurate understanding of changes in reservoir storage is important to achieve global water security. By enabling measurements of surface water inundated area and elevation for reservoir sizes exceeding 250 m^2 at a repeat orbit of up to 22-days, the NASA Surface Water and Ocean Topography (SWOT) satellite mission (anticipated launch date 2020) is expected to greatly improve upon existing reservoir monitoring capabilities. It is thus essential that spatial and temporal measurement uncertainty for different water bodies is known a priori to maximize use of SWOT observations in monitoring systems or models as data is acquired. In this study, we evaluate the spatial and temporal performance of SWOT reservoir observations using a three-pronged approach. First, we use sub-sampled in-situ reservoir storage observations for three size classes within the expected range of global SWOT repeat orbits and convert these records to monthly values to determine if signal aliasing will be a problem. Second, we simulate virtual SWOT observations of reservoirs using the SWOTsim instrument simulator to examine the influence of different theoretical reservoir spatial characteristics on SWOT observations and simulate measurements of California reservoirs covering three size classes. Lastly, we explore the use of SWOT reservoir observations in the calibration of large-scale reservoir models using the recently created RES-ADAPT model as a test case. Results indicate subsampling errors to be less than 5% for the smallest size classes.

Bio: Kurt Solander is a PhD Candidate in the Department of Earth System Science at the University of California, Irvine. His research involves reservoir modeling and analysis of the NASA Surface Water and Ocean Topography (SWOT) satellite mission observation of reservoirs. He hopes to better understand the hydroclimatic changes due to reservoir management, particularly under a changing climate, and aims to determine how SWOT will improve our reservoir monitoring capabilities towards this purpose. Kurt received his B.A. in Earth and Planetary Sciences and Environmental Studies from Washington University in St. Louis and an M.S. in Hydrologic Sciences from the University of Nevada, Reno. Prior to returning for his PhD, Kurt held positions in the private sector as well as the state and local government in water quality and regulatory compliance where he worked on a number of projects in the mining, agriculture, forestry, and oil and gas industries.

Soil and Water Assessment Tool (SWAT) applicability in mountainous watershed on nutrients loadings' prediction in Lower Bear Malad Watershed, Utah

Ali Salha, Utah State University
(co-author: D. Stevens)

The application of watershed simulation models is indispensable when pollution is generated by a nonpoint source. These models should be able to simulate large complex watersheds with varying soils, land use and management conditions over long periods of time. This study presents the application of Soil and Water Assessment Tool (SWAT) to investigate, manage, and research the transport and fate of nutrients in (Subbasin HUC 16010204) Lower Bear Malad River (LBMR) watershed, Box elder County, Utah. Water quality problems arise primarily from high phosphorus and total suspended sediment concentrations that were caused by increasing agricultural and farming activities and complex network of canals and ducts of varying sizes and carrying capacities that transport water (for farming and agriculture uses). Using the available input data (Digital Elevation Model (DEM), land use/Land cover (LULC), soil map and weather and climate data for 20 years (1990-2010) to predict the water quantity and quality of the LBMR watershed using a spatially distributed model version of hydrological ArcSWAT model (ArcSWAT 2012.10_1.14). No previous studies have been found in the literature regarding an in-depth simulation study of the Lower Bear Malad River (LBMR) watershed to simulate stream flow and to quantify the associated movement of nitrogen, phosphorus, and sediment. It is expected that the model mainly will predict monthly mean total phosphorus (TP) concentration and loadings in a mountainous LBRM watershed (steep Wellsville mountain range with peak of (2,857 m)) having into consideration the snow and runoff variables affecting the prediction process. The simulated nutrient concentrations were properly consistent with observations based on the R^2 and Nash- Sutcliffe fitness factors. Further, the model will be able to manage and assess the land application in that area with corresponding to proper BMPs regarding water quality management.

Bio: Ali A. Salha is a professional water and environmental engineer with solid procurement experience. He holds a bachelor degree in Civil Engineering and master degree in Water Resources Engineering from Palestine and currently is a research assistant (Ph.D.) in Environmental Engineering at Utah Water Research Laboratory in Utah, USA. Mr. Salha's research interests are hydrological studies, surface and groundwater quality modelling, dataset collection/analyzing, GIS Applications, watershed management, and assessment of land applications, WWTPs, agriculture impacts on streams/ rivers water quantity and quality using aided computer programs (e.g GIS, ArcSWAT, HEC-RAS, and Optimization). Mr. Salha's career experience focused on managing and implementing international /national projects in water and sanitation infrastructure. In addition, Mr. Salha enjoys carrying out Tutoring Services (performed for utilities in MENA and Eastern Africa regions) in fields of water revenues, sanitation, governance and land degradation. Mr. Salha believes that learning how to spin past career experience beside new knowledge would put him up for the next job challenge.

Creating a virtual water complement to the Colorado River Basin: How is the Colorado River actually shared among the seven basin states?

Richard Rushforth, Arizona State University
(co-author: B. Ruddell)

For many rivers in the western United States, the legal allocation of surface water rights were settled decades ago. The process of apportioning surface water between multiple stakeholders, in this case states, can be an arduous process wrought with conflicting values competing for scarce water. Often, once water allocations have been set, they will not be revisited because the political capital to re-allocate cannot be recovered. Take the Colorado River Compact, signed in 1922, which has been the law of the river for over 90 years. Since its signing, the population of the Colorado River Basin states has increased tenfold, while average flows have decreased due to threats unforeseeable to Compact signers, such as global climate change. Legal doctrines, like the Compact, govern the physical flow of water, but as economies have become more integrated water has become increasingly shared through the trade rather than aqueducts. States are no longer solely dependent on large volumes of physical water supplies to produce economic value. Through this lens, virtual water, or the water embodied by a good or service, can be viewed as a trade adaptation to limited factors of production, namely water and land, or regulations, such as air emissions regulations, and complementary to physical water resources. This study presents findings of an initial virtual water complement to the Colorado River Compact. The goal of this study is to determine how the allocation of physical water resources compare to virtual water resources in a shared river basin. Results for all sectors of California's economy will be presented, divided into northern and southern California, showing the geographic origin of virtual water from Colorado River basin states and the Upper and Lower basin. A water stress index will be calculated to show the systemic water stress of California's physical and virtual water resources.

Bio: Richard Rushforth is PhD student at Arizona State University in the School of Sustainable Engineering and the Built Environment. He is a published author on ecological, carbon, and water footprinting and has several water footprinting articles currently under review. His dissertation research focuses on understanding and optimizing water footprint trade networks and developing value-based metrics for environmental planning.

Vegetation canopy cover effects on sediment and salinity loading in the Upper Colorado River Basin and policy implications, Price and Ferron, Utah

Erik Cadaret, Desert Research Institute - Division of Earth and Ecosystem Sciences
(co-authors: K. McGwire, R. Blank, L. Saito, M. Weltz)

The Price River contributes only 1% of the water but 3% of the total dissolved solids in the Colorado River. To investigate mechanisms driving salinity loads in the Price river basin we are focusing on the saline and sodic soils associated with the Blue Gate member and Tununk member of the Mancos Shale formation. Rainfall simulations have been performed at two study areas across a variety of slope angle and rainfall intensity to evaluate the effects vegetation has on salinity and sediment concentration in runoff. Results of these simulations will be used to parameterize the dynamic Rangeland Hydrology and Erosion Model (RHEM) for saline and sodic soils of the Price rangeland areas and to assess the feasibility of mitigation strategies for reducing salt loads to the Colorado River. We discuss how our ongoing field efforts can be integrated with data from the U.S. EPA water BASINS GIS package on land ownership, land use management, and current environmental policy to address pressing water quality issues in the Upper Colorado River Basin.

Bio: Erik Cadaret is a second year graduate student working on completing his masters in hydrogeology and graduate minor in business administration. He is passionate about education and helped create a class at the University of Nevada Reno called STEM Education Outreach Experience that guides students through STEM education standards and how to make a lesson plan. The class also requires students to go out and tutor/be a teaching aid in local schools. His career goals are to work internationally on environmental and water/WASH development projects, collect cool rocks (geology!), teach math and science in Title-I schools wherever he lands up, create small businesses specifically to help women transition out of sex trafficking, and mentor students to be successful and reach their full potential.

Using conceptual ecological models as a framework to guide decision making for the LCR MSCP

Sonja Kokos, Lower Colorado River Multi-Species Conservation Program
(co-authors: R.S. Unnasch, D.P. Braun, C.J.W. McClure)

The Lower Colorado Multi-Species Conservation Program is developing conceptual ecological models (CEMs) for its covered species. CEMs are widely recognized and utilized in natural resource management and structured decision making, as they provide a clear framework for guiding management actions. CEMs were developed for southwestern willow flycatcher, yellow-billed cuckoo, and razorback sucker at the end of 2014, in which a collection of hypotheses, such as species' life cycles, species habitat requirements and limitations, the factors that control the abundance, spatial and temporal distribution, quality of these habitat conditions, and the causal relationships among them, were compiled. The level of understanding these elements and how they relate vary, with a high level of certainty in some cases, and a great deal of uncertainty in others. CEMs collectively and individually provide managers with: 1) a record of the current knowledge and level of uncertainty; 2) critical areas of uncertain or conflicting science; 3) crucial attributes to use while monitoring and predicting the effects of experiments and management actions; and 4) how characteristics of a resource are expected to change as a result of altering its shaping/controlling factors, including those resulting from management actions. Through the development and implementation of the CEMs, the LCR MSCP will reduce costs of research and monitoring and improve its science based management in Conservation Areas.

Bio: Sonja Kokos manages the Adaptive Management Program for the Bureau of Reclamation's Lower Colorado River Multi-Species Conservation Program (LCR MSCP). The LCR MSCP is a Endangered Species Act (ESA) Section 7 and Section 10 compliance program for Reclamation's river operations and maintenance activities on the lower Colorado River, and includes partnerships with 57 federal, state, and local agencies. Sonja ensures all aspects of the program are done in a scientifically rigorous, biologically effective, and cost efficient manner. She manages development of a data management system to house all program data and ensures its accessibility. She is also directing the development of conceptual ecological models for the species covered by the program to help guide future management decisions. Sonja has presented on the conceptual ecological models and data management at various meetings, such as, the Colorado River Terrestrial and Riparian Group in Nevada, Desert Landscape Conservation Cooperative in Mexico, and Pacific Northwest Aquatic Monitoring Program in Oregon. Prior to working at LCR MSCP, she worked for the Clark County Desert Conservation Program which oversees ESA Section 10 compliance for development in Clark County, Nevada where she developed spatial models for decision making for several federal and local agencies. She has also worked as the field station manager for the University of Nevada, Reno, managing research and monitoring projects for the US Fish and Wildlife Service and other agencies. Her interests are in developing spatial tools and other tools that provide for transparent data driven management decisions.

The diffusion of process innovation: The case of drip irrigation in California

Rebecca Taylor, University of California, Berkeley
(co-author: D. Zilberman)

This article uses drip irrigation to illustrate the evolution of process innovations during their diffusion—undergoing several waves of improvements and coevolution with other production practices in order to move across applications and locations over time. First, we integrate multiple data sources to trace the rich history of drip in California. We find that drip's evolution has been consistent with 1) the threshold model, which emphasizes the tendency to first adopt a technology at locations where it is most valuable and 2) the real option value model, which suggests that crisis situations trigger major transitions. We highlight the role of the private and public sector in adapting process innovations to local needs and show the necessity of historical analysis and perspective in assessing a technology's impacts. Second, we empirically investigate the productivity impacts of drip irrigation in California, focusing on changes in crop yields and farm income. We estimate a yield effect of drip ranging from 16-60%, depending on the crop and location, and an increase in farm income between 2.5-10.7% annually. On whole, we show that the diffusion of drip was gradual, Cooperative Extension was essential, and the gains for California agriculture were substantial.

Bio: Rebecca Taylor is currently pursuing a PhD in Agricultural and Resource Economics at the University of California, Berkeley. Her graduate work is generously supported by the National Science Foundation's Graduate Research Fellowship. She received her undergraduate degree in Economics from Washington and Lee University. From 2009 to 2011, she worked as a research assistant at the Federal Reserve Board of Governors in Washington, DC. During the summer of 2012, she worked in the Statistics Division at the Food and Agricultural Organization of the United Nations in Rome. Her research interests fall under one or many of the following categories: agricultural and environmental policy, economics of innovation, policy analysis, and behavioral economics.

Climate and choice of irrigation technology

Ting Bai, University of Arizona
(co-author: G. Frisvold)

Because studies of irrigation technology adoption often concentrate on small geographic areas with the same climate, few have estimated effects of climate on irrigation technology choice. They can say little, then, about how growers may adapt to climate change through irrigation technology choice. This study examines the choice of sprinkler versus gravity-flow irrigation across 17 western states using a special tabulation of USDA's Farm and Ranch Irrigation Survey. Analysis considers how climate and other factors affect irrigation choice. Sprinkler adoption increases with reliance on groundwater, water costs, agricultural wages, and an erosion index that captures effects of rainfall, field slope, and soil water-holding capacity. Sprinkler adoption was significantly lower for smaller farms. In colder areas, climate warming may lengthen the growing season, but increase susceptibility to frost during the expanded growth period, which may encourage sprinkler adoption. In warmer areas, there is less scope to adapt to warming by switching from gravity to sprinkler technology. Sprinkler adoption declines monotonically in Spring/Summer temperature and growing-season-adjusted Fall/Winter temperature. A drier climate would reduce sprinkler adoption, while climates with more rainfall and more intense rain events may see greater adoption.

Bio: Ting Bai is an MS student in the Department of Agricultural & Resource Economics, University of Arizona.

Irrigator demand for water management information

Ting Bai, University of Arizona
(co-author: G. Frisvold)

This study examines factors affecting the number and types of information that irrigators use for water management decisions. It also examines adoption of informal and scientific methods to schedule irrigation applications. The study makes use of a special tabulation of USDA's Farm and Ranch Irrigation Survey for 17 western states. Larger operations (in terms of sales) were more likely to use irrigation management information from any given source. Reliance on lower-cost sources of general information was more common, while larger operations relied more on private, tailored sources of information. Smaller farms were less likely to investigate irrigation improvements or to use management-intensive methods for irrigation scheduling. Larger operations were more likely to use data provided more directly (e.g. media and Internet reports) than smaller operators, who relied more on information provided by intermediaries. One striking result is that no single information source was used by more than half of irrigators. There is no "one-stop shopping"' information source for irrigation management. For federal agencies and extension, this means that most irrigators are not accessing their directly provided information. Public entities may have to consider delivering information both directly and indirectly. Extension may need to target news media, trade journals, irrigation district managers, and input suppliers as clientele. These sources can serve as 'retail outlets' for extension messages that irrigators fail to access directly.

Bio: Ting Bai is an MS student in the Department of Agricultural & Resource Economics, University of Arizona.

Estimation of spatial surface soil moisture by assimilation of Landsat vegetation indices and METRIC energy balance products using relevance vector machines

Alfonso Torres-Rua, Utah Water Research Laboratory
(co-authors: A. Ticlavilca, R. Bachour, M. McKee)

Spatial surface soil moisture is important for agriculture, but its estimation for the purposes of field management remains challenging due to the cost of direct measurement methods and the complexity of feedback processes of atmospheric, vegetation, and soil characteristics. While previous research on surface soil moisture using remotely sensed data based on surface energy balance, weather parameters, and vegetation indices have demonstrated their relationship to soil moisture, soil moisture spatial quantification is still unavailable for use in water and agricultural management activities. In this study, a methodology to estimate volumetric soil moisture is presented that uses Landsat vegetation indices, energy balance products, and weather data as predictors. This methodology employs a statistical learning machine called the Relevance Vector Machine (RVM) to relate the predictors to soil moisture by means of stratified cross-validation and forward/backward elimination. Soil moisture measurements from agricultural lands in Central Utah for the 2012 irrigation season, along with weather, vegetation indices, and energy balance products from the Mapping Evapotranspiration at High Resolution with Internalized Calibration (METRIC) algorithm, were used. The methodology, data, processing, and estimation accuracy are also discussed.

Bio: Dr. Alfonso Torres-Rua is a Research Engineer at Utah Water Research Laboratory, Utah State University.

Developing local watershed capacity: Essential leadership skills and effective training approaches

(Part I) Joe Bonnell, Ohio State University
(Part II) Lois Wolfson, Michigan State University
(Part III) Ann Lewandowski, University of Minnesota

Management of water resources at a watershed scale often occurs at the local level and relies on the effectiveness of local staff and leaders. Management at the local level is essential for water quality and quantity concerns. Individuals taking on this role must not only have expertise in the natural sciences, but must have skills in policy, leadership, administration, communication and collaboration. They must also be able to integrate these skills to solve problems. Several land grant universities are delivering watershed education and leadership training aimed at building these core skills. Online delivery has been an important training mode to meet the needs of working professionals dispersed across a state, but it has required trainers to examine how to best use online tools in conjunction with more traditional training modes. In this session we describe which core skills and competencies are essential in becoming a successful watershed leader, how four universities have approached this training, and how to effectively use various training methodologies. The first presentation will focus on the results of two research projects investigating core skills of watershed group leaders and will include the development of a conceptual framework for understanding effective watershed leadership and themes that emerged from analysis of the interview data. The second presentation will compare and contrast the Watershed Leadership programs developed at four Universities, including the range of topics; delivery approaches, from entirely online to in-person classes; costs; and evaluation of the students and the programs. The final talk will focus on various instructional approaches and methods in the programs, discussing ways to use online training effectively for professional audiences, and providing examples of unique and innovative aspects of the courses.

Bio:

Dr. Lois Wolfson is a Water Quality Specialist at the Institute of Water Research (IWR) and Department of Fisheries and Wildlife at Michigan State University (MSU). She directs the technology transfer and outreach program for the IWR; represents MSU on the North Central Region Water Program team, and provides leadership for water related programs for Extension, including aquatic plant ecology, harmful algal blooms, invasive species, water withdrawals, and lake management.

Dr. Joseph Bonnell is an Adjunct Assistant Professor and Program Leader in the School of Environment and Natural Resources at the Ohio State University. He is responsible for developing, delivering, and evaluating extension outreach programs aimed at addressing nonpoint sources of pollution, watershed management, and other natural resource management issues. His area of expertise includes human dimensions of watershed management and outreach program development and evaluation.

Ann Lewandowski is a Research Fellow at the University of Minnesota Water Resources Center. She coordinates research and outreach activities related to agriculture and water quality. She also manages the Watershed Specialist Training program for water resource professionals around the state.

Water runs through it: Educating the public about the food-water-energy nexus using online tools

Robin Madel, GRACE Communications Foundation

A major step in effectively managing our water resources is educating the public about the interconnections between water, food and energy systems. This is especially important given the extreme levels of drought that have affected the country in various agricultural and industrial regions over the last decade. Major problems arise when people (including system-level managers) perceive these three systems as isolated concepts and don't understand how the systems impact one another. In particular, research has shown that many people underestimate their water use, and may not feel that they need to conserve even if they are proponents of water conservation. Helping individuals understand their water use is a crucial first step toward educating them about the water, food and energy nexus. An educated public should demand more from their leaders in balancing how water is distributed and used in farming, industry and power production versus municipal and environmental settings. Greater public understanding allows leaders to make difficult decisions regarding resource allocation and planning that affects peoples' lives. GRACE Communications Foundation has developed online materials and tools to help people understand how each system impacts, and is impacted by, the others. GRACE accomplishes this, for example, by illustrating how diet, energy use and resource consumption impact water footprints. Specifically, GRACE's Water Footprint Calculator not only gauges direct water use but also illustrates virtual water use by asking questions about diet, driving and shopping habits, recycling and other behaviors and choices. This discussion will highlight GRACE's Water Footprint Calculator and associated content, and review lessons learned from efforts to help the public understand the food, water and energy implications of their daily decisions.

Bio: Robin Madel is a Senior Research and Policy Analyst for GRACE Communications Foundation. She focuses on educating consumers about sustainable food, water and energy systems and the interconnections between those systems. She has an M.S. in Environmental Science and Engineering from the Colorado School of Mines, a B.S. in Civil Engineering and a B.A. in Geological Sciences, both from the University of Colorado, Boulder. She worked on treatability studies and closure projects at the Rocky Flats Environmental Technology Site and worked in communications for the city of Boulder's Public Works Department. She writes and takes a lot of photos of water for Ecocentric blog.

"I'm feeling lucky": The impact of making water resources research freely available

Andrea Wirth, Oregon State University

The interdisciplinary nature of water resources research is readily apparent in the literature of the discipline. For experts and novices alike there is an overwhelming number of journals, across numerous domains, that publish on "water resources" making discovery of research results difficult for those who either do not have access and/or the training to navigate successfully. Simultaneously, more people are utilizing Google Scholar as their window to research articles even though following a link in Google Scholar may lead only to an abstract and a paywall. However, when articles are freely available as well as indexed by sites such as Google Scholar, the barrier is reduced. Authors use a variety of options to make their work freely available to other scholars and people outside of the academy, thus facilitating better access to research. Additionally, authors at academic institutions or those with federal grants may find themselves compelled to make their work openly available due to a growing number of policies supporting public access to research. While different institutions and agencies have varied requirements in regard to implementing public access, there are three primary methods of sharing research articles openly: publishing in an open access journal, publishing in a traditional subscription-based journal and paying to make the article open, or making a version of the work available in a repository. This paper will review 5 years of water resources literature as indexed by the Web of Science to determine which variety of open access is the most utilized by the authors of those papers and the citation trends of each. This analysis combined with insights into providing public access to research will be informative to both producers and consumers of water resources research.

Bio: Andrea Wirth is a Science Librarian and Associate Professor in the Center for Digital Scholarship and Services and the Teaching and Engagement Department at Oregon State University Libraries and Press. Her areas of expertise and interest include collection development and management, scholarly communication, and support for students and faculty in the earth and environmental sciences. In the Center, Andrea is part of a team that facilitates the addition of OSU research articles to the institutional repository, consults with faculty on OSU's Open Access Policy, and serves as a member of the Collection Development Council. As a member of the Teaching and Engagement Department, Andrea contributes to the overall instruction program of the OSU Libraries.

How to reconcile benefit cost analysis and integrated water resources management

Jonathan Yoder, Washington State University
Ari Michelsen, Texas A&M Agrilife Research and Extension Center at El Paso
Christopher Lant, Utah State University

As defined by the Technical Committee of the Global Water Partnership, Integrated Water Resources Management (IWRM) is a process that promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare without compromising the sustainability of ecosystems and the environment. Operationally, IWRM approaches involve applying knowledge from various disciplines as well as the insights from diverse stakeholders to devise and implement efficient, equitable and sustainable solutions to water and development problems. Often, to achieve stakeholder consensus, IWRM plans involve multiple projects.

Benefit Cost (B-C) principles require individual analysis of each of separable (independent) projects. This by itself poses no conflict with IWRM where each of the independent projects meets B-C criterion, that is, the B-C ratios are at a minimum greater than 1.0. However, there is a conundrum between IWRM and B-C when some of the separable projects included in an IWRM plan do not meet minimum B-C criteria. Economically disqualifying or thereby eliminating these projects from an IWRM plan can disenfranchise some of the stakeholders possibly resulting in collapse of IWRM plan agreement. As more succinctly said by Michael Campana (2015), "*What if, to obtain consensus on an IWRM-based plan, it's necessary to include some plan components that are, in economic terms, 'BCA [benefit-cost analysis] dogs'? If the 'dogs' are excluded, then the plan goes down the tube and square one looms large. If they're included, then funding might be at risk and the plan also goes down the tube.*"

An example of this quandary is the Yakima Basin Integrated Plan (YBIP), an integrated water resource management plan proposed for the Yakima Basin in South Central Washington State to help resolve decades of stakeholder issues. The Plan is intended to provide additional water storage to provide water security for instream and diversion benefits via several surface and aquifer storage projects, fish passage projects and habitat restoration for salmonid populations in the basin, and other related projects. A 2012 BCA of the entire YBIP compared to no-YBIP yielded overall B-C ratios greater than 1.0. However, results from a separate 2015 study mandated by the State of Washington Legislature to look at the separable component parts found that a number of the components would not satisfy B-C criterion in their own right.

When B-C criterion are not satisfied of separable projects included in an IWRM raises important policy questions and issues which may impede or prevent successful implementation of IWRM programs. The objective of this panel session is to examine these two elements of what can become a quandary in IWRM: (a) Under what conditions can there be a disconnect between IWRM and satisfaction of B-C tests for integrated plan components, and (b) to what extent, and under what circumstances is the imposition of a B-C criterion on component parts of an IWRM plan valid or informative? How can these issues be reconciled? The panel will include extensive panel/audience discussion.

Bio:

Jonathan Yoder is a professor in the School of Economic Sciences at Washington State University and Director of the State of Washington Water Research Center.

Ari Michelson is a professor of Agricultural Economics and Research Director of Texas A&M AgriLife Research and Extension Center at El Paso.

Christopher Lant is a professor and head of the Department of Environment and Society, Quinney College of Natural Resources, at Utah State University. He is the former Executive Director of UCOWR.

What we know, what we don't know, and what we need to know about unconventional oil and gas extraction

Mark Williams, University of Colorado

The current energy system in the United States relies on finite resources that are the major cause of climate change and a key source of global conflict. A sustainable energy system – one that uses renewable, low-carbon, affordable, and local energy sources – may be decades away. Natural gas is seen as the "bridge fuel" to a more sustainable energy system because natural gas combustion emits smaller amounts of greenhouse gases than coal combustion. However, conflicts have arisen between accelerated natural gas development and water and air resources protection. These conflicts are becoming acute in the Rocky Mountain region, which has always played an important role in the energy system of the United States. Here I present the vision and current research results from a large, integrated research activity funded by the National Science Foundation to address these conflicts. The mission of this Sustainability Research Network is to provide a logical, science-based framework for evaluating the environmental, economic, and social trade-offs between development of natural gas resources and protection of water and air resources and to convey the results of these evaluations to the public in a way that improves the development of policies and regulations governing natural gas and oil development. Our goal is to find the balance between maximizing the development of natural gas and oil resources – for the benefits of short-term reduction of carbon dioxide emissions from power generation and transportation, national energy independence, and national job growth – and minimizing damage to water and air resources and risks to human health. We fund 27 senior scientists; 35 graduate students, and 9 institutions. We'll chat about what we've learned over the last two and a half years.

Bio: Dr. Mark Williams, Fellow at the Institute of Arctic and Alpine Research and Professor of Geography, at the University of Colorado, received his Ph.D in Biological Sciences with an emphasis in ecology from the University of California at Santa Barbara in 1991. He is also on the core faculty of Environmental Studies. His research interest is the ecology of mountain areas, looking at the interaction of organisms with their environment, focusing on classical environmental variables such as soil, rocks, and minerals as well as surrounding water sources and the local atmosphere. Mark has current or past research activities in many of the mountain ranges throughout the world, including the Rocky Mountains, Sierra Nevada of California, the Tien Shan and Qilian Shan, China, Andes of South America, European Alps, and the Himalayas. Mark is on the faculty of the Hydrology Program in Geography and his classes can be used to satisfy the Hydrology Certification Program in Geography. Mark is the PI of the Niwot Ridge LTER program and a co-I on the research project: Contribution to High Asia Runoff from Ice & Snow (CHARIS). He was elected a Fellow of the American Geophysical Union in 2012. He was a Fulbright Scholar in Ecuador in 1999 and is a current Fulbright Scholar in Nepal for 2013-2014.

Water/land/energy nexus for unconventional energy in Texas

Michael Young, Bureau of Economic Geology, The University of Texas at Austin
(co-authors: J. Nicot, B. Scanlon, J.P. Pierre)

We focus on an aspect of the water-energy nexus that is discussed nearly daily in the media, specifically the use of hydraulic fracturing to produce natural gas and oil from shale and tight sandstone formations. Our focus is on experiences in Texas. The recent growth of exploration from these formations has yielded substantial quantities of natural gas and liquids (oil and gas condensates), benefiting the US economy in many ways and reducing energy-related CO_2 emissions. These changes have become possible because of the development and widespread use of horizontal well drilling and hydraulic fracturing technologies. In Texas, since 2005, more than 31,000 horizontal wells have been drilled and stimulated using hydraulic fracturing, with the Barnett (Ft. Worth area; 14,337 wells), Eagle Ford (south Texas; 10,116 wells) and Permian Basin (west Texas; ~6500 wells) representing the bulk of the exploration. This increase in energy recovery comes at a cost to the environment, however, especially in the areas of water and land use. For example, the median water volume used to stimulate each well in the Barnett play traditionally has been ~10,600 m^3 (2.8 Mgal), but more recently has increased ~17,000 m^3 (4.5 Mgal) because of increases in lateral lengths; the volumes per well are similar in other plays. Flowback and produced (F/P) water volumes differ between plays. F/P water in the Barnett can exceed 100% of water used in stimulation, but is generally around 20% in the Eagle Ford. Research is ongoing to reuse this F/P water for ongoing drilling activities and other beneficial uses. Land impacts from above-ground activities (well pads, pipelines, truck traffic, etc.) can also be significant. In the Eagle Ford, where a study was just completed, we show large reductions in larger core areas (>2 km^2) and increases in landscape patches, mainly from pipeline construction and related infrastructure. In La Salle County alone, about 3% of the land area has been disturbed, but a 14% of the larger core areas were lost. These issues will be discussed, as well as suggestions for reducing impacts to water and land resources.

Bio: Dr. Michael Young is Associate Director for Environmental and Senior Research Scientist at the Bureau of Economic Geology, Jackson School of Geosciences, University of Texas at Austin. In this capacity, he coordinates research programs for a group of ~25 scientists involved in a variety of research spanning energy/water issues, geological sequestration of CO_2, groundwater recharge processes, water quality and resources, coastal processes and geological mapping. Dr. Young has authored or co-authored over 60 peer-reviewed journal articles, several book chapters, more than 100 presentations at scholarly meetings and many other technical reports. He currently serves as Editor of the Vadose Zone Journal and on numerous other committees in scholarly organizations. His personal research interests and experiences include water/energy nexus; soil/water/plant interactions and solute transport in arid vadose zones; groundwater recharge; and the connection between water resources, landscape development, and human interactions. Previously, he served as the Acting Executive Director of the Division of Hydrologic Sciences (he was also Deputy Director for 5 years), Desert Research Institute, in Nevada. He left DRI with the academic rank of Research Professor. He held assistant and senior research scientist positions at the University of Arizona and Georgia Institute of Technology, respectively, between 1995 and 2000, and has more than 25 years of professional experience. Dr. Young received his B.A. and M.S. degrees in Geological Sciences at Hartwick College (Oneonta, NY, 1983) and Ohio University (Athens, OH, 1986), respectively, with a specialty in Hydrogeology at Ohio University. He earned his Ph.D. in Soil and Water Science (specializing in soil physics and hydrology) from the University of Arizona, Tucson in 1995. While at Arizona, he was named Research Specialist of the Year in the College of Agriculture.

Oil production and water quality: An econometric evaluation of hydraulic fracturing

Duran A. Fiack, University of California, Santa Cruz
(co-authors: C. Speir, A. Mamula, B. Haddad)

In recent years, fossil fuel production from hydraulic fracturing and other unconventional methods of hydrocarbon production within the U.S. has increased domestic oil production, but also raised serious questions regarding their effects on water quality. In this paper, we estimate an econometric model that relates observed levels of oil production to water quality in several important watersheds in southern California. Our study area is the southern California coast, which lies atop the Santos shale. Oil production using hydraulic fracturing in this area occurs in close proximity to critical habitat for endangered steelhead fish populations. We estimate a regression model with observed water quality, measured by concentrations of total dissolved solids (TDS), aluminum, and benzo(b)fluoranthene, as a function of upstream oil production. The results of the estimated models suggest that oil production in the south coast region of California does not increase observed levels of TDS, aluminum, or benzo(b)fluoranthene in watersheds located in California's south coast region.

Bio: Duran Fiack is a Ph.D. student in the Department of Environmental Studies at the University of California, Santa Cruz (UCSC). He holds a M.Sc. in Agricultural and Resource Economics from the University of California, Davis and a B.A. from the California State University, Sacramento. Duran's research interests include California water and energy policy. As a fellow of the Center for Stock Assessment Research, a partnership with the National Marine Fisheries Service and UCSC, his research investigates the water quality impacts of energy production in California, particularly in areas where hydrocarbon production occurs within close proximity to critical habitat for federally protected fish species. Such research will improve our understanding of the potential impacts that shale oil and gas development will have on California water users and the environment, and will benefit policymakers, environmental interests and economic stakeholders, by establishing linkages between hydraulic fracturing and impacts to water resources in the state.

Tools for improved in-pit dewatering optimization

Jay Dixon, Kinross-Round Mountain Gold

In-pit dewatering can be one of the most significant challenges in modern-day open pit mining. Mining around critical dewatering infrastructure requires careful planning and coordination. Round Mountain Gold recently implemented strategies that have helped optimize engineering, planning and permitting associated with the management of its in-pit dewatering system. We have found that managing the dewatering system similar to how a utility manages its distribution system has led to better planning and optimized designs of pipes, lift stations and pumps. The first step in this process was the development of a hydraulic model, which serves as the basis for future planned and unplanned changes in the network. On the permitting side, a recent conversion to a 'Super Permit' has allowed for more effective management of multiple permitted points of diversion in accordance with Nevada Water Law. This process has significantly reduced the time spent managing several 'temporary' water rights and provided for more operational flexibility when wells, drains and sumps need to be constructed inside the pit.

Bio: Jay Dixon, PE, WRS - Principal Hydrologist at Round Mountain Gold

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Making your research useful for decision makers: Why it is difficult and what you can do about it

Elizabeth McNie, University of Colorado, Boulder

Research in science policy has demonstrated consistent challenges in effectively linking environmental science with decision making. Some of these challenges are due to different cultures, epistemologies and priorities that separate science from policy. But one underlying challenge relates to the fact that most environmental-science research is undertaken in a mode consistent with a linear model of science policy, one that elevates the purpose and value of knowledge inquiry over the relevance of knowledge to inform decision making. Moreover, scientists often believe that if decision makers had more knowledge they would make better decisions, when in fact more research, that lacks relevance to the policy problem, fails to adequately inform decisions. This presentation will identify some of the challenges inherent in undertaking policy-relevant research and then explore ways that scientists and their organizations can re-shape their research agendas and organizational processes in ways that can increase the relevance and social value of the knowledge they produced.

Bio: Elizabeth McNie is a research scientist with the Western Water Assessment at the University of Colorado Boulder. She studies how to make scientific information useful for decision makers, how to shape research design, and how to build boundary organizations that link science and society.

Water resource management and tree-ring based reconstructions of hydroclimate in Northern Utah

Matt Bekker, Brigham Young University

The Wasatch Front in northern Utah is one of the largest and fastest-growing metropolitan areas in the semi-arid Intermountain West, and is largely dependent on snowmelt-fed streams to provide critical water resources. Yet, short instrumental records and complex interactions among climate drivers at different spatial and temporal scales hamper our understanding of hydroclimatic variability, and therefore our ability to appropriately assess risk of extreme events for water resource management in this region. Over the past four years, the Wasatch Dendroclimatology Research (WADR) Group has developed an extensive network of tree-ring chronologies covering the entire Great Salt Lake (GSL) watershed, and has partnered with all of the major water management agencies along the Wasatch Front in order to connect hydroclimatic reconstructions with water resources management. The chronologies have been used to successfully develop centennial-to millennial-scale reconstructions of major Wasatch Front rivers (Bear, Weber and Logan) as well as GSL Levels. The reconstructions indicate that many extreme dry and wet periods affected all of the Wasatch and western Uinta Mountains, but suggest some watershed-scale events as well. As is commonly the case in the western US, they also indicate extreme dry and wet events that were much greater in magnitude than anything during the post-1900 record. In particular, a 1,200-year reconstruction of the Bear River developed from Utah juniper shows a period of reduced streamflow during the Medieval Warm Period (ca. mid-1200s CE) that persisted for approximately 70 years. Recent research indicates a close association between the GSL elevation and a peculiar climate mode called the Pacific Quasi-Decadal Oscillation (QDO), and a statistical model based on this relationship was able to replicate and forecast turnarounds in the GSL elevation. A forecast of the GSL elevation out to 6 years based on this model also verified well with post-2005 observations. These efforts to combine extensive tree-ring records, climate dynamics, and empirical forecasting are providing new insights into drivers of northern Utah's hydroclimate, and improving risk assessment of extreme events.

Bio: Matt Bekker is Associate Professor of Geography at Brigham Young University in Utah. He specializes in applications of tree-ring analysis in reconstructing hydroclimatic variability as well as other environmental and ecological processes and disturbances. He is a member of the Wasatch Dendroclimatology Research (WaDR) group, an interdisciplinary team of researchers with the goal of expanding the spatial and temporal coverage of tree-ring data sets in the Intermountain West to inform hydroclimatic understanding and water resources management. He received a Ph.D. in Geography from the University of Iowa and M.S. in Geography from Penn State University.

Providing climate services in Alaska: A case study in creating versatile snow projections

Stephanie McAfee, University of Nevada, Reno
(co-author: J. Littell)

Alaska is on the forefront of climate change and so adaptation planning is underway. Managers and decision makers in a number of sectors are already thinking about how changes in temperature and precipitation might impact them, but a critical piece of information was missing: changes in snow. Nearly every stakeholder group, from water managers and transportation supervisors to the recreation industry is concerned about snow. This diversity of stakeholders translated to a range of needs, and data limitations posed significant technical challenges. We faced the question of how to develop a set of high-resolution snow projections that were scientifically sound, credible, consistent with temperature and precipitation projections already in use, suitable for scenario planning, adaptable to multiple needs, and that would be widely used. Meeting this broad range of goals required resourceful scientific thinking, established personal and institutional relationships, and a willingness to engage in on-going work with stakeholders.

Bio: Stephanie McAfee is an Assistant Professor of Geography at the University of Nevada, Reno. She previously worked for the University of Alaska Fairbanks from the USGS Climate Science Center office and for The Wilderness Society's Anchorage office. Jeremy Littell is the Lead Research Scientist at the Alaska Climate Science Center.

Some practical guidelines for science/decision-making collaborations

Connie Woodhouse, University of Arizona
(co-authors: D. Ferguson, J. Rice)

How can we do a better job of both generating useful science, and incorporating relevant science into water resource planning for improved management? It has become increasingly obvious that traditional academic research often does not produce knowledge that is relevant and useful for solving real word problems, while knowledge needs of resource managers often go unmet. A number of efforts are now addressing this disconnect, and we have learned some useful lessons that can promote interactions between producers and users of information that enhance informed decision making. This talk outlines a set of guidelines that have been developed through practical experiences of both scientists and water resource managers in three cities in the western US who have successfully collaborated with each other. These guidelines, or heuristics, apply to both researchers and practitioners, although are often applicable in different ways. They are presented as "rules of thumb" rather than a prescribed set of steps, and represent some best practices for developing and sustaining successful collaborations. Underlying these guidelines, we emphasize the need for persistence, iterative engagement, and the establishment of common areas of mutual interest in order to overcome cultural differences and solve pressing societal problems.

Bio: Connie Woodhouse is a professor in the School of Geography and Development at the University of Arizona, with joint appointments in the Laboratory of Tree-Ring Research and Department of Geosciences. Her primary research focuses on climatic and hydrologic conditions of the last 2000 years in western North America, using tree rings to develop reconstructions of past rainfall, streamflow and drought. Another area of research is on the connections between science and decision making. She received a B.A. in environmental education from Prescott (AZ) College, an M.S. in geography from the University of Utah, and a PhD in geosciences from the University of Arizona. She is currently the interim head of the School of Geography and Development.

Determining the distribution of springs ecosystems

Abe Springer, Northern Arizona University
(co-authors: L. Stevens, J. Ledbetter, K. Junghans)

Globally, springs ecosystems are poorly mapped, particularly in steep terrains, or because of differences in classification (such as groundwater-fed fens not always recognized as springs). Springs sources are nonuniformly distributed across the globe, but are most dense in regions with complex topography and are rarer on plains. We estimate that there are 10 million terrestrial springs on Earth, with a total area of approximately 10,000 km2 or 0.007 percent of the Earth's surface. We adapted the theory and application of a species-sample curve to predict the density of springs on specific landscapes. With increased sampling of the distribution of springs on a landscape, we theorize it is possible to predict the density of springs on the landscape. Successful location and mapping of springs through remote sensing varies in relation to topography and size of spring, but most countries have only mapped large or thermal springs. Seafloor geothermal vents and many non-geothermal subaqueous springs have been mapped extensively in some regions. We review the known springs types of the world and relate springs types and density to geomorphic analyses to provide an approach to refine mapping springs.

Bio: Abe Springer is Professor of Hydrogeology and was the Inaugural Director of the School of Earth Sciences and Environmental Sustainability at Northern Arizona. He received his B.A. in Geology from the College of Wooster and his M.S. and Ph.D. in hydrogeology from The Ohio State University.

Western groundwater rights: A Colorado perspective

Tom Cech, One World One Water Center

Water resource development in the western United States has been a story of exploration, economic development, and massive water projects. Without water development, the arid West could not support its population growth or agricultural production. However, the finicky dry nature of the region presents incredible challenges for water management, and climate change is providing new and untested situations. Geography, climate, mineral wealth, and the lore of "Manifest Destiny" (the 19th century belief widely held by Americans that the United States was destined to expand and settle west of the Mississippi River) have played important roles in our current water development system. An outgrowth of this expansion has been the unique water rights management system related to alluvial groundwater in Colorado. Colorado's Doctrine of Prior Appropriation (also referred to as the "Colorado Doctrine") has been the system used by most western states in the U.S. In Colorado, this legal rule of "first in time, first in right" has been adhered to quite rigidly because it provides certainty for senior water right holders. However, it can also be viewed as detrimental to environmental needs and holistic water management schemes. This debate is ongoing, and there is no place where conflict is more apparent than between alluvial groundwater irrigators and senior surface water right holders along the South Platte River of northeastern Colorado.

Bio: Tom Cech was born and raised on a farm near Clarkson, Nebraska, graduated from Kearney State College with a Bachelor of Science Degree in Math Education, and later received a Masters Degree in Community and Regional Planning from the University of Nebraska – Lincoln. He was Executive Director of the Central Colorado Water Conservancy District in Greeley, taught water undergraduate and graduate level water resources courses at the University of Northern Colorado and Colorado State University, and is now the Director of the One World One Water (OWOW) Center for Urban Water Education and Stewardship at Metropolitan State University of Denver. Tom wrote "Principles of Water Resources: History, Development, Management and Policy," published by John Wiley & Sons - currently in its 3rd edition. Tom also recently published "Introduction to Water Resources and Environmental Issues," (co-author Dr. Karrie Pennington) with Cambridge University Press, and "Colorado Water Law for Non-Lawyers," (co-author P. Andrew Jones) with the University Press of Colorado. He has also completed histories of the Colorado Water Conservation Board and the Colorado State Engineer's Office with Bill McDonald and Dick Stenzel, respectively.

Springs in Mojave National Preserve, California

Debra Hughson, Mojave National Preserve

Springs are an essential resource for wildlife populations and form a key ecosystem component in desert environments. Small springs in mountainous areas provide the only source of water for numerous wildlife species over a broad expanse of the Mojave Desert. A comprehensive inventory and annual surveys conducted over nine years in Mojave National Preserve indicated that many such springs occur in canyons and ravines along the slopes and near the base of mountain ranges associated with small, locally recharged, perched aquifers. Approximately half of the springs recorded in the inventory were either enhanced or perhaps even created by human activity related to mining and ranching. Spring enhancements typically included excavation, small dams, spring boxes, pipes, and troughs. Sub-horizontal tunnels excavated into hill slopes were used to enhance existing flow or perhaps create new springs where none had existed before. Within the 643,112 ha study area 135 spring systems consisting of 238 distinct surface water expressions were monitored. Reliability of available surface water was correlated with watershed catchment area and spring brook length. Geologic field mapping of a subset of 39 springs indicated that the area of colluvial sediment above barriers was correlated with persistence of surface water from year to year, but the area of phreatophyte vegetation supported by spring discharge and hydraulic conductivity of the sediment surface were not. Historical precipitation records show that severe decadal droughts are likely on a century time-scale and that multi-decadal mega-droughts are likely on a millennial time-scale. Global climate models indicate a general drying trend in the southwest into the 21st, suggesting that the likelihood of multi-year droughts may be increasing. Watershed catchment area, spring brook length, and area of colluvial sediment appear to be predictors of discharge persistence during drought for certain types of montane springs.

Bio: Debra Hughson is Chief of Science and Resource Stewardship at Mojave National Preserve, where she has worked since 2001.

Hydrogeochemical controls on groundwater quality in the West Mamprusi area, Northern Ghana

Karen Gastineau, Desert Research Institute
(co-author: B. Apambire)

In the Northern Region of Ghana where groundwater is scarce and borehole success rates are low, there are still large gaps in groundwater quality research. Generally, groundwater is a safer source of drinking water than surface water, but it can contain naturally occurring elements, such as fluoride and arsenic, that pose health risks. A better understanding of geologic controls on groundwater quality will help predict areas of poor quality groundwater before wells are drilled, leading to higher quality drinking water and lower project costs. This study focuses on the West Mamprusi area of Northern Ghana, where geology varies from coarse- to fine-grained sedimentary rocks to basement complexes consisting of metavolcanics, metasediments, and granitoids. Forty-seven new groundwater samples were analyzed for major ions and trace elements, and 25 samples were analyzed for carbon-13 isotopes. Graphical and statistical analyses, including Piper diagrams, principal component analysis (PCA), and cluster analysis, are used to categorize the water chemistry and determine important water-rock interactions within the aquifer. Geochemical modeling with NETPATH using results from major ions and carbon-13 isotope analyses will show saturation with respect to minerals, shedding light on geochemical processes occurring within the aquifer as well as groundwater flow paths. Water quality data, including element concentrations, will be integrated into GIS maps, focusing on potentially harmful elements. The analysis will lead to a better characterization and understanding of the geochemistry of groundwater resources in the West Mamprusi area.

Bio: Karen Gastineau is a Master's candidate in Hydrogeology at the University of Nevada, Reno working as a research assistant for Dr. Braimah Apambire at the Desert Research Institute's Center for International Water and Sustainability (CIWAS). Her research focuses on groundwater quality in northern Ghana, but she has been exposed to many different aspects of the WASH sector through working with Dr. Apambire. She is an active member in UNR's Student Association for International Water Issues (SAIWI) and the Nevada Water Resources Association (NWRA). Karen's interest in geology extends to her undergraduate studies as well, with a B.A. in Geology-Environmental Studies from Whitman College in Walla Walla, WA.

Global assessment of de facto reuse: Wastewater in irrigated agriculture

Anne Thebo, University of California, Berkeley
(co-authors: K. Nelson, P. Drechsel, E. Lambin)

A multitude of case studies have demonstrated that the reuse of untreated or partially treated wastewater in irrigated agriculture in developing countries is exceedingly common. Without proper safeguards, the use of these waters can present health risks. However, these same waters also provide a reliable and nutrient rich water source for farmers, often in regions where water is already physically or economically scarce. Such studies are essential for understanding local context, but difficult to interpret in aggregate at the global scale. Understanding the global extent of the reuse of untreated or partially treated wastewater remains a major knowledge gap. Several recently released global land use and water quality datasets have provided a unique opportunity to estimate, quantitatively, the extent of wastewater irrigation with dramatically lower computational complexity, higher accuracy, and in less time than was previously possible. This study uses spatial overlay analysis to provide the first global estimate of the extent of the reuse of untreated wastewater developed using a globally consistent methodology. Early results show 130 Mha or sixty percent of irrigated croplands are located within twenty kilometers of urban extents with populations exceeding 50,000. A substantial portion of these croplands are located in regions with low levels of wastewater treatment. Preliminary validation efforts show concentrations of fecal coliform in surface water sources used for irrigation in these regions averaging 4.2x106 MPN/100 ml. Understanding the global extent of the reuse of untreated wastewater in agriculture is essential for large scale water allocation planning and risk mitigation efforts.

Bio: Anne Thebo is a PhD candidate in environmental engineering at the University of California, Berkeley.

Brazilian law and policy influencing Indigenous water quality governance

Kate A. Berry, University of Nevada, Reno
(co-author: L.C. Forline)

With the largest economy in Latin America, Brazil is a globally important democracy in which a federation of states, municipalities, and federal district shares powers with the federal government. The federal government deals directly with Indigenous communities, primarily through *Fundação Nacional do Índio* or National Foundation for Indigenous People (FUNAI) and *Fundação Nacional de Saúde* or National Health Foundation (FUNASA). Colonial subjugation is still evident in some federal policies which paternalistically classify Indigenous people as 'tutees,' who are considered to be relatively incapable. Traditionally, Indigenous communities in Brazil employ consensus models for internal governance, however, many are starting to transition to a constitutional style of organization to form structures that facilitate external recognition of their jurisdiction. A major revision to Brazil's national constitution in 1988 was followed in 1993 with an order that Indigenous territories be delineated. Under the revised constitution, water associated with designated Indigenous territories was allowed to be used by outside entities, such as mining companies, only after legislative hearings that included participation of affected communities. However, this resulted in a decree by the national government in 1996 that delayed the delineation of some Indigenous reserves. In terms of water governance, a new management system was adopted nationwide in 1997 stressing integrated water resource management (IWRM) and encouraging states to formulate policies that meet federal requirements so they can govern their own water resources. So while states in Brazil may regulate water quality through granting of licenses for water discharges, to date Indigenous governments have no such formal regulatory authority, despite growing threats to water quality on Indigenous reserves from a variety of sources. Land grabs and illegal logging are common within and around reserves and are associated with waste disposal in rivers and stream degradation. Residual mercury from former mining is another water quality issue affecting some reserves. Indigenous communities in Brazil tend to negotiate with FUNAI and FUNASA for assistance when water quality becomes a concern or assert authority by dealing directly with state governments, the federal Prosecution Service or polluters. This paper examines laws and policies in Brazil that influence the governance of water quality by Indigenous communities.

Bio: Kate A. Berry is a Professor of Geography at the University of Nevada, Reno. She has experience in the analysis of water policy, with an emphasis on research about intergovernmental relations in water conflicts and examinations of the cultural and political dimensions of water conflicts and policy. She has worked extensively on indigenous resources issues, including tribal and Native Hawaiian water issues. Her projects have also focused on other contemporary indigenous issues as well as geographic dimensions of race, ethnicity, and indigeneity. Louis C. Forline is an Associate Professor of Anthropology at the University of Nevada, Reno. He has worked in the Brazilian Amazon with indigenous and peasant groups of this region, including work with the Awa-Guajá people since 1990, examining their experience of contact with Brazilian mainstream society and transition from foraging to farming. He has also worked among urban Indians in the city of Altamira, Brazil, examining their resurgence as indigenous players, and has conducted environmental impact assessments of hydroelectric projects in Brazil.

Safe and sustainable groundwater supply wells in developing countries

Steve Schneider, National Ground Water Research & Educational Foundation and Schneider Water Services

Extended Abstract

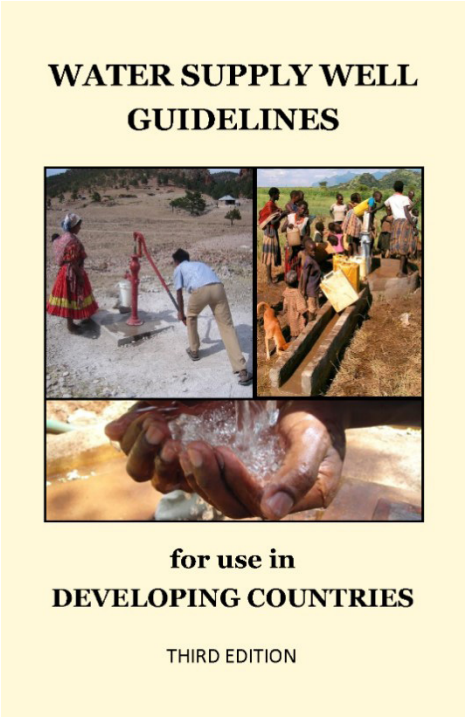
A common misconception by many working in developing countries is that if water has a clear appearance or is from a particular type of source it must be safe to drink, or, that water superior in appearance must be safer in quality. This misconception was at least in part supported by the measurement system used to determine the success of the Millenium Development Goal (MDG) for water. Rather than chemically measuring the safety of water, the MDG measured a count of 'improved' water sources. However, 'clean' or 'improved' does not mean 'safe' when it comes to drinking water supplies. A large percentage of 'improved' sources contain harmful pathogens. 'Safe' drinking water must be, at a minimum, free of *E. coli*, a fecal indicator bacteria (FIB).

Similarly, the term 'sustainable' does not apply to a water supply well that compromises the quality of an aquifer that wastes water, that is seasonally unreliable, or that utilizes materials of construction that fail to be cost effective for the long term use of the source. 'Sustainable,' with respect to drinking water wells, means that the well will produce water reliably through all seasons, for multiple generations, and without waste or contamination of groundwater resources.

At the 2008 National Ground Water Association (NGWA) Expo, several members of the NGWA's Developing Countries Interest Group (DCIG) realized the above misconceptions. This recognition then prompted the creation and distribution of several drafts of a document that has been vetted by hundreds, and eventually resulted in the publication: Water Supply Well Guidelines for use in Developing Countries.

This book is now in its Third Edition and is being used by academia, NGOs and other groups, agencies and individuals in the United States and internationally. It has been translated into at least five languages (English, Swahili, Spanish, Chinese and French). The book includes sections on:

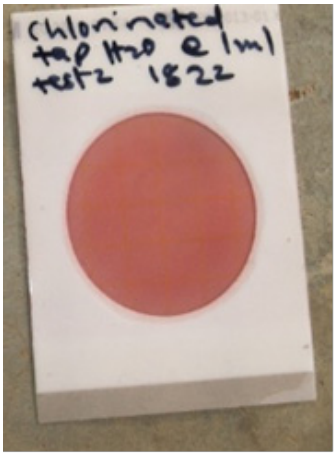
- Groundwater Availability
- Cost Benefit Analysis
- Definitions
- Well Location
- Drilling Method
- Drilling Products
- Well Annular Surface Seal
- Commingling and Leakage
- Casing, Liner and Other Well Materials
- Plumbness and Alignment
- Well Development
- Surface Completion
- Disinfection
- Testing
- Well Decommissioning
- Documentation
- Personnel Safety
- Filter Pack design
- Well Design Pros and Cons



In February of 2015, the National Ground Water Research and Educational Foundation (NGWREF), the charitable arm of NGWA, co-sponsored the NGWREF's initial educational and training program with a grant from that foundation's Developing Nations Fund. The program consisted of two short courses, a 3 day course for drillers and a 2 day course for NGOs and Government officials. The 3 day course included continuous translation into one of the local Bantu dialects. The courses were held in Mzuzu, Malawi. The program used the aforementioned book as the course guide for both sessions. By using presenters from the NGWREF and also from the local university, along with a variety of presentation formats, participants were kept engaged throughout the event. The courses exceeded the expectations of not only the primary presenters, but also the local co-sponsor and host, the SMART Centre at Mzuzu University. The courses drew the attention of the Malawi government, whose Water Minister provided both opening and closing remarks at the 2 day course.

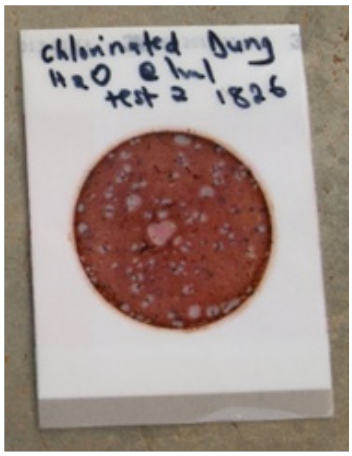
The Mzuzu courses included discussions and demonstrations of local drilling methods, methods that often included the use of dung in the drilling fluids in certain situations (e.g. lost circulation or water bearing formations). The desirable functions of a drilling fluid were identified by the attendees. Safe alternatives to the water, clay/dung fluid were then demonstrated; alternatives that could achieve all of the desired functions without having to introduce FIB.

Water sampling and analysis were also demonstrated and discussed in order to highlight the extremely elevated FIB content of dung based fluid. Photographs of 3M Petrifilm slides shown below demonstrate a few of the samples analyzed and their water source. Many, if not most attendees had never before seen the physical evidence of FIB that these photographs revealed. It was especially interesting to note that even after exposure to chlorine disinfectant for over 24 hours, the dung contaminated water still showed a large count of FIB along with other bacteria.









J. Whinnery in 2012 developed a Cost-Benefit Analysis (CBA) that compared properly completed wells versus inferiorly completed wells. The CBA revealed the following:

- Almost 40 times more benefit than cost is provided with a properly constructed, operated and maintained well system.
- There is approximately 5 times more net value realized solely as a result of the implementation of an operation and maintenance (O&M) program.
- Wells providing localized poor water quality should not be considered acceptable. Construction of such a well results in a negative net present value; that is, there is more cost than benefit (a benefit-cost ratio less than 1).
- A properly constructed well will have at least 3 times more net value than an inferior well. The multiplier approaches infinity if water quality has also been compromised in the inferior well.
- Inferior construction that results in groundwater contamination or aquifer damage should not be considered acceptable.

Although it is not specifically analyzed in the CBA, it can be inferred that well construction which compromises aquifer quality or results in loss of aquifer head (e.g. commingling of aquifers or uncontrolled artesian pressure), will have negative impacts in the form of reduced large-scale benefits in addition to added costs of remediation or mitigation. These negative impacts will most certainly result in a negative net present value.

Ms. Whinnery has made a spreadsheet available that is customizable and includes the formulas used to compute the cost-benefit. Her report and spreadsheet are available for download from the References web link provided below.

With over 100 times more 'fresh' groundwater than surface water available on our planet, groundwater holds the promise of fulfilling the continued and increasing need for water, especially for domestic purposes. Wells will continue to be the primary method of accessing groundwater and their proper construction is of paramount importance, especially in rural areas where the number of wells is increasing rapidly.

True science and education are critical in creating an understanding of the benefits of and methods available for constructing safe and sustainable drinking water supply wells, especially in developing countries. This author anticipates an increase in education and training programs similar to the Mzuzu program and welcomes suggestions and potential venues for such.

References available at: www.schneiderwater.com/pages/Hydrophilanthropy_Well_Guidelines.html

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Bio: Stephen J. Schneider (Steve) manages the drilling division at Schneider Water Services of St. Paul, OR, USA a contracting business employing approximately 25 people in water related activities including: drilling, pumps & water systems installations, water treatment and service. With a BS degree in mechanical engineering from Oregon State University, Steve worked for the US Department of Defense as a civilian engineer, which included writing/editing many technical specifications. He has drilling licenses in the states of Oregon, Washington and Idaho and pump installer licenses in Oregon and Washington. He is a National Ground Water Association (NGWA) Master Ground Water Contractor (MGWC). Steve has presented educational seminars and workshops via Webinars and in person at NGWA Expos, NGWA Groundwater Summits, Oregon Ground Water Association (OGWA) conventions, WEDC International Conference, and other events. He was the first non-government presenter of required continuing education related to well construction rules in Oregon. Steve has also served on State well construction rules and advisory committees, numerous National and State groundwater association committees including as officer/director, and is a current director and past-president of the National Ground Water Research and Educational Foundation. Steve continues to be active in NGWA's Developing Countries Interest Group and has made several trips to, and continues to work with, a mission in Mexico developing groundwater supplies for the indigenous Tarahumara Indians. He has also presented water supply well workshops in Africa.

Impact of climate change on ecosystem management in Central Valley of California

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Water is non-optimally distributed across time and space in California. Vast engineering networks were constructed in 1940s and 1960s to move water from places of abundance to places of scarcity; however, at a cost to the State's aquatic ecosystems and freshwater dependent species in terms of reduced environmental flows. The water supply network heavily dependents on sociopolitical and economic constraints that often limit efficiency and discourage equity. Global warming and regional hydroclimatic alteration are likely to exacerbate the water scarcity problem. This paper examines the impact of a warm-dry climate scenario, changes in water infrastructure and competing environmental flow demands on water deliveries to eleven National Wildlife Refuges (NWRs) in California's Central Valley. Alternate water management schemes are evaluated to enhance resiliency of NWRs to face uncertainties in water supplies. The study is conducted within a statewide framework to capture the physical, environmental and policy constraints present in the existing water management system. This is achieved by employing CALVIN, a hydro-economic optimization model of the State of California. Historical and a warm-dry form of climate change are explored. Region of Hydrologic Influence (RHI) is determined for each refuge which includes inflows from topographically generated surface water runoff and water delivered through engineered conveyances. Lastly, the NWRs are integrated into the statewide CALVIN model. Several simulation runs are set-up to examine the hydrologic, economic, and ecological consequences of alternative management schemes and climatic scenarios on the NWR water deliveries. Results highlight vulnerabilities in the water supply system, and the potential of water markets, water banking and other water management tools to cope with water scarce conditions.

Bio: The study is conducted by a consortium of researchers from UC Davis Center for Watershed Sciences (CWS) specialized in the generation of data, development of tools, and synthesis of information to improve water management and resulting environmental outcomes. Dr. Lund is the Director of CWS and a Ray B. Krone Professor of Environmental Engineering, Department of Civil and Environmental Engineering. He has received numerous professional awards in the field of water resources management and co-authored over 100 refereed journal publications. Dr. Medellin is an expert modeler for CALVIN applications, including climate change, adaptation and economic costs of salinity in California. Karandev Singh and Mustafa Dogan are graduate student researchers at CWS. Mr. Singh received his Bachelor's in Civil Engineering with a Communication minor from University of California, Davis, in June 2013. Mr. Dogan received his Bachelor's in Civil Engineering from Dokuz Eylül Üniversitesi, Turkey, in June 2011.

Climate change modeling and measurement in Lake Mead, Arizona-Nevada

Todd Tietjen, Southern Nevada Water Authority
(co-author: E. Schlickeisen)

Lake Mead is one of the largest impoundments in the United States and serves an important role in water supply for municipalities and agriculture in Nevada, Arizona, California, and Mexico. The Colorado River, which provides >95% of the water in Lake Mead, is currently in a drought that has lasted more than 10 years. This drought has resulted in falling lake surface elevations in Lake Mead and changed the interactions between the lake and the upstream and downstream Colorado River. These changes have allowed us to extrapolate some of the changes that might be encountered with increasing impacts of climate change. The most pronounced changes measured to date have been associated with dissolved oxygen concentrations near the upstream confluence with the Colorado River. In 2014 ~2 C° warmer temperatures in the inflowing Colorado River resulted in the development of anaerobic conditions in upper Lake Mead, extending ~50 km/30 miles into the lake. In the past this pattern, as well as other patterns of anoxic development have been measured, suggesting that the interaction is related to the management of the upstream river. 3-dimensionsal hydrodynamic and biogeochemical modeling of the lake has been conducted for a variety of purposes, including attempts to evaluate the potential for changes in climate to impact lake dynamics. Assuming river discharges remain similar to recent historical conditions, the water quality in Lake Mead is expected to change only slightly. Most of these changes are expected to be closely related to the temperature changes. Downstream of Lake Mead the impacts of climate change are intertwined with changes driven by the falling surface elevation of the lake, changes in the temperature of the water released downstream can occur quickly and produce significant downstream impacts.

Bio: Dr. Tietjen joined the Southern Nevada Water Authority in 2008 to work as their in-house limnologist examining water quality issues in Lake Mead. Todd received his Ph.D. in Aquatic Ecology from the University of Alabama in 2002, a M.S. in Aquatic Biology from Southwest Texas State University in 1996, and a B.A. in Environmental Studies from Alfred University in 1990.

The landscape imperative and the research agenda

John Wiener, University of Colorado

Extended Abstract

This argument is that the research agenda most needed from UCOWR and allies may appear to lack scientific charm, but it concerns the imperative for landscape conservation. The water science community and municipal water providers may be the most important U.S. actors in the application of integrated water resource management (IWRM) principles for not only water supply, but also water quality, conservation of agricultural capacity, and work on the missing link: landscape-scale management of ecosystem services and production, including local food security. By "actors" I mean that water providers on the medium to large scale can access long-term financing, using bonding capacity and large tax bases – they literally can act! – while small land owners such as most farmers typically operate on much shorter time horizons (indeed, this is an important and under-explored research topic). Here, the focus is on agriculture.

IWRM has achieved ever greater potential importance. Water goals are tactically but not strategically separable from the other inextricable values. Further, water providers are the most credible and capable science sources reaching the public (Raucher et al. 2014), particularly on climate change, according to research by the Water Research Foundation, Stratus Consulting and Yale University, even where there are fiercely vocal but very small minorities fond of attending meetings. This extended abstract essentially references points already made and some discussions too long to include here, so the majority of citation is provided elsewhere (Wiener 2014a, 2014b). Water providers and scientists may have to lead where others cannot or will not.

The fundamental ideas of watershed protection (AWRA 2012) include the safety and hazard resilience of a landscape, and the ecosystem services value of a landscape depend on the same qualities that support useable flow volumes and qualities. The consumers of urban water also seek quality of life, real estate values, recreational and amenity benefits, food security, and increasingly local and more regionalized food production with seasonality and perceived health qualities. Ecosystem valuations are an important frontier of improving IWRM because of the need to integrate the full range of water-resource-relevant issues (Wiener 2014a and b, and see also EarthEconomics.org).

The 2014 UCOWR presentation by this author concerned increasing water supplier leverage on land use. Why bother? There is little discussion about the importance of urban form and land use; the serious discussions presently center on issues such as how to promote and achieve "smart growth", on which the United States Environmental Protection Agency has collected a large supporting set of studies (some discussion appears in Wiener 2014a). Driven by the short-term valuations and markets, there are two conflicting trends at work on the peri-urban landscape: first, the emerging preference for organic, local and high-preference food, and second, the continuing loss of the best quality land and the best soils. Although the annual growth rate for organic food sales fell from the double-digit range in 2008 as the U.S. economy slowed, its 7.4-percent growth rate in 2012 was more than double the annual growth rate forecast for all food sales in 2012 (USDA ERS 2011 and USDA ERS 2012). Consumers show willingness to pay price premiums for organic and local foods (Adams and Salois 2010; Wiener 2014a and 2014b). The "alternative" food market is an opportunity for supporting transitions and viability for some farms and for groups of farms. But, the critical problem for the huge farmland resources owned in small and often economically vulnerable parcels is that present conditions are strongly unfavorable to long-term conservation of the whole range of ecosystem, amenity, agricultural, and real estate values we will soon wish we had conserved (Wiener 2014b). Not only are the economics adverse for small parcels, we also face destructive fragmentation of landscapes just as we show the need for flexible agroecological management (elaborated in Wiener 2014a and 2014b; the best single source may be National Resource Council 2010).

Why is the landscape imperative the critical agenda? Because we can't operate well enough on the farm scale, and we don't know enough about the regional scales. We do know that we are in very bad trouble on the global scale. And, we know that we are not going to downscale our way from global levels to wisdom. On one end of science, there is cutting-edge modeling reported in The Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP) (reported recently in 13 articles in a March 2014 Special Feature of the Proceedings of the National Academy of Sciences of the U.S.; Volume 111 No. 9) and some related publications. This is a multi-institutional international effort to apply common inputs to enable testing differences between leading global models, using including common climate scenarios, representative gas concentration pathways, and standardized socio-economic projections (Schnellnhuber et al. 2014; Warszawski et al. 2014). The sectors modeled and linked in the ISI-MIP are agriculture, biomes, coastal infrastructure, human health (represented by malaria), and water. On the other end, there is extremely conservative reporting of best-available science from the IPCC.

Elliott et al. (2014) considered the impacts of climate change on rain-fed and irrigated cropland, but not land conversion from other uses, changes in irrigation efficiency or techniques, land degradation and soil quality loss (see DeLong et al. 2015). Even with increased irrigation where it is possible, there are going to be net losses of production, despite CO_2 fertilization and some favorable changes in growing seasons. Losses would increase with adverse factors, such as CO_2 fertilization of weeds, soil quality changes from many causes, and pest and disease problems, as well as the increased intensity of precipitation and weather extremes. The role of soils as an additional constraint is known but some steps away from these global levels of analysis, and indeed infrequently considered above field-scale analyses (Adewopo et al. 2014; Karlen et al. 2014; Hatfield 2013; American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America 2011; Baveye et al. 2011; Richter et al. 2011).

Applications of global gridded crop models (Rosenzweig et al. 2014) found that inability to include extreme weather events, intense precipitation, timing of changes and extremes as they relate to critical growth stages and requirements, and changes in the rate of soil processes are important because the dismal findings may be optimistic! The crop models study found "strongly negative" effects on crop yields, especially at lower latitudes, including the benefits as variously estimated from CO_2 fertilization. Models which included N stresses found substantially larger losses (See also Bouwman et al. 2013; Herrero et al. 2013).

Nelson et al. (2014) compared linkages of economics to agricultural changes, with inclusion of endogenous responses to yield reductions and price changes, addressing the need to include agricultural responses to changing conditions. This study did not include CO_2 fertilization, of crops or of weeds, nutrient problems or constraints, biotic stresses, or changes in timing of water availability or extreme weather events or their timing. The direct impact of 17% loss of crop yields would likely be moderated to only a net yield loss of 2%, if one is willing to allow an increase of 11% in cropland used, and a 20% global food price increase. This is a substantial intensification of investments, as well as expansion onto lands which are not identified. The kinds of compensation needed for the synergistic impacts of climate change may be themselves quite unsustainable at agreeable levels (consider Turner 2008).

From the other end of science, working strictly from "established" peer-reviewed science, the Intergovernmental Panel on Climate Change Working Group II report on Climate Change 2014: Impacts, Adaptation and Vulnerability confirms that soil quality and productivity remain badly under-appreciated as a source of potential land degradation and loss of food security (Porter et al. 2014; IPCC 2014). Soil issues are noted more than a dozen times, but the essential point made is that critical qualities, biotic conditions, and relationships to management are almost always assumed in the modeling of agricultural impacts and adaptations and climate change (Porter et al. 2014). "All aspects of food security are potentially affected by climate change, including food access, utilization, and price stability (high confidence)." (IPCC 2014: 18). Climate change without adaptation is projected with high confidence to have more common negative impacts than positive impacts even including the high latitudes being uncertain and perhaps positive in some places (IPCC 2014: 4-6), even for the short term. After 2050, the risks of severe decreases in yields increase sharply with projected rates of global atmospheric change (IPCC 2014: 17-18).

Little relief is forthcoming from reductionist or holistic conventional research. Productivity threats multiply with recognition of the severe lack of knowledge on soil conservation issues and success (Delong et al. 2015, and see Apodowe et al. 2014; Herrero et al. 2013; Baveye et al. 2011; Richter et al. 2011). Karlen and colleagues (2014) credited the successes of reductionist research but showed its insufficiency for multi-factorial highly interactive systems (see also Francis 2010). The needs are too urgent and the challenges too great to work in only traditional methods now, for adaptation to climate change as well as mitigation of it (Hatfield 2013; Tanaka et al. 2008). Where incentives and policy are aligned and governance is provided for the benefit of resources as well as the human short-term dimensions, there can be remarkable success, but what if research is essentially a private investment (Welsh and Glenna 2008; Zadoks and Waibel 2000)? "Conventional" versus "alternative" agriculture splits must be overcome!

Who can finance transitions to the long-sought more-sustainable agricultural systems needed for the 21st Century (National Research Council, 2010), if not those with substantial tax bases, high credibility, long records of institutional success, and access to low-cost capital?

There is need and opportunity for UCOWR and allies to provide leadership on landscape scale conservation. In particular, the research agenda to consider should include (1) the quality and extent of land at risk for conversion to other uses, locally, and regionally; the kind of gross mapping often available is not very helpful, and must be supplemented by far more carefully designed long-term agroecological planning (summaries in Wiener 2014a and b); (2) ecosystem services

dependent on irrigation and agricultural/silvicultural management must be at least estimated so that cities can begin to appreciate the scale of risks faced and coming; and (3) institutional and financial obstacles and opportunities for local and regional landscape scale conservation and adaptive management must be better understood and modeled. There are huge needs for transition budgets and support for making long-term investments that do not appear to be met by conventional enterprise budgets. The UCOWR members may have astounding opportunities to address multi-disciplinary challenges and build new alliances with other schools, NGOs, local governments, and stakeholders. The agroecological/ecosystemic models are landscape scale, and regional; the opportunities for near-by high-value and high-impact work are tremendous. The research imperative concerns the landscape scale, in terms of all of the watershed values.

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Impacts of climate change on Southwestern working lands and water resources: A report from the inaugural year of the USDA Southwest Climate Hub

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Extended Abstract

In February 2014 the USDA established seven regional climate hubs to assist farmers, ranchers and foresters in adapting to the effects of climate change. The Southwest (SW) region encompasses six states (including Hawaii) and provides highly diverse agricultural crops including cotton, stone fruit and grapes. The SW relies on irrigation more heavily than any other region in the US and water supplies are critical to meeting regional irrigation needs. In addition, seasonal and annual rainfall amounts dictate livestock numbers that regional rangelands can support. Projected mid-century temperatures indicate a 2 to 4°C average annual temperature increase across the region. This increase will further limit presently scarce water resources by increasing regional evaporation and transpiration. Models predict that drought and water competition will likely be a more frequent reality in future. To help SW working land owners cope with the impacts of climate change, the Hub has established formal agreements with Cooperative Extension and hosted regional climate change workshops. The Hub funded development of a climate change module for regional rural and urban schools. Hub staff drafted a Vulnerability Assessment of SW crops, animal agriculture and forests to climate change. Vulnerability to climate change is generally defined in terms of exposure, sensitivity and adaptive capacity. Given temperature increases and reduced winter chilling hours, certain crops will have likely have reduced yields while others, given adequate water, will be less effected. Similarly, certain livestock and geographic regions are more vulnerable to projected climate change. Water is a critical component of agricultural vulnerability in the SW and results are presented from a hydrologic perspective.

Introduction

In February 2014 the Secretary of the U.S. Department of Agriculture created seven regional hubs and three subsidiary hubs across the U.S. for climate change adaptation and mitigation. The regional climate hubs are located at Agricultural Research Service (ARS) or U.S. Forest Service research laboratories. The overall goal of the regional hubs is to maintain and strengthen agricultural production and natural resources under increasing climate variability and environmental change. The mission of the hubs is to develop and deliver science-based, region specific information and technologies to agriculture and natural resource managers to enable climate-informed decision-making and provide assistance to land managers to implement those decisions.

The Southwest Climate Hub

The USDA Southwest Regional Climate Hub, with headquarters at the Jornada Experimental Range in Las Cruces, NM, works in six states: New Mexico, Arizona, Utah, Nevada, California and Hawaii (plus the Trust Territories of the Pacific Islands west of Hawaii). The SW region possesses both great physiographic and climatic diversity. The region contains both the highest and lowest annual precipitation in the US, along with the highest and lowest elevation. There are major deserts in five of the six SW hub states and water is pivotal in maintaining agricultural production and local economies of the region.

Providing Climate Information to Stakeholders

Cooperative Extension

Since our goal is supporting the needs of regional working lands managers, we partner with the Cooperative Extension Service at land grant universities in each of our states to reach farmers, ranchers and foresters. This partnership led to a collaborative meeting of Cooperative Extension (CE) leadership and development of a plan for basic continuity on how CE will work with the stakeholders on climate change issues. The CE at each land grant university in our states entered into a specific cooperative agreement with the ARS (Agricultural Research Service) in Las Cruces.

The overall goal of the formal agreements was to provide knowledge to support informed decision-making and to garner feedback from farmers, ranchers, and forest land owners. In the first year, workshops with farmers and ranchers addressed the topics of weather and climate information, drought, food security and wildfire.

Adaptation Tools Database

The SW Hub began an inventory of climate change adaptation tools. Other hubs began a similar process which merged into a national effort across all hubs to develop an adaptation tools database. The intention of this database is to inventory tools across the country that can assist in climate change adaptation on working lands (agriculture, forestry, grazing land,

and livestock), and to present these tools to the public in a searchable, user-friendly format. The database includes tools that are directly relevant to climate change, as well as tools that assist in managing factors that interact with climate change, such as drought, pests, and extreme weather. The target audience is extension and consultants, but the database could also be useful for land managers, land owners, and researchers. There are now more than 100 tools in the database and we continue efforts to make the database comprehensive. As such, there is a "suggest a tool" option for anyone who works with tools not yet in the database. The Adaptation Tools Database is on-line and hosted by the SE Climate Hub http://tools.taccimo.info/tbl_tools_list.php.

Newsletter and Website

One concern identified in initial meetings with CE was that county agents rarely have the time to sift through peer-reviewed journal articles to provide the latest regional climate change information to local farmers, ranchers and foresters. In response, the SW Climate Hub launched our newsletter with a section devoted to distilling and summarizing recent climate change research for the Southwest. Newsletters are published at least 6 times per year. Past SW climate hub newsletters and a form to sign-up for future newsletters are available here http://jornada.nmsu.edu/sw-climate-hub/newsletter. In our first year we also launched the SW Climate Hub websites (http://climatehubs.oce.usda.gov/southwest-hub and http://swclimatehub.info)

Educational Curriculum on Climate Change in the Schools

The SW Climate Hub, in partnership with Asombro Institute for Science Education, is developing a middle and high school climate change curriculum, and the first unit is focused on the impacts of climate change on the hydrologic cycle. Students will begin by learning about the greenhouse effect and climate change with engaging, hands-on activities. They will then learn about the hydrologic cycle with a paper-ball tossing game, and the effects of climate change on the water cycle with a Chutes-and-Ladders-style board game called "Streams and Steam". Learners will continue to gain a better understanding of water availability and issues with more games, experiments, and examination of hydrological and ecological data. This past fall, the climate change module was taught and evaluated in local schools where it underwent an iterative process of testing and refinement. The unit will be ready for expansion across our 6-state region in summer 2015. Parts of the hydrologic module are available for download at the SW climate hub website (http://swclimatehub.info). The long-term goal is to develop a group of knowledgeable SW graduates who are well informed about climate change and various adaptation and mitigation strategies.

Assessments and Research

The SW climate hub conducts and supports research activities to translate climate change impact results into management actions. In our inaugural year, we conducted a regional vulnerability assessment which led to an online searchable database. We also conducted hydrologic research on the impacts of climate change on water resources of the Upper Rio Grande Basin, which we plan to expand to other regional mountain ranges. We derived expected temperature and precipitation changes at the county level based upon the Multivariate Adaptive Constructed Analogs (MACA) (Abatzoglou and Brown 2012) data product and tested a monitoring technique to estimate changes in groundwater stores, the NASA gravity recovery and climate experiment (GRACE) twin satellite system.

Southwest Regional Vulnerability Assessment

The Southwest Regional Climate Hub and the California Subsidiary Hub are working together to assemble information to serve the needs of agricultural stakeholders and also increase the value of our research information for outreach and educational efforts. One necessary early study was the vulnerability assessment of the Southwest Region to climate change. Scientists predict with high confidence that temperatures in the Southwestern U.S. will increase in the coming decades. Agriculture in the six state region will be impacted by temperature increases. The vulnerability assessment report details potential impacts to specialty crops, field crops, forests, and animal agriculture.

Possible impacts of the increases in both maximum and minimum temperatures are serious. They include substantially reduced capacities to produce forage for livestock, lower yields of specialty and field crops, diminished quality and quantity of particular temperature sensitive crops such as corn and wheat, a shifting of existing crop distribution, and increased severity of forest fires. There will also be indirect effects of climate change related to health and quality of soil and water resources as well as economic and social health of the region. The purpose of this analysis is to detail both the regional vulnerabilities to climate change and the adaptive actions that could be employed in order to maintain agricultural productivity and rural economies in coming decades.

Several selected systemic impacts of climate change are listed below.

- Elevated temperatures are associated with reduced yields for some crops and failure of other corps
- Crops grown in some areas might not be viable under future climate conditions, but other crops could likely replace them.
- Under warmer winter temperatures, some pests are likely to persist year round and new pests and diseases may become established.
- Pollinators may be vulnerable to climate change impacts
- Southwestern agriculture is defined by availability of water for irrigation

Journal Map

Writing the SW vulnerability assessment led to a database of over 700 articles related to climate change and working lands in the region. Those articles are being shared in *JournalMap*, a public, searchable geodatabase. Users can now quickly find research conducted in a specific location in the region. The general Climate Hub collection is viewable on the Collections tab on *JournalMap*. https://journalmap.org/usda-southwest-regional-climate-hub/climate-hub

Sources of Irrigation Water for Crops

If sufficient irrigation water supplies exist, the potential for marked agricultural production can be high in the region. California depends heavily on irrigation in the Central Valley to the extent that it is the highest ranked state in agricultural production in the U.S. In fact, this is the primary reason that the SW Regional Hub has a Subsidiary Hub located in California. There are many high-value specialty crops grown in California. For many specialty crops, California is the only commercial producer in the U.S., and for other specialty crops California's share approaches or exceeds 90% of the U.S. production (Starrs and Goin 2010).

Snowmelt produces a large portion of the water used for irrigation in the southwest. In certain snowmelt mountain basins like the Rio Grande, snow is the source of 50-75% of the seasonal water supply (Rango 2006). In portions of certain basins, snowmelt runoff produces as much as 90% of the water supply. The snow cover in New Mexico, Arizona, Utah, Nevada, and California usually persists for up to six months or more, which acts as a natural reservoir releasing the snowmelt water gradually during the early part of the growing season. Storage of water runoff from snow in artificial reservoirs then takes over in supplying irrigation water for the latter part of the growing season. Farmers do need supplemental water supplies during drought years in the SW Hub states. Most of this comes from pumping of water from wells which can result in a declining water table. The underground water supply is not always easily recharged so that such activities are essentially mining the groundwater. In 2013, shortage of surface water and groundwater accounted for more than 50% of the diminished crops yields due to irrigation interruption in regional states (Fig 1). Historically, the reason for discontinued irrigation is not consistently lack of water. For example, in 2003 most farmers cited sufficient soil moisture as the reason for discontinued irrigation, whereas shortage of surface and groundwater was the major reason in 2013 (Fig 2).

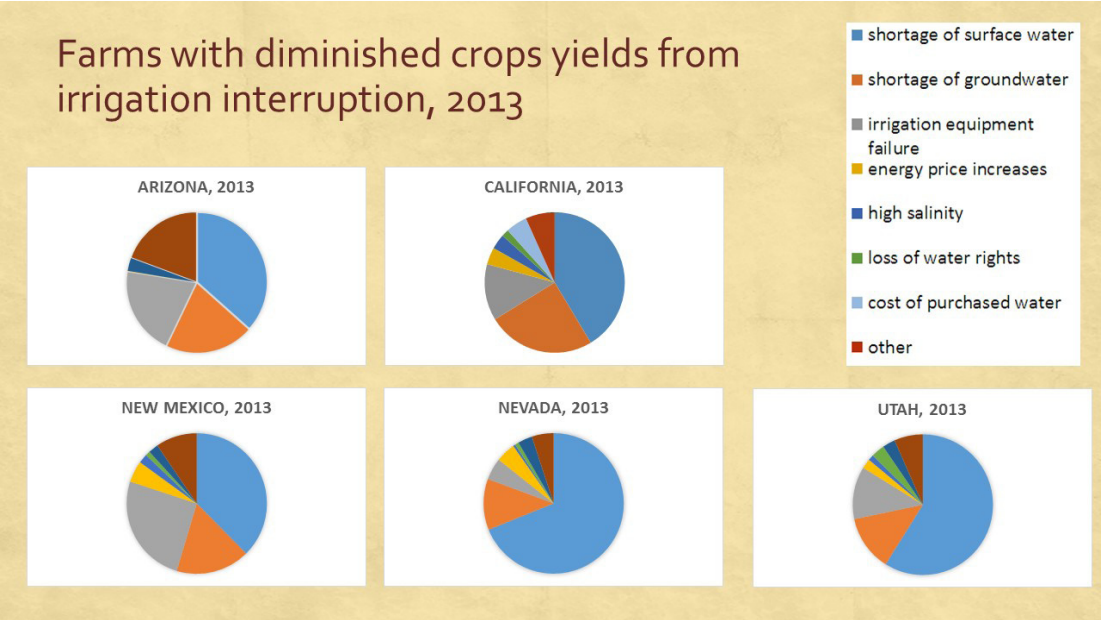

Figure 1. Diminished crop yields from irrigation interruption by source (Farm and Ranch Irrigation Survey, 2013).

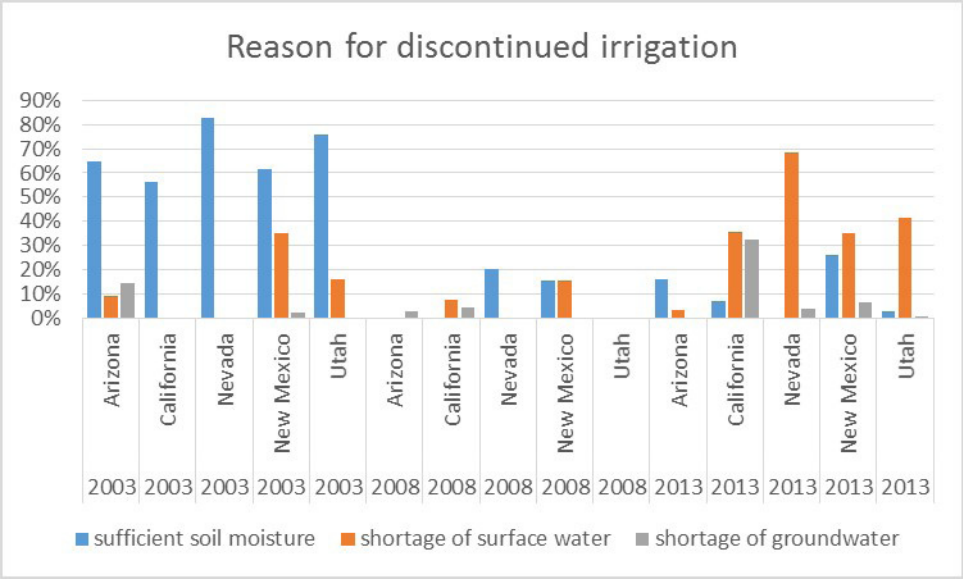

Figure 2. Reason of discontinued irrigation in 2003, 2008 and 2013 in continental Southwestern Climate Hub States (Farm and Ranch Irrigation Survey, 2013).

Snowmelt Runoff Model Research

A project funded by EPSCoR (Experimental Program to Stimulate Competitive Research) examined the impacts of climate change on 24 subbasins of the Upper Rio Grande. The results of this work were recently published in the *Journal of Hydrology*: Regional Studies in an article titled *Assessing climate change impacts on water availability of snowmelt-dominated basins of the Upper Rio Grande*. We use the Snowmelt Runoff Model to evaluate impacts of climate change on snow covered area (SCA), streamflow timing and runoff volume. Simulations investigate four future conditions using models downscaled to existing climate stations. Twenty-four subbasins of the Upper Rio Grande containing appreciable snowmelt and a long-term gauging station are simulated. Future annual volume is 193-204 million m^3 more to 448-476 million m^3 less than the pre-climate change value of 2,688 million m^3. There is disparity between increased volume in wetter simulations (+7%) and decreased volume (-18%) in drier simulations. Peak flow is 14-24 days early in the future climates. Among the twenty-four subbasins there is considerable range in mean melt season SCA (-40% to -100%), total volume change (-30% to +57%) and runoff timing advancement, indicating that climate change is best evaluated at the subbasin scale. Daily hydrographs show higher streamflow in March and April, but less from mid-May until the end of the water year. The large decrease in volume in May, June and July will compound water management challenges in the region. Similar research to inform water management will be conducted in other locations across the region.

Summary

- The USDA SW Regional Climate Hub was established in February 2014.
- Climate change information is being produced to allow land managers to arrive at informed decision-making for agriculture.
- The six SW states are extremely variable and cover extremes unmatched by other Regional Climate Hubs.
- Irrigation of croplands in the six SW states allows high agricultural productivity in the Region. Most of the irrigation water supply comes from snowmelt runoff.
- Cooperative Extension Service personnel are working closely with USDA to get information out to stakeholders through workshops in each of the states.
- Education curricula on climate change are being developed and tested at a number of grade levels in the SW region, and are being transferred to other states.
- A vulnerability assessment has been completed for the SW Region. Information from the assessment is being used by Cooperative Extension and transferred to stakeholders.
- First year efforts led to multiple tools to support adaptation and mitigation including county level temperature and precipitation projections, a searchable database for adaptation tools, a geospatial library of SW climate change articles, a periodic newsletter for farmers and ranchers and an established website of climate change information.

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Bio: Emile Elias is deputy director of the USDA Southwest Climate Hub and research hydrologist at the USDA-ARS. Her current research focuses on the impacts of climate change on water quantity and quality in the Southwestern US. Additional recent research includes vulnerability assessment of Southwestern crops to a changing climate. Al Rango is a research hydrologist at the USDA-ARS-Jornada Experimental Range in Las Cruces. He directs the Unmanned Aerial Vehicle research program that has operated in New Mexico, Idaho, Arizona, and Alaska. He was also recently selected as the Director of the USDA Southwest Climate Hub that covers NM, AZ, UT, NV, CA, and HI. Caiti Steele is deputy director of the USDA Southwest Climate Hub. Her primary research interests are terrestrial remote sensing (vegetation and snow); current research focuses on how climate change affects the contribution of snowmelt to surface water availability. Additional research includes vulnerability assessment of agricultural and forest resources in Hawaii and US affiliated Pacific Islands. Kris Havstad is Research Leader and Supervisory Range Scientist at the USDA-ARS Jornada Experimental Range. His primary research interests include rangeland ecology and management. He recently authored the vulnerability assessment of animal agriculture to climate change in the Southwest.

Water supply planning for an uncertain future: Two case studies in Northern Utah exploring climate change and paleo drought

Tim Bardsley, Western Water Assessment
(co-authors: M. Bekker, L. Briefer, S. Paxman, S. McGettigan, D. Rosenberg)

Water managers in Utah and elsewhere have successfully managed limited water resources in the face of severe drought and dramatic inter-annual variability. Until recently, their planning has been largely based on the range of hydrologic conditions documented within the gaged record. In northern Utah, where the vast majority of the water supply is derived from mountain snowpacks and most of Utah's population lives along the Wasatch Front, the combination of climate change and a rapidly growing population are challenging water managers to continue to meet water demands. These challenges have motivated two collaborative studies involving two major water providers. These partnerships have explored climate change sensitivities as well as extreme droughts informed by recently available tree-ring reconstructions. The climate change hydrologies indicate earlier runoff, which will have significant impacts on the ability to meet late season demands, while the tree-ring reconstructions indicate droughts or intensity and duration not seen in the observed record. In combination with systems modeling, the analysis allows water managers to look both forward and back to inform water planning on a wide range of possible scenarios in an effort to guide adaption and inform no-regret actions.

Bio: Tim Bardsley serves as the Utah Liaison and Research Integration Specialist for Western Water Assessment (WWA), a NOAA-funded Regional Integrated Sciences and Assessments program that uses scientific expertise in climate and hydrology to help improve water reliability in the Intermountain West, especially in the context of climate variability and change and subsequent impacts. Based in Salt Lake City and hosted by the National Weather Service's Colorado Basin River Forecast Center, Tim partners with Utah water and land managers in numerous projects to help them plan for climate variability and change. Tim holds a Bachelor's degree in Civil Engineering from the University of Colorado-Boulder and a Master's in Hydrology from the University of Nevada-Reno. He has worked in Colorado, Utah, Nevada and California for over twenty years, specializing in hydrology and environmental sciences. Prior to joining WWA, Tim worked for the Niwot Ridge Long Term Ecological Research Program, and as a hydrologist with the Natural Resources Conservation Service's Utah Snow Survey Office.

Healthy watershed approach to managing streams: Role of science, stakeholders, education and partnerships

Tom Arsuffi, Texas Tech University Llano River Field Station
(co-authors: E. Seldomridge, K. Rainwater, T. Mclendon, K. Wagner)

Watershed is a productive scale to evaluate streams to perturbations. Such disturbances affect stream flow and water quality. To manage and maintain the ecological integrity of the Upper Llano River, Texas using a partnership approach, the TTU Llano River Field Station, Texas A&M Water Resources Institute, Texas Parks and Wildlife Department are working with the South Llano Watershed Alliance to develop and implement a Healthy Watershed Protection Plan (WPP) through a federal Clean Water Act 319(h) grant from the Texas State Soil and Water Conservation Board and U.S. Environmental Protection Agency. We characterize complexity of the watershed ecosystem through an integrated assessment of the landscape and biotic condition, abiotic parameters, critical watershed functional attributes and water yield from implementation of best management practices (BMP). The WPP uses a stakeholder process for decision-making on issues; economics of BMPs; landowner concerns; types of treatment measures needed/recommended; and implementation. Watershed education includes public workshops and curriculum for K-12 students. Agency partnerships, stakeholder/landowner involvement and education should be considered resistance and resilience components of watersheds that promote stability by increasing capacity to absorb disturbances.

Bio: Tom Arsuffi is Director of the Llano River Field Station at Texas Tech University in Junction. He received his Ph.D. at New Mexico State University in 1984 and did a post doctorates at the University of Georgia Marine Institute on Sapelo Island and Mount Allison University in New Brunswick, Canada. His research interests are in aquatic and watershed ecology and environmental education. He served as member of the Texas Natural Resource/Environmental Literacy Writing Team (TNR/ELP), Chairs the newly formed TNR/ELP Task Force, served as appointed member of the Senate Bill 3 Nueces River Corpus Christi Bay Basin and Bay Expert Science Team and is coordinator in developing a watershed protection plan for the Upper Llano rivers, funded by Texas State Soil and Water Conservation Board through EPA's Healthy Watershed Initiative.

A 50-year projection of Colorado River water supply and demand for five Arizona tribes and the Central Arizona Project

Carrie N. Joseph, University of Arizona
(co-author: M. Mahmoud)

The southwest, and particularly Arizona, has been in drought conditions since the beginning of the twenty-first century. The impact of drought coupled with climate change in the Colorado River Basin has been shown to reduce available water supply while demand is increasing. Climate change will affect tribal communities at a greater magnitude than other water users due to a lack of water infrastructure, poor water quality, subsistence based on cultural knowledge, economic stress, and water rights issues. In this study, a 50-year projection of Colorado River water supply is explored for five Arizona tribal communities and the Central Arizona Project (CAP) using the Colorado River Simulation System (CRSS) and CAP's Arizona On-River Model. Available Colorado River water supply was simulated based on the Colorado River's historical hydrological record, and which was then cascaded through individual Colorado River entitlements within the state of Arizona. Multiple demand scenarios were defined to approximate the consumptive use of each use while considering their priority on the Colorado River. The study found that the priority and demand of users had an impact on tribal and CAP water allocations: users with present and perfected rights remained unaffected and users with lower priorities suffered shortages. This study will aid the decision-making process as tribe's and water managers tackle the complexities of how to manage water resources while drought conditions persist.

The Las Vegas Wash: A multi-agency stakeholder process to protect and enhance a key ecological and hydrologic resource

Jason R. Eckberg, Southern Nevada Water Authority

The Las Vegas Wash (Wash) is the primary drainage channel for the 1600-square mile Las Vegas Valley, draining treated wastewater, urban runoff, shallow groundwater and storm flows to Lake Mead. The Wash is an integral component to Southern Nevada's water resources providing a conduit to return treated wastewater to Lake Mead. The Wash also has a substantial impact on the water quality of Lake Mead. The Las Vegas Wash Coordination Committee (LVWCC) was formed in October 1998 to create and implement a long-term management plan for the Wash, which had suffered significant erosion, degradation of water quality, and loss of wetlands in prior decades. In January 2000, the 29-member LVWCC published the Las Vegas Wash Comprehensive Adaptive Management Plan, a document outlining 44 action items necessary to stabilize the channel, improve water quality, and restore ecological functions, including reestablishing wetlands. Since 2000, the LVWCC has been implementing these action items through a collaborative stakeholder process. Achievements include construction of 18 of 21 planned erosion control structures, removing more than 500 acres of invasive plants, revegetating more than 400 acres with native plants, initiating several water quality and biological resource monitoring studies, and conducting numerous public outreach events.

Bio: Jason Eckberg is an Environmental Biologist with the Southern Nevada Water Authority (SNWA) where he has worked since 2000. He holds a B.S. in Environmental Studies and a M.S. in Environmental Science from the University of Nevada Las Vegas. He has multiple responsibilities at two major restoration projects in Southern Nevada for SNWA. First, he is responsible for designing and implementing revegetation and restoration programs along the Las Vegas Wash, the primary drainage for the 1600 sq. mi. Las Vegas Valley. This program has resulted in the creation of over 400 restored acres so far. Jason is also involved in many wildlife monitoring and research activities including overseeing all invertebrate monitoring activities at the Las Vegas Wash as well as at the SNWA owned Warm Springs Natural Area (WSNA) near Moapa, NV. Also at the WSNA property, Jason operates the propagation facility which provides plant material to restoration projects both at the Las Vegas Wash and the WSNA itself. In his free time, Jason enjoys spending his free time traveling with his wife and son and is active in church activities.

Groundwater oscillations associated with the phreatophyte *Sarcobatus vermiculatus* under a falling water table in the Great Basin, NV

Dale Devitt, University of Nevada, Las Vegas
(co-authors: B. Bird, L. Fenstermaker, L. Apodaca)

Groundwater in remote valleys of the Great Basin (NV,USA) have been approved by the State Engineer (NV) for pumping and export. Deep rooted shrubs such as greasewood (*Sarcobatus vermiculatus*) are partially dependent on this groundwater to meet plant water needs. If groundwater levels decline, these shrubs could become decoupled from this otherwise reliable source of water. We monitored groundwater levels and daily oscillations for 6 years in a greasewood plant community in East Central Nevada. Our goal was to assess the impact of a falling water table on groundwater oscillations and to determine the relationship between groundwater evapotranspiration (ETg), plant community level evapotranspiration (ETec) and plant level transpiration during a well- defined groundwater oscillation period. Groundwater levels declined 130 cm in a highly linear fashion. However, if the linear decline in the water table continues, it is conceivable that within the next decade greasewood could become decoupled from the groundwater at this site based solely on groundwater pumping associated with the irrigation of alfalfa fields within the basin.

Bio: Dr. Devitt is a soil and water scientist with the School of Life Sciences at UNLV. He is also the Director at the Center for Urban Horticulture and Water Conservation. He received his BS, MS and PhD all at the University of California Riverside.

Effects of the toxigenic alga *Prymnesium parvum* on a freshwater zooplankton community

Brenda Allison Witt, University of Oklahoma
(co-authors: J. Beyer, T. Hallidayschult, K.D. Hambright)

The toxigenic, invasive alga *Prymnesium parvum*, commonly known as golden algae, has received increased attention in recent years due to its expanding presence in freshwater systems, with at least 17 states reporting blooms. Many species of algae, including *Prymnesium*, cause temporary harmful algae blooms (HABs) and produce toxins that can have negative effects on coexisting organisms in the system, changing the composition of the community. Zooplankton can be directly affected by HABs and are an important part of freshwater food webs as they serve as a food source to young-of-the-year and planktivorous fishes. However HAB effects tend to be taxonomically specific as some zooplankton, such as *Daphnia*, feed indiscriminately on particles suspended in the water, while other taxa, such as copepods, are highly selective feeders. In addition, some species may possess a stronger resistance to toxins than others. We hypothesized that a zooplankton community exposed to a bloom of *Prymnesium* would show differential survivorship based on varying levels of feeding selectivity and subsequent exposure to *Prymnesium* toxins. To test this, we conducted a laboratory experiment in which zooplankton communities collected from Soldier Creek Inlet (Lake Texoma, OK-Texas) were exposed to densities of *Prymnesium* ranging from 50,000 to 200,000 cells/mL (densities as low as 25,000 cells/mL have been known to cause fish kills in Lake Texoma) and incubated in 2-liter bottles for 48 hr. At the conclusion of the experiment, all bottles were filtered through 20µm filter mesh for zooplankton collection and stored in 80% ethanol. Identification and enumeration of the zooplankton communities showed differential survivorship among taxonomic groups, thus supporting the idea that some zooplankton species are less affected by *Prymnesium* blooms and suggesting that zooplankton communities could shift if HABs continue to increase in frequency as well as spatially.

Bio: Brenda Allison is a graduate student at the University of Oklahoma working towards her M.S. in biology. She obtained her B.S. in zoology at the University of Oklahoma while working as an undergraduate research assistant in the Plankton Ecology and Limnology Laboratory. Her current research interests include harmful algal blooms and invasive species, specifically focusing on the effects of *Prymnesium parvum* on aquatic food chains.

Physical, chemical, and biological cycling of selenium in Las Vegas Wash

Sahar Ehsani, Desert Research Institute & University of Nevada, Las Vegas
(co-authors: K. Acharya, D. Hayes)

Selenium bioaccumulation in the food chain causes dietary selenium exposure to aquatic organisms and their predators. Selenium bioaccumulation is strongly affected by the speciation, or different chemical forms of selenium. Recently, there have been concerns over the elevated concentrations of Selenium in the tributaries that feed the main stream Las Vegas Wash. The Las Vegas Wash drains into Lake Mead which provides drinking water supply to the city of Las Vegas. Therefore, studying biogeochemical cycling of Se speciation is important in order to help understand the processes that affect the transformation of Se speciation and their potential accumulation or release affecting Lake Mead water quality. In this study, modeling is combined with laboratory and field data collection to understand the fate and transport of various forms of Se and underlying mechanisms (i.e., chemical, biological or hydrological) in the Las Vegas Wash water column and sediments. The main goal of the research is to understand whether the Las Vegas Wash act as sink or source for various species of Se (i.e., selenite, selenite, selenide and elemental selenium).

Bio: Ms. Sahar Ehsani has a B.S. in Water Engineering from University of Tehran, Iran, a M.S. in Civil – Water & Environmental Engineering from University of Surrey, England, and is currently studying PhD in Civil – Environmental Engineering at University of Nevada, Las Vegas. Her research in PhD involves studying the fate and transport of Selenium speciation in the Las Vegas wash. Previous research experiences include analyzing the effects of dredging on PCB pollution in the Green Bay, Wisconsin.

The environmental fate of the phytoestrogens genistein and daidzein

Megan Kelly, Lake Superior State University

Genistein and daidzein are two phytoestrogens, compounds that come from plants (especially legumes) and interact with the estrogen receptors present in humans, fish, and other animals. Although these compounds are naturally produced in the environment, they can become concentrated in the effluent of facilities treating the waste of plant-processing industries. They are also detected in run-off from fields where plants such as red clover are found. At environmentally-relevant concentrations, genistein and daidzein have been shown to produce reproductive, behavioral, and immunosuppressive effects in fish. This work develops the chemical and microbiological parameters necessary to predict the concentrations of genistein and daidzein in a body of water receiving a discharge containing the phytoestrogens. The attenuation processes studied include direct and indirect photolysis, sorption to settling particles, and biodegradation. Biodegradation is shown to be an extremely efficient removal process. Work by the Aquatic Toxicology Lab at Saint Cloud State shows that estrogenicity is removed by biodegradation, but some component of the biodegradation product mixture produces an androgenic or anti-estrogenic effect. More research is needed, therefore, to fully understand the exposure of aquatic wildlife to phytoestrogens and their degradates.

Integrating water resources and demand to improve drought resilience and build water strategies: A pilot approach to Kenya's arid and semi-arid lands

Sarah Sparker, Millennium Water Alliance
(co-author: *S. Dundon)
*Presenter - Sarah Dundon, Millennium Water Alliance

Building long-term resilience against recurrent drought in arid lands is one of the challenges addressed by the Kenya Arid Lands Disaster Risk Reduction – Water, Sanitation, and Hygiene (KALDRR-WASH) program, a two-year program supported by USAID and The Netherlands. This presentation focuses on an innovative approach developed and tested in the program, using local, participatory water planning to match water resources with water demand and using hydrogeological data at the catchment level to build natural and artificial storage to improve groundwater water recharge, retention and reuse. The challenge In Kenya's arid and semi-arid lands (ASALs), the total demand for water often exceeds the water available to people and livestock. This problem is compounded by weak support from government and competition for resources amongst water users, which creates the potential for conflict. Most water-related interventions are short term and target a single problem, rather than the whole complex of problems that communities face. Although Kenyans experience periods of severe water scarcity, annual rainfall is actually sufficient to support their livelihoods. The gap arises because a large portion of the water disappears unused through surface runoff, flooding and evaporation. Integrated approach to matching water supply and demand in collaboration with Dutch technical partners Acacia Water, IRC, and Aqua for All, MWA members executed an innovative approach that integrates the management of local water resources and services. Using the RIDA framework (for resources, infrastructure, demand and access), it evaluates on one hand the potential of water resources and existing supply infrastructure, and on the other hand total water demand and water access challenges. This integrated, area-based approach encompasses all local water uses (domestic, livestock, agriculture), all local water resources and all local water stakeholders (operators, users, government). Based on field assessments and research, an estimate is made of the actual water gap for the coming ten years. Next, strategies are developed to meet these gaps through water infrastructure, water governance, water service management, and capacity development. Stakeholders divide responsibilities for coordinating the different strategies of the water master plan. Cost estimates for the strategies are based on the life-cycle costs approach analysis of water services. Stakeholders then select recharge, retention and reuse strategies to complement traditional water sources, to increase the amount of useful water. 3R interventions extend the chain of uses and store water in shallow aquifers, the soil profile, open water and tanks. The ultimate goal is to create secure water buffers that can meet the local water demand. This translates into increased resilience during droughts, higher productivity and better access to drinking water.

Promising findings and initial successes from the pilots: a) Only a relatively small amount of rainfall needs to be stored to meet demand in rural areas, even in the driest years. b) Local, participatory water master planning is a strong tool for guiding interventions and building resilience to drought. c) In Wajir, the participatory planning meeting addressed and defused conflicts over water and land. The mapping of the water gaps informed discussions on options for grazing land strategy in both wet and dry seasons. Participants agreed to create new water sources near homesteads to avoid conflicts with neighboring clans with migrating herds. d) In Moyale, stakeholders said that the tools provided an excellent opportunity to integrate traditional water management practices, which are neglected in most other planning processes. e) In Marsabit, Wajir and Turkana, government representatives recognized the link with Kenyan planning mechanisms, and said the new tools would help them translate county plans into actions.

Future directions: The pilot was based on proven approaches developed in different contexts but tailored to ASALs in Kenya. The next task is to refine the methodology so that it will be replicable and can be scaled up. Steps include the following: 1) Linking the methodology to the government's existing water management planning approach and institutions. 2) Improving interpretation and applicability of the maps (e.g., for irrigation or specific conservation techniques). 3) Streamlining participatory processes for small sub-catchments, catchments and/ or county administrative levels. 4) Improving planning with information on the financial sustainability of water interventions.

Specific examples of the use and results of the methodology will be given as part of the presentation.

Bio: Sarah Sparker is a Program Officer with MWA. Previously, she worked in Monitoring and Evaluation at the International Finance Corporation, a member of the World Bank Group, as well as in development project coordination at the International Development Group. Sarah has field experience in Central America and India, and a strong interest in WASH, public health, and Monitoring and Evaluation. She received an MA in International Economics and Development from the Johns Hopkins School of Advanced International Studies, and a BA in Development Studies from the University of California, Berkeley.

Multi-criteria decision support within the robust decision making framework with an application to climate change adaptation in Lake Tana, Ethiopia

Julie Shortridge, The Johns Hopkins University
(co-author: S. Guikema)

Climate change is expected to have dramatic impacts on the water supply sector, and there is increasing concern that some degree of adaptation will be required to ensure sustainable water management in many regions of the world. However, adapting to future climatic conditions is challenged by the considerable uncertainty surrounding projections of future hydrologic conditions. This has prompted the development of a number of approaches aimed at supporting decisions under "deep-uncertainty" which cannot be represented probabilistically. One such methodology is Robust Decision Making (RDM), which uses simulation models to assess how strategies perform over a wide range of future scenarios and then identifies and characterizes scenarios where the strategy fails. While RDM has been used to support long-term planning in a number of water supply contexts, it has generally assessed outcomes over only one or two metrics (e.g., cost or water delivered). However, many water resource systems are characterized by the need to meet multiple objectives, including cost minimization, provision of water to multiple sectors, and maintenance of environmental flows. This research assesses different methods for incorporating multiple criteria into the RDM approach and evaluates how these methods might impact RDM outcomes and insights. These methods are applied within an RDM analysis of the Lake Tana basin in Ethiopia, where multiple newly constructed and planned water infrastructure projects must supply water to support diverse economic sectors and protect environmental resources. Different methods are compared to assess whether the choice of multi-criteria method impacts the strategies identified as most robust and the future scenarios under which preferred strategies fail.

Bio: Julie Shortridge is a PhD candidate in the Department of Geography and Environmental Engineering at the Johns Hopkins University. Her research focuses on adaptation to climate change and the accompanying issue of deep uncertainty, with a particular focus on water resource systems. She aims to address the question of how highly uncertain climate change projections can be incorporated into long-term management of natural and engineered water systems. She is interested using systems engineering methodologies, including risk and decision analysis, optimization, simulation, and statistical modeling, to address these issues.

Impact assessment of illegal dumping in borrow pits on shallow groundwater in Thailand

Uma Seeboonruang, King Mongkut's Institute of Technology Ladkrabang

With the regional economic and industrial development in Thailand, particularly in the eastern seaboard of Thailand, polluted and degraded environments of the area becomes the greatest concern to the country. Recent illegal disposal of toxic waste in old and abandoned borrow pits has been discovered extensively in many locations, mostly in Chachoengsao province. In this study, we focus beyond just identifying the most potential illegal dumping destinations but also establishing impact assessment of the sites on groundwater and surface water in order to propose a scheme for monitoring the high risk areas for illegal toxic waste disposal. The key features for the exposure factor in the previously illegal dump sites in the East of Thailand include the distances from borrow pits to the nearest villages and highways, and the sizes of borrow pits. Consequently, the sensitivity factor is modified based on the well-known DRASTIC method, and the key attributes are topography, the ease of pollutants to transport through soil surface, vadose zone, and saturated layer. Individual borrow pits are grouped according to the particular features by the cluster analysis. Rates and weights for each feature are given based on previous studies and recent expert analysis. Maps for particular exposure and sensitivity factors are delineated. Finally, a risk or impact assessment map with hotspots is constructed indicating zones with low, medium, and high in risk. Frequent and constant monitoring including environmental measurement should be put in place for these hotspot sites.

Bio: Uma Seeboonruang graduated from University of California, Davis. Her research has focused on groundwater flow and contamination transport in subsurface heterogeneous fields including groundwater flow and reactive solute transport numerical modeling. Recently, her research focus has shifted to the vulnerability assessment of climate change impacts and anthropogenic effects on groundwater. She has received research funds on projects related to climate change and groundwater related topics. These are "Quantification of transient groundwater age to the understanding and measurement of climate change" and "Quantitative Analysis of Impacts of Climate Variability on Deep Groundwater Signals in an Intense Groundwater Pumpage Area Research". She joined the G@GPS (Groundwater@Global Palaeoclimate Signals) initiative group. Currently, she is involved on a number of government projects, which helps broaden her perspectives in the climate change field and vulnerability assessments, as the main principle investigator and a research team member on several occasions.

A methodology for informing management decisions in groundwater dependent communities coping with climate uncertainty

Susanna Eden, University of Arizona Water Resources Research Center
(co-authors: S. Megdal, E. Shamir, K. Chief)

Extended Abstract

Climate uncertainty increases management challenges for groundwater dependent communities in arid and semi-arid regions where local climate fluctuation has a significant influence on their water supplies. This project, funded by the U.S. National Oceanic and Atmospheric Administration, employs a novel modeling framework and extensive stakeholder interactions to achieve the following three objectives: (1) Address water resources management issues in light of the projected increase in climate uncertainties; (2) Increase stakeholder capacity to adapt water planning and management to future climate uncertainties; and (3) Establish the transferability of the modeling framework and capacity building approach. The modeling framework links climate through precipitation, streamflow, recharge and groundwater response components to groundwater management decision making. Monte Carlo techniques are used to generate likely precipitation scenarios to capture the uncertainty associated with intra- and inter-annual rainfall variability. The precipitation generator was enhanced to account for projections of future climate change that indicate even greater uncertainty. Information from dynamically downscaled regional climate model projections was used to adjust the probabilities of seasonal wetness in summer and winter.

Stakeholders hold the key to linking models of physical processes with groundwater management. A robust stakeholder engagement process was employed along with the modeling framework to establish mutual understanding of the management challenges and goals. Through extensive work with stakeholders and agency personnel, this effort explored how climate science information and surface water-groundwater connectivity can inform groundwater management efforts.

The methodology was applied to a case study on a series of small alluvial aquifers along the Upper Santa Cruz River. These small aquifers are used by the City of Nogales, Arizona for approximately half its water supply. A community on the Arizona-Mexico border, Nogales balances the use of the renewable groundwater in these alluvial aquifers with other groundwater resources of lower quality that are more expensive to pump and treat. Stakeholders in the region are concerned about meeting the management goal of avoiding long-term water table declines. Building on a model depicting localized and regional hydrologic conditions that was created by the Arizona Department of Water Resources, the modeling framework is capable of analyzing the impact of various pumping strategies on stated management objectives, such as ensuring supply reliability, increasing recharge, or protecting riparian vegetation. The case study modeling results indicate that an optimal groundwater management strategy can be obtained.

Stakeholder workshops were employed to investigate the transferability of the modeling framework and stakeholder engagement methods to regions beyond the case study. Research into the transferability of the methodology to other regions yielded a number of scenarios in which the ability to link climate, streamflow and groundwater could produce useful information for water planners and managers. A workshop involving participants from Mexico discussed potential for cross-border implementation of the methodology. The presentation will introduce the modeling framework and stakeholder process, describe the case study and delve into the results of the transferability research for other applications.

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Bio: Susanna Eden is the Assistant Director at the Water Resources Research Center, University of Arizona. She holds a Ph.D. in Water Resources Administration from the University of Arizona and has been engaged with water resources research and administration for more than 25 years. Her research centers on policy and decision making in water management and the use of scientific information. Recent research focuses on water harvesting as an adaptive strategy with multiple benefits to communities, stakeholder engagement and the use of modeling information in water resources planning. She also edits the WRRC's quarterly newsletter, Arizona Water Resource, and the annual Arroyo publication.

Predicting nutrient and dissolved oxygen concentrations in the Spokane River under future development and climate conditions

Zubayed Rakib, University of Utah
(co-author: M. Barber)

Recent and projected urban growth coupled with climate change implications have raised concerns about potential future impacts on water availability and water quality in the Spokane River. Previous studies have detected significant trends of decreasing monthly mean streamflow and annual 7-day low streamflows along the Spokane River, leading to concerns about water availability and increased water quality problems. Excessive algal blooms contribute to both an aesthetic problem and a low dissolved oxygen (DO) level during low flow in the summer months, causing portions of the river to violate the Washington State water quality standards for DO. The original Spokane River CE-QUAL-W2 model used by Washington State Department of Ecology was set up to model a portion of a historic low flow year (2001). TMDLs developed using a model for a single low flow condition may not accurately reflect climate induced changes in the runoff cycle or nutrient cycling initiated by high flow years. This study modified the original CE-QUAL-W2 model to simulate hydrology and water quality over a 10 year historic period and then examine water quality changes in response to various climate and population growth change scenarios for the 2040s, with particular attention to phosphorus, nitrogen, DO, and river temperature. This study used a ten year window (1999-2009) to reflect a variety of flow conditions and facilitate investigation and decisions regarding permissible nutrient levels that include a variety of hydrologic conditions. Model calibrated for an extended period will be more predictive of the nutrient dynamics under varying flow states. Finally, the calibrated model was used to explore the impacts of climate change and population growth scenarios on water quality and allowable nutrient loading in the Spokane River. Initial results indicate lower flows will exacerbate existing conditions. Final results will be available in the near future.

Bio: Zubayed Rakib is a Master's student at the University of Utah since January 2014. He is a research assistant working with Dr. Michael E. Barber, and is working on the study of water quality modeling of the Spokane River. His work is devoted towards understanding the nutrient and dissolved oxygen concentrations in the Spokane River under future development and climate conditions. Previously, he completed his B.Sc. from Bangladesh University of Engineering and Technology in 2012. Dr. Michael E. Barber, P.E. is the current Department Chair of Civil Engineering at the University of Utah. Previously, he worked as professor at Washington State University from 1994-2013, and was the Director of State of Washington Water Research Center, SWWRC and Center for Environmental, Sediment and Aquatic Research, CESAR. His research focuses on water quality and quantity modeling, hydrology, surface-ground water interaction, constructed wetlands and wet ponds, and remote sensing. Dr. Barber completed his Ph.D. in Civil Engineering from University of Texas, Austin. Previously, he did his M.S.C.E. and B.Sc. in Civil Engineering from Purdue University and University of New Hampshire.

A tale of two cities: Comparison of water resource management system response under varying climate and population growth in Salt Lake City, UT, and Las Vegas, NV

Erfan Goharian, University of Utah
(co-authors: S. Dawadi, S. Ahmad, S.J. Burian)

Managing tradeoffs among water uses from different water sources supplying metropolitan areas is a complex task. The challenges of complexity inhibit the ability to comprehensively study integrated water systems in cities. One major uncertain and complex component is representing future water resources systems responding to climate variability. It is widely regarded that climate change can have a significant effect on the long-term reliability of municipal water supplies. Moreover, population growth and resulting increases in water demand can exacerbate the condition. Both climate change and population growth are important drivers in western US water management, especially in semi-arid areas. While there are some similarities in terms of water stressors in western USA, there are important and subtle differences among nearby cities. In order to present the complexity and feedbacks in simulation, the water systems responses are studied using system dynamics models. In this study, two cases are selected to explore how water resources systems respond to climate change and population growth. Specifically, Salt Lake City, Utah, and Las Vegas, Nevada are the focus of this comparative analysis. A range of water management solutions are investigated in both cities to mitigate the impact of population growth and climate change. Results show that, in both systems, if no further demand management policies are implemented the water supply would not be able to meet future demands. However, the Las Vegas' water system is much more vulnerable than Salt Lake City's system.

Bio: Erfan Goharian is currently a PhD Candidate at the University of Utah.

Hydrogeologic framework characterization in America's newest national monument: Primetime in Glitter Gulch

David J. Donovan, Aqua Petrus

On December 19, 2014 Congress authorized a large national monument (22,400 acres) along the northern tier of the metropolitan area of Las Vegas Valley. Designated Tule Springs Fossil Beds NM. The new monument is bounded on the south by existing urbanization, and on the north by the Desert National Wildlife Refuge (the largest WR in the contiguous US). The purpose of the monument is the preservation of Pleistocene megafauna fossils as well as, archeological resources and (modern) endangered species. During full glacial conditions, Nevada (and the Great Basin) was significantly wetter than present and hosted very large lakes such as Bonneville, Lahontan, Manly and lessor known endorheic lakes confined to the valley floors of the basin and range. Although early hydrologic reports on the Las Vegas Valley (LVV) theorized a "Lake Las Vegas", subsequent reports have shown conditions in LVV to be paludal (marsh like) and similar to areas higher in latitude and altitude in the Great Basin. The best available data suggests that a good description is a shift of ~ kilometer in altitude. That is, an area located currently at 2,500 ft amsl (750 m - the area of the monument) would be similar to 5,750 ft (1,750 m) in modern conditions. As a result LVV was a large grass land with abundant water sources; an ideal location for large extinct herbivores and associated predators. And indeed, such fossils are abundant in this area. In general, the paleospring areas surround the modern spring areas and wetlands, however, the area of the monument had no known historic springs. This presentation will describe the new monument, fossil resources that have been identified, and describe the changes in the climatic conditions in LVV.

Bio: David J. Donovan has worked professionally in Nevada for over 25 years as a geologist and hydrologist. He has worked in both northern and southern Nevada, receiving a Master's of Science with University of Nevada, Las Vegas in 1996 and the Bachelor of Science in Geology from Northern Arizona University in 1987. He is also an Arizona Registered Geologist (RG) and an AIPG Certified Professional Geologist (CPG). David has been actively involved with research on the history of ground-water development, hydrogeological framework, and geochemistry, effects of artificial recharge, natural recharge, and discharge for multiple ground water basins in eastern Nevada. He has published journal articles on several hydrogeologic topics including cost-benefits of a ground water management program, natural ground-water recharge, and discharge in Las Vegas Valley. His main geologic interests have been to associate the local stratigraphy to hydrostratigraphic formations, as stated in his MS Thesis (1996), for Las Vegas Valley.

Adaptive water governance: A framework for integrating the human dimensions into the governance of water resources in the face of uncertainty

Kofi Akamani, Southern Illinois University

The conventional command and control paradigm of water resource management that dominated much of 20th century water policy was characterized by an emphasis on prediction and control of water resource systems, overreliance on reductionist science, pursuit of narrow sectoral goals, and a top-down decision-making process. This approach has resulted in vulnerabilities due to inadequate consideration of the human dimensions and failure to prioritize the need for learning and adapting to change and uncertainties. In response to recognition of these shortfalls in the conventional water management paradigm, recent years have seen the emergence of various concepts and policies aimed at addressing these shortfalls. However, efforts aimed at integrating the human considerations into water resource decision-making and policy goals (e.g. collaborative water resource management, and integrated water resource management) have not paid adequate attention to building the capacity of water resource systems to learn and adapt to change. On the other hand, concepts and policies aimed at enhancing learning and flexibility through adaptive management have not given adequate attention to social and institutional considerations. This paper therefore proposes adaptive water governance as a promising institutional mechanism for integrating the human dimensions into water resource governance while building the capacity of water resource systems to learn and adapt to change. Adaptive governance is underpinned by complexity and resilience thinking and its key attributes include: adaptive, integrated resource management goals; analytic deliberation process; diverse knowledge systems; and polycentric institutional structures. Through these mechanisms, adaptive governance can contribute to sustainability, good governance, conflict management, and resilience-building in water resource systems.

Bio: Kofi Akamani is an Assistant Professor of Forest Recreation and Conservation Social Science in the Department of Forestry at Southern Illinois University. He received his Ph.D. in Natural Resources from the University of Idaho. His interdisciplinary teaching and research agenda involves the integration of concepts from social-ecological systems research, rural sociology, and common pool resources among others with the aim of gaining a theoretical understanding of human-environment interactions across multiple scales from the local to the global, and informing policies that promote human well-being and ecosystem health across the rural urban continuum. He is particularly interested in understanding and enhancing the resilience of rural forest-dependent communities and the adaptive governance of forests, land and water resources.

Eliciting stakeholder knowledge for water resource decisions: The case for socio-hydrology in the Murray-Darling River basin, southeastern Australia

Ellen Douglas, University of Massachusetts Boston
(co-authors: S. Wheeler, D.J. Smith, I. Overton, N. Crossman, T. Doody)

Water stress and over allocation are at the forefront of water management and policy challenges in many parts of the world, not the least of which in the Murray Darling Basin (MDB), the most agriculturally intensive river basin in Australia. The MDB Plan, enacted in November 2012, has at its core the goal of balancing economic, social and environmental outcomes within the Basin. However, even with the legislation in place, questions remain about how such a policy can balance social and environmental goals concurrently. Socio-hydrology is an emerging field that offers promise in this regard in that human systems, such as irrigated agriculture, are viewed as dynamic components in the hydrologic system rather than as external forcing to the system. We define socio-hydrology as the study of the emergent properties of the human-hydrology interface. For both environmental and economic reasons, irrigators in the MDB have become experts in water use and water efficiency. Because irrigated agriculture is a major social and economic component of the MDB, farmer decision-making plays a major role in the overall sustainability of agricultural production in the region. Water managers and government officials often benefit by partnering with farmers and incorporating their expertise into water management and policy decisions. Through workshops with farmers, we used a fuzzy cognitive mapping methodology, a so-called 'mental modeling' approach, to understand the perceived constraints of farmer water use decisions in the MDB. The approach allowed us to elicit and document farmer insights into the multifaceted, complex and networked nature of irrigation water use decisions in relation to farm-based dynamics. We will present the results of this case study and recommendations for advancing the socio-hydrologic perspective.

Bio: Dr. Ellen Douglas is a hydrologist and engineer with broad expertise in the analysis of water-related issues. She earned a BS in Hydrology and an MS in Civil Engineering from the University of New Hampshire and a PhD in Water Resources Engineering from Tuft University in 2002. Dr. Douglas joined the faculty of UMass Boston in 2006 and was granted tenure in 2012. Dr. Douglas' research interests include evaluating the impacts of climate change on New England hydrology, assessing the vulnerability of coastal communities to flooding, improving methods for sustainable water resource management and monitoring the performance of river restoration through dam removal. Dr. Douglas has authored or co-authored 22 peer-reviewed publications, four book chapters, and is a contributing author for the 2013 U.S. National Climate Assessment and the IPCC Fifth Assessment Report. She is a co-author of "Preparing for the Rising Tide", a report on climate change vulnerability and adaptation options for Boston sponsored by The Boston Harbor Association. Dr. Douglas was awarded a 2013-14 Fulbright Scholarship to work in Australia with the CSIRO on the Water Values and Benefits project.

Community involvement leads to a winning hand

Erika Wettergreen, Marstel-Day LLC

Scientific research, analyses, and modeling play a vital role in promoting sustainable water management. Presenting complex water resource concepts and describing scientific/technical processes and results to "non-scientists" can be challenging. Scientists and engineers should have access to the appropriate tools and training to be effective communicators. A strategic communications approach accommodates building bridges for strengthening public support and improve community awareness and advocacy. Implementing innovative, creative ways for making science accessible and understandable supports the acceptance of scientific research and findings. In addition, proactively developing strategies that anticipate and counter misinformation and misconceptions that may confuse public debate will facilitate positive interaction and productive dialogue. Community Water Dialogues allow stakeholders to share their sense of the most critical water concerns and needs. Their participation is most valuable when their contributions have been heard and actually inform the decision makers.

Bio: Erika Wettergreen is a Senior Analyst for Marstel-Day, drawing on her 22 years of experience in water resource planning and environmental management. She served as the Water Resources Planner for the Army Water Security Strategy, which was developed to assist the Army in identifying how water affects its ability to successfully accomplish its vital missions in support of U.S. national interests. She also led the development of the Marine Corps East (MCIEAST) Standard Operating Procedures (SOP) for water resources partnerships, which focused on addressing regional water issues in the Southeast and exploring how long-term water availability may impact military operations. In the past, Mrs. Wettergreen has worked with agencies and communities, assisting them with successfully moving through collaborative, decision-making processes and mediating multi-party disputes.

Stakeholder involvement process and outcomes in developing a state-wide nutrient loss reduction strategy

Brian Miller, University of Illinois
(co-authors: M. Willhite, W. Goetsch, A. Walkenbach, L. Merrifield, C. Layfield)

The United States Environmental Protection Agency (EPA) has directed each state in the Mississippi River drainage to develop a nutrient reduction strategy that will result in a 45% reduction in phosphates and nitrates reaching the Gulf of Mexico. We completed a yearlong process of engaging stakeholders in the development of a strategy that addresses agricultural, urban, point source, and environmental stakeholder concerns. A state-wide policy work group and working subcommittees representing stakeholder interests: 1) developed criteria for setting watershed priorities, 2) identified practices and compliance levels possible through ongoing voluntary programs, 3) explored a continuum of regulatory options to close gaps 4) identified key policy elements necessary to ensure stakeholder viability and buy-in, 5) debated nutrient reduction criteria 6) and identified 5 entities necessary for strategy implementation and adaptive management. We will present points of consensus, contention, and selected solutions in each of the 6 element areas explored.

Bio: Dr. Brian Miller is a Natural Resource Social Scientist and Wildlife Biologist. He is the Director of the Illinois-Indiana Sea Grant College Program and the Illinois Water Resources Center. His research focuses on factors influencing natural resource planning and decision making. He has developed, led, or been involved in land use engagement programs and online DSS projects including Planning with POWER, Local Decision Maker, Tipping Point Planner.org , and Great Lakes Monitoring.org. He is the National Co-Chair of Sea Grant's Sustainable Coastal Development Focus team and a member of NOAA's Great Lakes Regional Collaboration Team. He is experienced in facilitating community land use discussions and currently serves as the facilitator for the development of the Illinois Nutrient Reduction Strategy to reduce nutrient inputs resulting in Gulf Hypoxia.

Enhancing the success of water quality management programs

Kevin Wagner, Texas Water Resources Institute
(co-authors: L. Gregory, A. Berthold)

According to the National Water Quality Inventory Report (i.e. 305(b) report), the majority of waterbodies in the US do not meet established water quality standards. Over half of river miles, two-thirds of lake acres, and almost three-quarters of the bay and estuary area assessed were impaired in 2010. Pathogens (in rivers and streams) and mercury (in lakes, reservoirs, bays, and estuaries) are the leading causes of water quality impairment. When a waterbody is listed as impaired, states may use a variety of methods to address the impairment, including evaluating the appropriateness of existing water quality standards, collecting more data, or developing restoration plans. For waterbodies requiring restoration, total maximum daily loads (TMDLs) / TMDL Implementation Plans or other watershed based plans describing the means by which these waterbodies will be restored must be developed and implemented. To assess the characteristics of successful watershed plans, 52 of the 295 Clean Water Act §319 Nonpoint Source Success Stories were evaluated representing almost every state in the US. For each success story, the parameter addressed, percent reduction achieved, segment size and/or watershed size, duration of implementation, implementation costs, and key practices implemented were documented and analyzed. This presentation will describe these strategies, discuss their pros and cons, provide insight into the characteristics of successful watershed plans, and make recommendations on how to improve water quality management.

Bio: Dr. Kevin Wagner currently serves as associate director of the Texas Water Resources Institute and adjunct professor in Texas A&M University's Department of Soil and Crop Sciences. He provides leadership and administration for institute water programs; conducts research on watershed response to management; develops and evaluates management systems designed to sustain agricultural productivity and protect water resources; trains water professionals and students on watershed planning, assessment and policy; and conducts watershed assessment, planning and stakeholder engagement to address water issues. Dr. Wagner serves on the Brazos G Regional Water Planning Group, Brazos River and Associated Bay and Estuary System Basin and Bay Stakeholder Committee, Texas Groundwater Protection Committee, Texas Water Conservation Advisory Council, and the Universities Council on Water Resources. Wagner received a PhD in agronomy from Texas A&M University, master's degree in environmental science from Oklahoma State University, and bachelor's degree in biology from Howard Payne University.

Nutrient trading – Is this a worthwhile pursuit for water pollution control?

David Stevens, Utah State University

Water quality trading is an innovative approach to achieve water quality goals more efficiently. Trading is based on the fact that sources in a watershed can face very different costs to control the same pollutant. Trading programs allow facilities facing higher pollution control costs to meet their regulatory obligations by purchasing environmentally equivalent (or superior) pollution reductions from another source at lower cost, thus achieving the same water quality improvement at lower overall cost. This talk will explore the potential for trading in the context of nutrient management in agricultural watersheds.

Bio: David King Stevens, Ph.D. is Professor and Head of the Department of Civil and Environmental Engineering Utah Water Research Laboratory at Utah State University. He has a B.S. in Civil Engineering from Tufts University and a Ph.D. in Civil and Environmental Engineering from the University of Wisconsin-Madison. He a registered Professional Engineer with the state of Ohio. Dr. Stevens has 30 years of experience in Environmental Engineering and his areas of expertise and research interests include development and integration of water quality and quantity models for water supply and watershed assessment, and statistical and experimental design methods for environmental engineering research. He has recently worked in integrated watershed assessment and decision support for culinary water improvement through reservoir management in Utah's Weber and Ogden River Basins, in the mitigation of selenium contamination in Utah's Ashley Valley through integrated watershed assessment and irrigation management, in the integration of high frequency water quality monitoring data with models and data analysis tools for watershed improvement, and in monitoring and statistical analysis for toxic contaminant levels in water distribution systems. Dr. Stevens has been a P.I or Co/P.I. on a number of projects funded by U.S. EPA, USGS, USAF, USBR, DOE, private industry, and Utah and Idaho agencies, and has served as a consultant to both industry and government. He has published over 50 refereed journal articles, technical reports, and book chapters.

Lake Havasu water quality monitoring program five year study 2010-2014

Heidi McMaster, US Bureau of Reclamation
(co-authors: J. Kirsch, D. Anat, J. Stegmeier, M. Maynard)

Quagga mussels were discovered in Lakes Mead, Mohave, and Havasu in 2007. State regulations authorized by the Aquatic Invasive Species Interdiction Act were put into effect in 2009 and updated in July. In October 2009, Reclamation staff began a pilot study to collect data on quagga mussel veliger abundance. Data collected included secchi disk depth (with and without scope), Eureka multiprobe profiles (temperature, pH, conductivity, dissolved oxygen, and depth), and zooplankton tows. The pilot study established five sampling locations across Lake Havasu. In July 2013, the pilot study shifted from a quagga mussel monitoring study to a more robust water quality monitoring program with the addition of chlorophyll, total phosphorus, and phytoplankton monitoring parameters added in July 2013 and combined inorganic nitrogen added at the May 2014 sampling trip. Cladocera species have a greater biomass through the system than the other divisions (50%). Annual Bivalvia averages have remained steady and only account for 2% of the total biomass average. The Bacillariophyta division of phytoplankton accounts for 44% of the total biovolume with Chrysophyta comprising 12%. Chlorophyll a averaged 2.28 mg/m^3 for all locations with July and September having approximately double the averages for all other months in 2014. Total phosphorus averages 0.0077 mg/L throughout the lake; however, phosphorus levels increase an order of magnitude during storm events. Higher chlorophyll levels are directly correlated with water clarity, higher levels leading to decreased water clarity. There does not appear to be a correlation between water clarity and quagga veliger abundance in Lake Havasu. Continuation of the monitoring program is essential to understanding the reservoir and the many variables affecting this ecosystem.

Bio: Heidi McMaster has Bachelor's degree from University of Las Vegas in Environmental Science and a Master's degree in Public Health from the same university. Her work with the US Bureau of Reclamation is primarily focused on water resources conservation and management through various partners in the Lower Colorado River. The co-lead on the project, a hydrologist, Janet Kirsch, proves the project with ecosystem functions within the reservoir and over 15 years of water quality studies and hydrology in the Lower Colorado River. Dana Anat, an Environmental Protection Specialist, set up the original study plan in 2009. Jessica Stegmeier is the Natural Resources Specialist, providing expertise on biological systems. Management and oversight of the project from Marc Maynard provided guidance and historical insight into the reservoir. The team, the Resources Management Environmental Compliance Office staff has a well-rounded education and experience in water management and research.

Discovering and interpreting time series data for interdisciplinary water science

Jon Pollak, CUAHSI
(co-authors: M. Seul, R. Hooper, E. Geosling)

How does one find the right data to effectively test interdisciplinary hypotheses in an uncertain environment? Do data exist in my study area? Are data trustworthy? What tools are available to access and manage it? The CUAHSI Water Data Center (WDC) is a community-governed, NSF-funded facility that strives to aid researchers in answering these questions. The broad goals of the WDC are to improve water science by enabling data access and publication through an extensible web-services oriented architecture. The catalog maintained by the WDC is the largest catalog of time series water data in the world, which includes data sources that range from global to local coverage and include data sets that describe climate, streams, and soil. This presentation will discuss the data available through the CUAHSI WDC, the methods that researchers can employ to access data, and how you can become involved in the WDC community.

Bio: The CUAHSI Water Data Center provides data services to the hydrologic science community and other critical-zone science communities that require access to various sources of water data to perform research on fundamental challenges in hydrology and Earth System science. We enable the water research community through supporting data access and publication, software development and curation, in addition to the development of standards.

National Water Census: Water availability and use studies and the data portal

Ari Michelsen, Texas A&M Agrilife Research and Extension Center at El Paso
(co-authors: S. Jones, E. Evenson, D. Blodgett)

Many reports have recognized the need for a national water census for the United States. For example: the U.S. Water Resources Council, 1968 and 1978; National Research Council, 2002 and 2009; and National Science and Technology Council 2007. Responding to this need the U.S. Congress, in the Omnibus Public Land Management Act of 2009 (Public Law 111–11) Subtitle F, established the SECURE Water Act. In particular, Section 9508 of the SECURE Water Act establishes a "national water availability and use assessment program" within the USGS – this is the research program known as the National Water Census. Program implementation began in 2011 through USDOI's WaterSmart Initiative. Programmatic goals include: providing a more accurate assessment of the status of the water resources of the United States; assisting in the determination of the quantity of water available and quality of water resources; identifying long-term trends in water availability; and providing open access to existing and new water resources information and tools.

Water Availability and Use projects currently underway include topical studies and focused geographic studies. Topical studies are designed to develop methods to estimate components of the water budget at a national scale, while the geographically focused studies are designed to look at specific areas where competition for water resources is high. Topical area studies are developing new methodologies, improving data accessibility, and quantifying and reducing data uncertainty. Focus area studies are testing and improving approaches for quantifying water-budget components to address stakeholder identified water-management challenges. There were three initial focus area studies, the Apalachicola-Chattahoochee-Flint, the Colorado River, and the Delaware River Basins. Three new geographic focus area studies will begin in 2016. These are the Upper Rio Grande River Basin, Red River Basin and Coastal Carolina river basins.

The Data Portal of the National Water Census provides the actual access to National and detailed hydrologic data (HUC-12), streamflow statistics, aquatic biology, water availability and use studies and other information and applications. This paper will present on-going development and components of the National Water Census and Data Portal.

Bio: Dr. Ari Michelson is a Professor of Agricultural Economics and Research Director of Texas A&M AgriLife Research and Extension Center at El Paso.

Predicting and managing outdoor residential potable irrigation using parcel level databases

Ken Friedman, Northwest Florida Water Management District
(co-author: J. Heaney)

The Conserve Florida Water Clearinghouse research team has developed internet based software called EZ Guide to assist Florida water utilities in evaluating water use efficiency. Our process based modeling approach estimates single family outdoor water use for every parcel using a uniform statewide property appraisers' database to estimate irrigated area for each parcel. Water utility billing data are needed to estimate the irrigation application rates for each parcel, although few utilities have made this link. Analyses using these unique databases for a benchmark utility in Florida provide new insights into the overall impact of single family outdoor water use and cost-effective management options. A key result is that only a small percentage of homes are large irrigators which are candidates for irrigation best management practices. However, this study also shows a dramatic rise in the prevalence of in-ground sprinkler systems over the last few decades, which has led to increased irrigation application rates. The methodology also includes establishing a benchmark irrigation application rate that can be compared with theoretical irrigation rate estimates from a daily time step irrigation simulation model. Water savings are then evaluated for all irrigators as the difference between actual usage and the established benchmark application rate. Only the small subset of customers who over irrigate should be considered for outdoor BMPs which are aimed at reducing irrigation to a desired threshold. The impact of not selectively targeting this subset of irrigators is also presented.

Bio: Dr. Ken Friedman earned his B.S., M.E., and Ph.D. in Environmental Engineering from the University of Florida. He currently works as a Water Resources Planner with the Northwest Florida Water Management District, where he serves an active role in statewide and regional water resources and water conservation planning efforts, including with the FSAWWA Water Use Efficiency Division. Ken is the 2015 UCOWR Ph.D. Dissertation award recipient. Dr. James Heaney is a Professor in the Department of Environmental Engineering Sciences, U. of Florida who specializes in urban water demand management. He was the recipient of the UCOWR 2013 Warren A. Hall Medal.

Design of a probability plotting positions, of precipitation data of Galveston County, Texas, without using the traditional assigning of ranges to data and the usage of formulas to calculate return periods and probabilities of occurrence

Hector Quevedo Urias, Universidad Autónoma de Ciudad Juárez

The objective of this study was the application of statistical functions to a 60 year data sample of precipitation in Galveston County, Texas (period 1940-2012). This research prepared descriptive statistics to calculate measures of central tendency and measures of variability. It also included the calculation of cumulative and density probabilities. The study attempted different continuous probability distributions fitting the data as the normal, lognormal, Gamma, Weibull, etc., using the Minitab computer program to identify the best one. Subsequently, this method constructed a probability plotting position going as a function of precipitation values, probability of occurrence and return periods. This educational approach is valuable, because it first identifies the proper probability continuous distribution fitting the data, without relying on the traditional assigning of ranges to the data, and the use of formulas, to calculate the probabilities of occurrence and return periods. The results showed the continuous normal distribution fits the data much better basing the criterion on the Anderson-Darling goodness-of-fit-test value of 0.453. It is concluded that this hi-tech method is more precise than the traditional plotting positions methods currently used. It is settled that the selection of the best probability plotting position is very important to determine precise estimates for return periods and occurrence probabilities for precipitation data, in the designing of prime hydrological structures to protect the welfare of people.

Bio: Dr. Hector Quevedo Urias received his Ph.D from the Oklahoma University. He is a professor and researcher at the University of Ciudad Juarez.

Mapping and modeling groundwater in real-time

Val Kofoed, Willowstick Technologies
(co-authors: M. Jessop, D. Bierman)

It has been said that water is the natural capital of the world's growing population and economy. If this is true, services built on characterizing, defining and delineating the world's water are the currency of the 21st century. Understanding the location and extent of groundwater resources is becoming increasingly more important in a host of applications. Not only is protecting water an important application, but preservation of water for drinking and power, and identification of polluted waters for remediation are critical to preservation of this resource. Awareness of the special distribution as well as the variability of groundwater quality defines how the world manages today's infrastructure and builds for tomorrow. The best way to characterize and delineate groundwater is by direct measurement, which usually involves drilling wells. But, when exploration or monitoring wells fails to provide enough information to answer the important questions, a typical approach is to drill more wells. In the long term, this approach is cost-prohibitive and still may not provide sufficient information. A more practical approach in characterizing groundwater is to combine data from a minimal number of strategically placed observation wells with data from a Willowstick geophysical investigation a geophysical method—specifically designed to map and model groundwater. In most cases, this will result in a cost effective and accurate prediction of groundwater conditions. This approach allows a comprehensive model of the distribution and location of preferential groundwater flow paths in combination with measured groundwater properties from a select number of observation wells. The overall investigation provides sufficient detail to properly evaluate the subsurface areas between boreholes. This paper will present three case studies in which the Willowstick method provided solutions to problems in the dam, mining, and environmental industries.

The effect of technical change on groundwater use and depletion

Nicolas Quintana Ashwell, Kansas State University
(co-author: J. Peterson)

Irrigated agriculture is among the largest users of groundwater in the world. Irrigators extract and apply groundwater to satisfy their crops water requirement to achieve yield levels so as to maximize farm profits. Extraction occurs as long as the value marginal product of groundwater equals the marginal cost of applying it. Since groundwater is a fugitive resource, the stock available to an irrigator depends dynamically on the levels of extraction by neighboring irrigators. This constitutes the common resource property of groundwater. Dynamic coefficients in a water-yield production function represent the technical change embedded in plant science and irrigation technology and which is assumed to be such that similar irrigated yield levels can be achieved with lower levels of water being applied as time passes. Although technical progress makes it possible to produce at the same level with less water use, it also poses the incentive to expand irrigated acreage and intensify water application per acre, so the net effect is unclear in general. This paper explores the effect of technical progress on groundwater use and depletion using a model of inter-temporal common pool groundwater use, where pumping cost and stock externalities arise from the common property problem. Preliminary results from the case study indicate that periods of increasing as well as decreasing groundwater extraction may be expected on a managed path. An important policy implication is that policy instruments fixed at a constant level over time may be inadequate and that aquifer- or state of technology-indexed policy instruments may be more appropriate.

Bio: Nicolas Quintana Ashwell is a PhD Candidate and Graduate Research Assistant in the Department of Agricultural Economics, Kansas State University. His previous research experience includes the adaptation of dynamic models to evaluate groundwater policy in the presence of the common-resource-pool externality. He expects to enter the job market later in 2015.

Multiyear study of the binational Hueco Bolson Aquifer reformulates key conceptual models of groundwater flow

Barry Hibbs, California State University, Los Angeles
(co-authors: C. Eastoe, J. Hawley, A. Granados)

Extended Abstract

From 2002 to 2011 groundwater studies of the Hueco Bolson aquifer were undertaken by a team of scientists and engineers employed by several universities and governmental agencies. Lead entities in the study included the NSF funded Science and Technology Center (STC) at California State University-Los Angeles (CEA-CREST) and at the STC at the University of Arizona (SAHRA). Other participating organizations included the Universidad Autonoma de Ciudad Juarez, New Mexico Water Research Institute, and City of El Paso Public Services Board. Investigatory tools employed in the study included stable and radiogenic isotope analysis of Rio Grande water and groundwater, ion analysis of surface water and groundwater, drilling of test holes, installation of water wells, and groundwater modeling. Hundreds of water samples were collected for hydrochemical and isotopic analysis. These data helped reformulate key conceptual models of groundwater flow. This paper summarizes the important discoveries that were made during the multi-year investigation, including: 1) most of the aquifer underlying Ciudad Juarez was recharged by the pre-dam Rio Grande in predevelopment times; 2) intrusion of post-dam Rio Grande water in the Hueco Bolson exceeds 600 ft in depth due to developmental pumping cones of depression; 3) a sub-regional buried salt playa and cross-formational flow creates most of the salinization of the Rio Grande and Rio Grande aquifer below San Elizario, Texas; and 4) several other key conceptual models of groundwater flow have been reformulated with new data and with stable and age-dating isotopes.

Introduction

Water supply and water quality problems facing the City of El Paso and Ciudad Juárez are complex and interrelated. The twin-cities share the water resources of the Hueco Bolson, a Tertiary and Quaternary basin fill aquifer spanning the international border (Figures 1 and 3). The binational metroplex is located at the junction between the western edge of Texas and the northernmost part of Chihuahua, Mexico. Over-pumping of the Hueco Bolson aquifer has resulted in drawdown of the water table, encroachment of brackish groundwater, and the early retirement of wells. Pumping cones of depression in municipal wellfields are the focal points of drawdown. Most of the drawdowns near municipal wellfields vary from 50 to 150 ft. Although a shared resource, there has been no comprehensive study of the Hueco Bolson aquifer along its full trans-international extent. Most of the technical studies conducted by groundwater hydrologists in the United States and Mexico have terminated at the international border. Other projects provided exchanges of existing binational data. Lack of newer data needed to perform a complete analysis acts as an impediment to binational management of the aquifer. Thus, there is a need to develop cooperative binational studies as a positive step to the eventual development of an international agreement or management plan for this binational aquifer. Furthermore, there are many conceptual models of groundwater that need to be re-evaluated, tested, and updated due to the expanding data base of hydrogeologic information on the Hueco Bolson aquifer.

In response to these needs, several Mexican and American universities formed a partnership to study the surface and groundwater resources of the El Paso/Juarez area. Collaborative institutions in the study include California State University-Los Angeles, the University of Arizona, New Mexico Tech-Socorro, New Mexico State University, Universidad Autónoma de Ciudad Juárez, and United Nations University. Governmental agencies also participated in the project by providing existing data, access to water wells, and other support services. These agencies included El Paso Water Utilities, US Environmental Protection Agency, International Boundary and Water Commission, Comisión Internacional de Limites y Aguas, Comisión Nacional del Agua, and Junta Municipal de Agua y Saneamiento de Ciudad Juárez. Methods of investigation included groundwater age-dating with radioisotopes, stable isotope analysis of surface water and groundwater, and halide analysis to assess salinization of waters. This paper provides a brief overview of a few of the primary results of the multiyear investigation, leading to reformulation of key conceptual models of groundwater flow in the Hueco Bolson. Summary sections are included as follows.

1. Most of the aquifer underlying Ciudad Juarez was recharged by the pre-dam Rio Grande in predevelopment times.
2. Intrusion of post-dam Rio Grande water in the Hueco Bolson exceeds 600 feet in depth due to developmental pumping cones of depression.
3. A sub-regional buried salt playa and cross-formational flow creates most of the salinization of the Rio Grande and Rio Grande aquifer below San Elizario, Texas.

4. Other key conceptual models of groundwater flow have been reformulated with new data and with stable and age-dating isotopes.



Figure 1. Location of the study area.

Finding 1: The aquifer underlying Ciudad Juarez was recharged mostly by the pre-dam Rio Grande in predevelopment times

Stable O and H isotopes show that Rio Grande water recharged prior to the construction of Elephant Butte dam is the principal source of groundwater in the Hueco Bolson aquifer beneath Ciudad Juárez (Figure 2). Previous interpretations incorrectly noted most recharge occurred at Juarez by runoff along mountains and mountain fronts. Mixing between pre-dam and post-dam river water occurs in samples from the aquifer beneath the Rio Grande floodplain, where tritium is also measured. Along the flanks of the Sierra de Juárez, mixing occurs between per-dam river water and water derived from the Sierra de Juárez. Carbon-14 content generally decreases from northwest to southeast, but the lowest value is in a mixture containing water from the Sierra de Juárez. Sulfur isotopes in groundwater of pre-dam river water origin and anion rations (Cl/Br and Cl/SO_4) in general are consistent with mixing of solutes from native Hueco Bolson groundwater with river water. In the lower Juárez Valley, stable O and H isotopes show that groundwater is derived from river water in the floodplain, and originates from precipitation in nearby mountain ranges in wells on the mesas and mountain flanks.

Overall Observations:

1. Groundwater in the Hueco Bolson aquifer beneath Ciudad Juarez originated mostly as Rio Grande river water recharged before the construction of Elephant Butte dam, New Mexico.
2. Mixing with post-dam Rio Grande river water is observed mainly in samples from beneath the Rio Grande flood plain.
3. Isotope evidence shows mixing between pre-dam river water and native Hueco Bolson groundwater along the flanks of the Sierra de Juárez, and at a single sample point in the flood plain.
4. Groundwater with finite tritium is largely confined to the aquifer beneath the Rio Grande floodplain.
5. Carbon-14 content in groundwater decreases to the south and southeast, consistent with groundwater flow from the northwest to southeast.
6. The major anion chemistry of groundwater requires recharge of river water under conditions of high flow (low salinity) and low flow (high salinity), but does not preclude additions from sources within the Hueco Bolson.
7. Further details are presented in Eastoe et al. (in press).

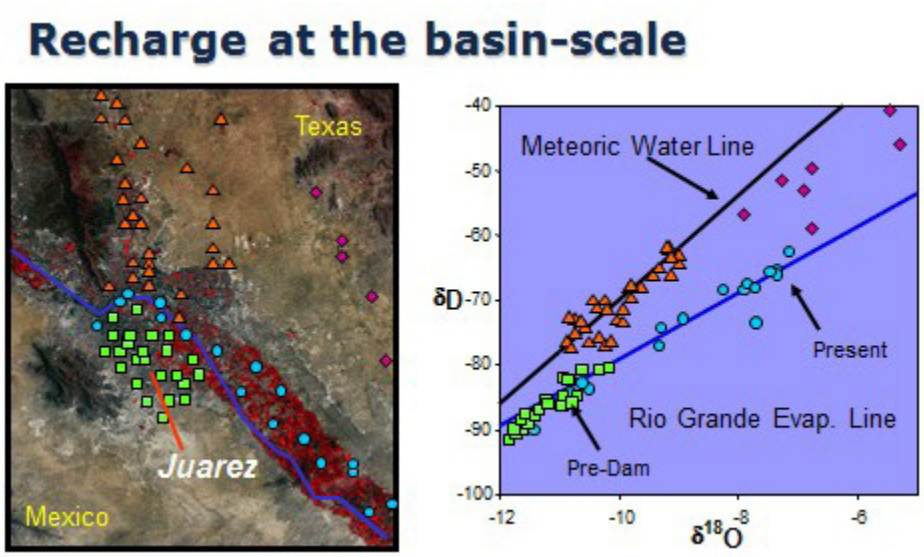

Figure 2. Most of the recharge under Juarez plots along the Rio Grande Evaporation Line demonstrably linking it to recharge from the pre-dam Rio Grande.

Finding 2: Intrusion of post-dam Rio Grande water in the Hueco Bolson exceeds 600 feet in depth due to developmental pumping cones of depression

Cross-formational flows between the Rio Grande, Rio Grande aquifer, and Hueco Bolson aquifer are indicated by isotopic and hydraulic head data collected at a multi-level well nest in the El Paso/Juárez Valley (Figure 3). The Rio Grande is unlined at this location. Wells screened above 100 ft are installed in the Rio Grande aquifer and wells screened below 100 ft are installed in the Hueco Bolson aquifer. The hydraulic head gradient is oriented vertically downward. Mixing between Rio Grande water, Rio Grande aquifer water, and Hueco Bolson aquifer water is indicated by stable isotope data (Figure 3). Wells at intermediate depth show stable isotope signatures that are intermediate between the isotopically heavy water from the shallowest well in the Rio Grande aquifer (JL-49-21-324) and the isotopically lighter water at the deepest well (JL-49-21-322). Tritium is found at a depth of nearly 600 ft (Figure 3).

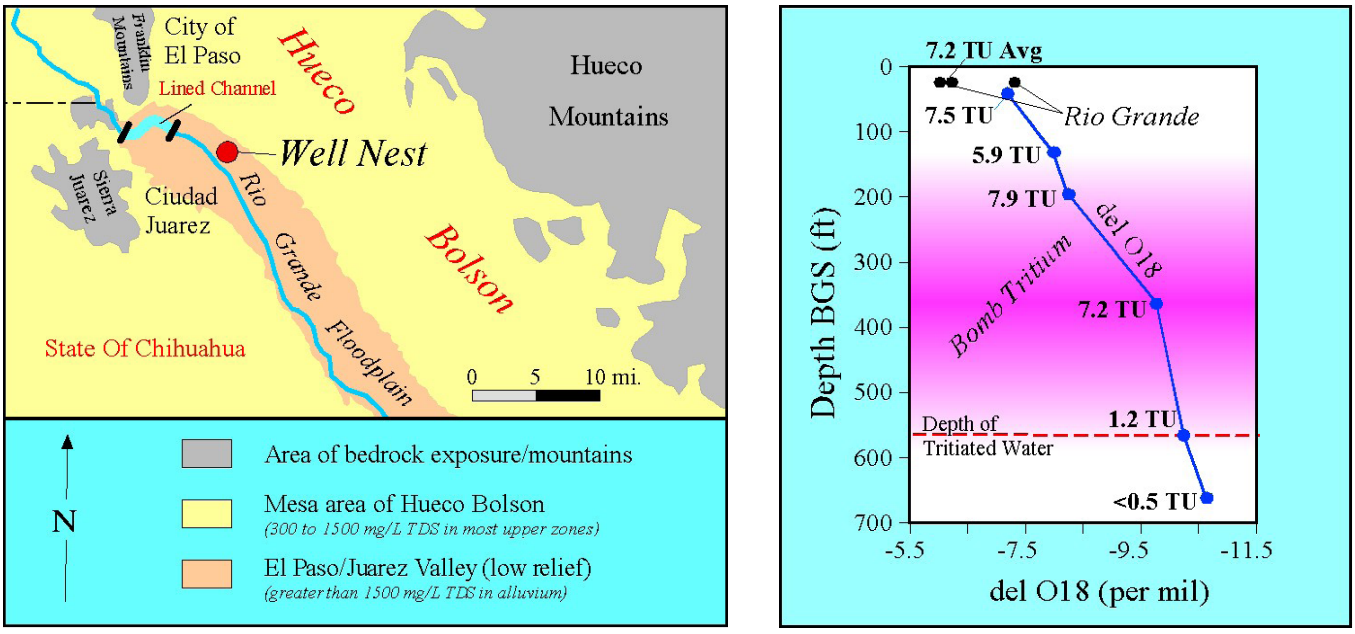

Figure 3. Hydraulic head data collected from a well nest near an unlined segment of the Rio Grande. The well nest is approximately 200 ft from the Rio Grande. Data indicate downward vertical flow between the Rio Grande, Rio Grande aquifer (up to 100 ft below ground surface [bgs]), and Hueco Bolson aquifer (> 100 ft bgs).

Tritium (^{3}H) data provide clues to the distribution of recharge and relative ages of groundwater. Pre-1950 values for tritium in northern hemisphere precipitation were about 5 tritium units (TU), where one TU is equal to one atom of ^{3}H in 10^{18} atoms of hydrogen. Tritium has a half-life of 12.3 years (Mazor 1991) and ^{3}H values less than about 0.5 TU usually indicate groundwaters recharged before 1952, provided that extensive dilution by older groundwaters has not occurred (Mazor 1991). Tritium in northern hemisphere precipitation increased to more than 2,000 TU as a result of above-ground testing programs for nuclear weapons in the 1950's and 1960's. Tritium has decreased to near-background levels in recent years (Mazor 1991).

Tritium is highest in intermediate wells screened between 181 and 358 ft (Figure 3), indicating residual "bomb" tritium, probably recharged between 1960 and 1985. At this distance from the natural recharge areas in the mountains, any tritiated water must have come from the Rio Grande. Post 1952 and tritiated groundwater penetrates to a depth of almost 600 ft below ground surface at the well nest (Figure 3). This could develop only because of induced infiltration from the Rio Grande aquifer. The hydrogeologic data indicate downward vertical flow and recharge to the Hueco Bolson aquifer from the Rio Grande aquifer and Rio Grande. Empirical data on induced recharge are site-specific. Modeling studies were also employed to provide a regional and quantitative estimate of induced recharge (Hutchison and Hibbs 2008; Eastoe et al. 2010). Only a small amount of Rio Grande water has reached depths around 600 ft. Hydrodynamic dispersion dilutes the advancing/infiltrating water front from the river.

Finding 3: A sub-regional buried salt playa and cross-formational flow creates most of the salinization of the Rio Grande and Rio Grande aquifer below San Elizario, Texas

The Rio Grande alluvial floodplain aquifer between El Paso/Juarez and Fort Quitman, Texas has been intensively tilled and irrigated since 1910. Presently, salinity of surface water and groundwater increases from 800 - 2000 mg/L total dissolved solids (TDS) near El Paso, Texas to 2500 - 10,000 mg/L TDS near Fort Quitman, Texas, approximately 90 miles downstream. Chloride (Cl) and Chloride/Bromide (Cl/Br) ratios increase downstream. Groundwater sampling in a reach of the floodplain aquifer, extending from 20 to 40 miles below El Paso, identified two distinct water types. The first water type is a relatively dilute groundwater type containing 1000 to 2000 mg/L TDS, 250 to 600 mg/L Cl, and Cl/Br weight ratios of 550 to 900. The second water type is a relatively saline groundwater type containing 2000 to 9000 mg/L TDS, 900 to 3800 mg/L Cl, and Cl/Br weight ratios of 1200 to 3500. Drilling of nested monitoring wells detected a very saline, silty-clay, water bearing unit at 150 to 250 ft bgs, directly below the Rio Grande alluvial deposits. This saline water bearing unit contains about 15,000 mg/L Cl and Cl/Br weight ratios of about 5800 (Table 1). Halide mixing data indicate this saline unit is the primary source of high salinity in the Rio Grande and Rio Grande aquifer (Table 1). Chlorine isotopes also establish this unit as the mixing source, with a chloride age of about 0.75 m.y. (million years) to 1.25 m.y. This is consistent with the timing of the final transformation of the local basin (Hueco Bolson) from a topographically closed and undrained basin, to a through-flowing and drained basin. We interpret this saline unit to be the residual of a closed basin, paleo-phreatic (salt) playa that was buried beneath the contemporary Rio Grande floodplain after the Rio Grande cut through the El Paso/Juarez narrows some 0.65 to 0.75 m.y. ago (Figure 4).

Table 1. Comparison of Hydrochemical Parameters: Rio Grande-Rio Grande Aquifer-Hueco Saline 150 to 250 ft Well

Sample Station	Total Dissolved Solids (mg/L)	Chloride (mg/L)	Chloride/Bromide weight ratio	$^{36}Cl/Cl \times 10^{15}$
Rio Grande	**1107**	**207**	**567**	**267**
Alluvium 1	1345	217	606	215
Alluvium 2	1453	248	653	191
Alluvium 3	1654	314	672	191
Alluvium 4	1876	416	779	182
Alluvium 5	4234	1516	1318	71
Alluvium 6	6213	2086	1655	71
Alluvium 7	6987	2350	2008	56
Alluvium 8	9122	4503	3737	28
Saline Well	**26,130**	**14,657**	**5881**	**10**

Table explanation: Alluvial groundwater with high chloride and high Cl/Br (> 1500 mg/L Cl; > 1300 Cl/Br ratio) have demonstrably older chloride ages, as shown by $^{36}Cl/Cl \times 10^{15}$ ratios less than 71. Alluvial groundwater with relatively low

chloride and low Cl/Br ratios (< 420 mg/L Cl; < 800 Cl/Br ratio) have $^{36}Cl/Cl \times 10^{15}$ ratios greater than 182 and are closer to values measured in the Rio Grande irrigation waters. The chlorine isotopes combined with halides provide compelling evidence of a geological source of salinity in the Rio Grande aquifer resulting from artesian upwelling.

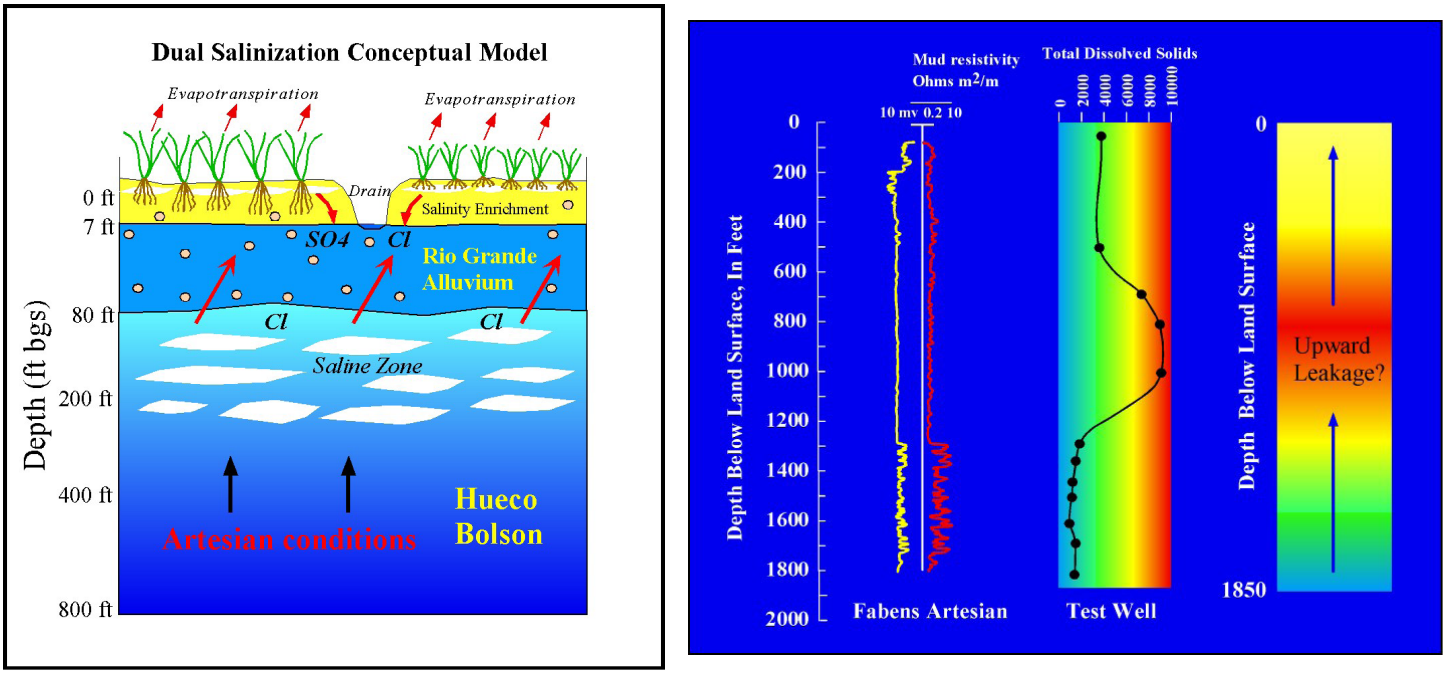

Figure 4. Conceptual model for salinity enrichment of the Rio Grande aquifer. Reaction of upwelling groundwater with late stage basinal evaporite deposits beneath Rio Grande alluvium carries saline groundwater into the Rio Grande aquifer.

Salinization of the Rio Grande and Rio Grande aquifer has often been attributed to irrigated agriculture and excessive evapotranspiration in the arid region. Our updated results suggest that irrigated agriculture is probably not the primary source of salinity in the El Paso Valley, supporting interpretations by Hibbs and Darling (1995) that upwelling of saline groundwater from deeper sources is an important factor in salinization. It probably is the most important factor, as demonstrated by increasing chloride and Cl/Br ratios in the Rio Grande and Rio Grande aquifer, downstream of Fabens. More details are found in Hibbs and Merino (2006).

Finding 4: Key conceptual models of groundwater flow have been reformulated with new data and with stable and age-dating isotopes

Many other sub-studies completed by the research team have not been mentioned. Armed with new drilling information and data, Hawley et al. (2009) reanalyzed and created new geologic and hydrostratigraphic interpretations of the Hueco Bolson and surrounding areas. These new interpretations have proven highly beneficial in groundwater modeling studies. Druhan et al. (2007) identified hydrogeologic controls on groundwater flowpaths and salinization of the northern Hueco Bolson by analyzing nested well samples for a suite of geochemical tracers. On the basis of δ^2H and $\delta^{18}O$ data, two regional recharge sources were recognized; one originating from western mountain-fronts and one from through-flow of the adjacent Tularosa aquifer. Eastoe et al. (2009) used stable isotope data for the Hueco Bolson aquifer (Texas, USA and Chihuahua, Mexico) to identify several water types regionally across the Hueco Bolson aquifer, including pre dam Rio Grande water, post dam Rio Grande water, and internally recharged water that varies from west to east across the Hueco Bolson. Two final papers are in preparation. In one, a study presented in Hibbs et al. (2003), a suspected slope front recharge area at the boundary between the Hueco Bolson and Rio Grande floodplain was found instead to be pre-dam river water moving downward into a buried paleo channel formed by the ancestral Rio Grande. Another body of work focuses on compartmentalized groundwater systems that are thermally, isotopically, and hydrochemically distinct on the eastern margins of the Hueco Bolson. To date the published work has been prolific, with the tally including 8 journal papers, technical reports, book chapters, and two more journal papers in preparation.

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Better targeting water quality remediation using bacterial source tracking

Kevin Wagner, Texas Water Resources Institute
(co-authors: T. Gentry, G. DiGiovanni)

Bacterial source tracking (BST) is a valuable tool for identifying human and animal sources of fecal pollution. In 2003, Texas initiated a BST program to help better assess bacterial sources. DNA fingerprinting methods selected for use were enterobacterial repetitive intergenic consensus sequence-polymerase chain reaction (ERIC-PCR) and riboPrinting® (RP). These methods required development of a BST Library. Since initiation of the BST program, the library has been populated with 1,669 E. coli isolates obtained from 1,455 different domestic sewage, wildlife, livestock and pet fecal samples collected from a dozen watersheds. Utilizing the statewide BST library, comprehensive BST is being conducted or has been completed to identify the source of bacterial impairments in 16 watersheds across the state. The BST Library has performed well, particularly for identifying broad source categories. A 100% rate of correct classification has been achieved when identifying relative contributions of human, domestic animals, and wildlife. Few isolates are unidentifiable. BST has provided watershed planners better data regarding sources of bacteria that were not previously available. This presentation will summarize these and other findings from work completed to date and discuss future directions of bacterial source tracking.

Bio: Dr. Kevin Wagner currently serves as associate director of the Texas Water Resources Institute and adjunct professor in Texas A&M University's Department of Soil and Crop Sciences. He provides leadership and administration for institute water programs; conducts research on watershed response to management; develops and evaluates management systems designed to sustain agricultural productivity and protect water resources; trains water professionals and students on watershed planning, assessment and policy; and conducts watershed assessment, planning and stakeholder engagement to address water issues. Dr. Wagner serves on the Brazos G Regional Water Planning Group, Brazos River and Associated Bay and Estuary System Basin and Bay Stakeholder Committee, Texas Groundwater Protection Committee, Texas Water Conservation Advisory Council, and the Universities Council on Water Resources. Wagner received a PhD in agronomy from Texas A&M University, master's degree in environmental science from Oklahoma State University, and bachelor's degree in biology from Howard Payne University.

Modeling *E. coli* levels in the Lake Erie nearshore at Cleveland, OH

Nathan Zgnilec, Great Lakes Research Center, Michigan Technological University
(co-author: M. Auer)

Combined sewer overflows (CSOs) are known to deliver large volumes of untreated waste water containing high concentrations of *Escherichia coli* (*E.coli*) and potential pathogens. Defining the specific local impacts, from CSOs, on receiving waters is difficult. The North East Ohio Regional Sewer District (NEORSD, Cleveland, OH) serves 61 communities and over one million citizens through the operation of three waste water treatment plants, handling over 200 million gallons per day. Like many older, eastern US cities, the District operates more than 100 CSOs which, during wet weather events, discharge to local tributaries and Lake Erie. These discharges accumulate to 4.5 billion gallons per year. In accordance with a consent decree, NEORSD will reduce discharges from its CSOs through a tunnel storage and treatment system that will cut CSO discharges by 98% at a cost of $3 billion over the next 25 years. To provide a means of predicting the impacts of the tunnel project, a linked hydrodynamic-water quality model was developed. For calibration and validation of the hydrodynamic-water quality model, an in-depth field monitoring program was performed during the summer of 2014. This program captured both dry and wet weather conditions throughout the District. The results of this program were then coupled with a collection of storm water management models to quantify loading sources of the measured analytes affecting the Lake Erie nearshore. The linked hydrodynamic-water quality model has since been utilized in projecting public health benefits (e.g. *E.coli* swimming standard) accrued through completion of various stages of the tunnel project. Here, the utility of deterministic (i.e. average year) and probabilistic (i.e. multi-year) approaches will be discussed.

Bio: Nathan has earned a B.S. in Civil Engineering and is pursuing an M.S. in Environmental Engineering at Michigan Technological University. As a research assistant at Michigan Tech's Great Lakes Research Center, Nathan has had the opportunity to explore the waters of Lakes Ontario, Erie and Superior. Scheduled for graduation in the fall of 2015, Nathan is looking forward to a career dedicated to improving the quality and accessibility of waters around the world.

Assessing impacts of nutrient loading on culturable *E.coli* fate in re-created natural stream mesocosms

Lucas Gregory, Texas A&M University
(co-authors: R. Karthikeyan, J. Aitkenhead Peterson, K. Wagner, T. Gentry)

Fecal indicator bacteria are used globally as a surrogate to estimate potential for human pathogen presence in surface waters. Their presence in water presumably signifies recent fecal contamination as *Escherichia coli* and other fecal indicator bacteria were once thought to survive poorly outside of the large intestine. Recent findings prove otherwise; however, knowledge regarding the mechanisms influencing fate and transport of these organisms in soil and water environments remains incomplete. A number of external factors influence survival of *E. coli* in the environment including temperature, moisture, ultra-violet light exposure, pH, salinity, nutrient supply as well as competition and predation from the microbial community. Despite past research, interplay between these factors and the fate of *E. coli* in the environment remains somewhat of an enigma. An improved understanding of *E. coli* fate and transport in the environment will provide useful information that can potentially minimize erroneous waterbody impairments and improve water quality managers' efforts to understand and manage bacteria levels at a watershed scale. This presentation presents findings from an experiment utilizing laboratory based stream mesocosms to simulate an instream environment while controlling microbial inputs and holding certain water quality parameters constant. High and low level nutrient treatments applied to simulate nutrient loading to the stream occur during a runoff producing rain event or wastewater inflows were applied and variable flow rates were used. The response of *E. coli* to applied treatments was documented along with changes in other ambient water quality constituents to assess the overall response to nutrient loading. Microbial activity increased following nutrient amendments; however, significant *E. coli* growth did not occur as expected.

Bio: Dr. Kevin Wagner currently serves as associate director of the Texas Water Resources Institute and adjunct professor in Texas A&M University's Department of Soil and Crop Sciences. He provides leadership and administration for institute water programs; conducts research on watershed response to management; develops and evaluates management systems designed to sustain agricultural productivity and protect water resources; trains water professionals and students on watershed planning, assessment and policy; and conducts watershed assessment, planning and stakeholder engagement to address water issues. Dr. Wagner serves on the Brazos G Regional Water Planning Group, Brazos River and Associated Bay and Estuary System Basin and Bay Stakeholder Committee, Texas Groundwater Protection Committee, Texas Water Conservation Advisory Council, and the Universities Council on Water Resources. Wagner received a PhD in agronomy from Texas A&M University, master's degree in environmental science from Oklahoma State University, and bachelor's degree in biology from Howard Payne University.

Synergistic effects of radiation and temperature on microbial growth in 19 Litre water dispensing containers

Michael Keogh, Royal College of Surgeons in Ireland - Medical University of Bahrain
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Solar Disinfection (SODIS) of water is a simple, WHO recommended method involving exposing contaminated water to sunlight in transparent plastic containers that permit passage of UV radiation in order to inactivate water borne pathogens. SODIS is effective using bottles up to 2 litres and a synergistic thermal-UV effect exists for microbial inactivation in volumes up to 2 litres (1). Larger volumes are more suitable for long term sustainability within communities. We examine the use of 19 litre water dispenser containers (WDC) on in high and low UV and temperature to mimic varying environmental conditions. Methods: Six 19 L WDCs were inoculated with 1x107/ml *E. coli* or *E. faecalis*, and exposing to direct sunlight for up to 6 hours, half of these were placed on ice to regulate temperature (n=3). Water samples every at set intervals up to 6 hours were taken to analyse cell number as well as recording temperature and total UV radiation. These experiments were repeated in summer and winter conditions. Results: Following 6 hours solar treatment we observed total inactivation of *E. coli* in both summer and winter conditions; regardless of temperature control. *E. faecalis*, inactivation was only observed in the standard SODIS reactors in summer conditions only. Total coliform inactivation required at least 500kJ/m^2 of solar radiation. We found greater levels of disinfection resulted in WDCs with higher temperature and UV exposure. These results support findings in smaller 2 litre reactors. Our results suggest that the 19 litre water dispenser reactors may be used for SODIS water treatment and that thermal-UV radiation synergy can improve the efficiency of disinfection. These findings provide a platform for community based SODIS treatments in disadvantaged regions globally.

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Water storage and water markets as substitutes for drought risk mitigation

Jonathan Yoder, Washington State University
(co-authors: M. Brady, J. Cook)

Water storage mitigates drought risk by allowing water to be saved when relatively plentiful for use during dry seasons and droughts. Economically, this is equivalent to reallocating water from periods where its marginal value is low, to periods where its marginal value is high. Similarly, water markets facilitate moving water from low-valued uses to high-valued uses through exchange. In doing so, markets alleviate the economic impact of drought by minimizing curtailment of high-value water uses at the expense of low-value uses. Further, given diminishing returns to water (downward sloping demand), additional water storage that reduces curtailment risk reduces potential water market gains from trade. Conversely, well-functioning markets reduce the value of additional storage by reducing the economic consequences of curtailment. Thus, markets and storage are substitutes in that an increase in storage reduces potential gains from trade, and more efficient markets reduce the value of storage. This paper examines the extent to which water storage and water markets act at substitutes for mitigating economic losses from drought. Our analysis is based on irrigated agriculture in the Yakima Basin of Washington State. Five reservoirs and mountain snowpack provide storage to supply water for the dry summer growing season, but water curtailments occur, and the prospect of reduced snowpack due to climate change has raised concern. We use simulated curtailment data, production and water rights characteristics of irrigation districts in the basin, and focus on water storage projects currently under consideration for investment in the basin. Results show that the storage projects provide benefits of $154 million with no trade, and $53 million with frictionless trade (net present value). Water markets provide potential gains from trade of $280 million with no new storage, and $170 million with the storage projects.

Bio: Jonathan Yoder is a professor in the School of Economic Sciences at Washington State University.

An investigation into the interdependence of global water indices: A VAR analysis

Rajibur Reza, Griffith University, Australia
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Water investment is now an issue of growing concern for companies and countries around the globe because the demand for this finite resource is growing at an accelerated rate. There are significant imbalances worldwide with respect to the distribution of water and existence of suitable infrastructure. The development of water index is one vehicle that has improved the water market, particularly for interested investors. There are now a number of water related indices. Aspects such as stock returns, the complexity in the stock prices, and the impact of investor adoptions' relationships all contribute to future investments in the water companies that make up water indices. It is important for investors to examine the price linkages among water indices around the world. In this study, we investigate the extent and manner of equity price interdependence among water indices of World Water Index (WOWAX), S-Network Global Water index, S&P Global Water Index and MSCI ACWI Water Utilities Index using the Vector Auto-regression (VAR) framework. Moreover, we examine Granger causalities, Variance Decomposition and Impulse Responses covering the period 2004-2014. We find that world water stock indices price are significantly interdependent and have become more so over the years. The S&P Global Water Index and MSCI ACWI Water Utilities Index are most linked to others; while WOWAX are S-Network Global Water index are the most influential. Although the indices are significantly linked, the level of integration is still at a relatively low level. Unfortunately, in depth studies of price linkages between water indices is generally lacking and investors are not well-informed about international diversification benefits of water industry. This knowledge is important for investors because the benefits from international diversification depend on the extent of linkages among four water indices.

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Implications of discounting assumptions on priority across alternative water projects

Ronald D. Lacewell, Texas A&M AgriLife
(co-authors: L. Dutton, M.E. Rister, A. Sturdivant)

With increasing population and global economic growth, the pressure on natural resources grows continuously. The typical approach is to look to conservation and/or alternative development for water supply. This involves discounting future streams of costs and benefits to estimate a present value. Applying capital budgeting techniques to water management strategies is an effective method to account for temporal costs and benefits, alternative annual water saving levels and expected useful lives. This means 'normalizing' such flows by calculating the respective alternative projects' net present values and associated annuity equivalents using a discount rate. If dollars are discounted, what is the perspective on discounting future water savings to a present value? The issue does not lend itself to a consensus but provides interesting implications, particularly when prioritizing alternative projects. Depending on the variables used for the discount rate in each scenario, the impact of discounting physical units of water, affects the priority of alternative projects. Which variables are used in the discount rate and the level those rates are set at, can have a significant impact on the priorities and rankings of alternative projects. An example of the impact on relative priority of selected projects due to alternative assumptions related to discounting is presented.

Bio: Ron received his BS and MS in Agricultural Economics from Texas Tech University and PhD from Oklahoma State University. He worked for the Bureau of the Census in Washington, Texas Tech University, the Economic Research Service and finally Texas A&M. Currently he is Assistant Vice Chancellor for Federal Relations for Texas A&M AgriLife as well as Professor in the Department of Agricultural Economics.

A survey of water experts relative to issues in discounting and appropriateness of discounting physical resources

Lindsi Dutton, Texas A&M University
(co-authors: M.E. Rister, R.D. Lacewell)

This presentation is a companion to the one on implications of discounting assumptions on rank order of alternative projects. Not only is there debate on the appropriate discount rate, should it vary over length of an analysis but is it appropriate to discount natural resources (water)? To gain insight and alternative perspectives on discounting, several resource economists and stakeholders were surveyed in 2011 where 95 percent had a PhD and 85 percent worked at a university or with the government. A major interest was the attitude of this group related to appropriateness of discounting natural resources when a project extends over many years. In this case, 44 percent supported, 34 percent did not support and 22 percent had no opinion. The arguments pro and con are as one would expect, discounting natural resource is unfair to future generations but discounting would provide a basis for comparing apples to apples among different projects. In addition it was suggested that the natural resource be monetized and then handle discounting. Of course the perspective that water is water and same in 50 years as today was expressed. Other topics related to appropriate discount rate in public versus private projects with 40 percent suggesting the private rate be greater than the public rate while 15 percent felt the public rate should be zero. The typical issues of intergeneration fairness, advances in technology, resource mining, and are there cases where a negative rate is appropriate entered into the survey responses.

Bio: Lindsi received her BS and MS in Agricultural Economics from Texas A&M University. She worked for HighMount E&P after attending Texas A&M. Currently she works at Breitburn Management Company, LLC as an Advanced Buyer in the Supply Chain Organization.

Oneida Dam – Hydro power vs. competing environmental goals

David Stevens, Utah State University

Hydropower is a mixed blessing in our carbon-obsessed society. On one hand every kilowatt produced by hydro is one less produced by coal/oil/gas. On the other, hydropower has a large, albeit local, environmental footprint (or bootheel, depending on your perspective). Canyons are flooded, rivers are subjected to changed flow regimes, fisheries are disturbed, and recreational users get mad. This talk examines the tradeoffs and stakeholders involved in even a small hydropower licensing effort in the intermountain west and shows how strange bedfellows can be.

Bio: David King Stevens, Ph.D. is Professor and Head of the Department of Civil and Environmental Engineering Utah Water Research Laboratory at Utah State University. He has a B.S. in Civil Engineering from Tufts University and a Ph.D. in Civil and Environmental Engineering from the University of Wisconsin-Madison. He a registered Professional Engineer with the state of Ohio. Dr. Stevens has 30 years of experience in Environmental Engineering and his areas of expertise and research interests include development and integration of water quality and quantity models for water supply and watershed assessment, and statistical and experimental design methods for environmental engineering research. He has recently worked in integrated watershed assessment and decision support for culinary water improvement through reservoir management in Utah's Weber and Ogden River Basins, in the mitigation of selenium contamination in Utah's Ashley Valley through integrated watershed assessment and irrigation management, in the integration of high frequency water quality monitoring data with models and data analysis tools for watershed improvement, and in monitoring and statistical analysis for toxic contaminant levels in water distribution systems. Dr. Stevens has been a P.I or Co/P.I. on a number of projects funded by U.S. EPA, USGS, USAF, USBR, DOE, private industry, and Utah and Idaho agencies, and has served as a consultant to both industry and government. He has published over 50 refereed journal articles, technical reports, and book chapters.

Optimal reservoir operations policy for maximum fish survival

Lauren Adams, University of California, Davis
(co-authors: J. Lund, R. Quiñones)

Extreme droughts are difficult to predict and may incur large economic and ecological costs. Dam operations in drought usually consider minimizing economic costs. However, dam operations also offer an opportunity to increase wild fish survival under difficult conditions. We produced a probabilistic optimization approach to developing reservoir release schedules that maximize fish survival in regulated rivers. Model application to Folsom Dam operations resulted in an optimal reservoir release policy schedule recommendation for maximum survival of wild Fall-run Chinook Salmon on California's Lower American River.

The use of indirect measurement to determine peak discharges of flood events in Southern Nevada

Christopher Morris, U.S. Geological Survey

In arid regions, high magnitude flood events play major roles in recharging local water tables, filling reservoirs, modifying channel shape, and sustaining riparian ecosystems. In normally dry channels, such floods characterize most flow events, but even in perennial systems, floods may provide the majority of the flow for the entire year. Many locations in the southwestern U.S. are already facing water shortages and some climate change scenarios indicate an increase in the intensity and frequency of these flood events. Quantification of peak discharges during these events is necessary for water authorities, land managers, and the public to make more educated decisions regarding water supply, infrastructure, and land use. However, due to their flashy and dangerous nature, direct measurement of discharges during floods are difficult or impossible. The U.S. Geological Survey uses a variety of indirect methods, including slope-area, contracted opening, flow over dams, and flow through culverts, to determine peak flows after the event. These indirect methods require accurate surveying of the elevation of the water surface at the peak, geometry of the channel, roughness from channel material and vegetation, as well as physical structures such as culverts and bridges. Hydraulic computations are used to relate these features to the peak discharge. Examples from recent floods illustrate how the use of these indirect measurement techniques provide reliable and defensible computations of flow.

Bio: Christopher Morris is a Hydrologic Technician at Nevada Water Science Center, U.S. Geological Survey.

Studies of stream-aquifer interactions in urban watersheds with predominately grout lined channels

Barry Hibbs, California State University, Los Angeles
(co-authors: M. Lee, M. Harrison, G. Demeter, Y. Wong)

Extended Abstract

Concrete lined storm drains are used worldwide to convey storm runoff away from urban areas. They also convey dry weather flows such as car wash runoff, lawn runoff, and other "nuisance flows" in urban centers. Areas in southern California and elsewhere have shallow water tables where dry weather flows in concrete lined storm drains consist primarily of perennial groundwater baseflows. In these areas, groundwater leaks through cracks, joints, weepholes, and intentional dewatering structures into storm drains, which eventually flows into natural channels, coastal wetlands, and estuaries. The "lined" sections of these channels are hardly impervious; in fact, the lining of the channels often affords excellent opportunities to collect groundwater samples at discrete points that are usually not present along unlined channels where well control is sparse or where technical or legal issues prevent installation of piezometers. Frequently, as much as 95% of the nutrient and trace element loading to urban catchments during dry weather is from seepage of groundwater that is laden with pollutants. This project presents several examples of our experiences in conducting stream/aquifer studies in lined and semi-lined channels in southern California. Sub-projects include evolution of groundwater quality along flowpaths, detection of unwanted recharge mounds in shallow groundwater systems due to leaky water main pipes, and geologic factors in water quantity and water quality fluxes in urban catchments. Tools that are utilized and described include isotopic tracers (O-H-S-N stable isotopes); trace element speciation analysis; and innovative sampling methods.

Introduction

In urban area of southern California, many channels are lined with grout concrete. These channel linings are installed in order to route stormwater runoff away from urban areas as fast as possible. Due to rising or shallow groundwater, many grout lined channels have weepholes and dewatering appurtenances installed, along with secondary seeps developing where groundwater flows into streams (Figure 1). During flood stage, these conduits act to allow surface water to recharge aquifers. Solutes and toxins in the stormwater runoff can degrade groundwater quality during exfiltration, or may improve water quality, depending on the quality of underground water and timing and quality of stormwater runoff. Where the water table is in direct contact with the storm drain, exfiltration from storm drain to groundwater occurs during storm events while infiltration from groundwater to storm drain occurs during dry weather. Fluxes of solutes from storm drains to groundwater and vice versa can be minimal or great, depending on presence and density of weepholes and other permeability conduits that may be part of the channel design. Secondary permeability conduits along cracks and cave-ins created by settling or subsidence are other important flux generating features in grout lined channels in urban catchments (Figure 1).

Other issues associated with storm drains relate to groundwater dewatering flows. Shallow groundwater dewatering facilities lower the water table near construction sites, bridge underpasses, and high rises (Figure 1). Frequently dewatering flows contain nutrients, trace elements, and organic contaminants that are discharged to storm drains. Concrete-lined conduits and channels may not have intrinsic remediation processes that are operative in unlined and vegetated channels and streambeds. Many older dewatering operations that discharge to storm drains are not known except when detected by underground inspections. Older, permanent dewatering operations are sometimes grandfathered by regulators. In such cases, solute-laden groundwater continues to flow unabated into storm drains (Hibbs and Sharp, 2012).

Demonstration Study

A study in El Modena Channel in San Diego Creek Watershed of Orange County California demonstrates the important stream/aquifer interactions and processes associated with changing land use activity along a lined channel (El Modena Channel). El Modena Channel flows into Peters Canyon Wash below Walnut Avenue (Figure 2). Near-channel groundwater sample points included four weepholes (EMW-1weep, EMW-2weep, EMW-4weep, EMW-Wweep) and a shallow water well in the dividing area between Peters Canyon Wash and El Modena Channel (CW1-2D) (Figure 3). These weepholes and water wells are oriented along a groundwater flowpath that moves subparallel to the direction of surface water flow in Peters Canyon Wash and El Modena Channel. This channel begins above, and later enters a land region that was once occupied by a large regional marsh known as the "Swamp of the Frogs Marsh" (Hibbs, 2001). The channel is lined along the whole reach investigated.

Chloride, sulfate, and selenium data collected from weepholes and from the shallow water well are plotted as bar graphs and line graphs (Figures 3 and 4). The graphs indicate that selenium and sulfate increase significantly between Bryan Ave

and Walnut Ave. In this region, selenium increases from a low value of 20 µg/L (weephole EMW-2) to a high value of 178 µg/L (weephole EMW-W) along the groundwater flowpath. Sulfate increases simultaneously from a low value of 458 mg/L (weephole EMW-2) to a high value of 1430 mg/L (weephole EMW-W) as groundwater flows down the hydraulic gradient. Hibbs and Lee (2000) noted that the chloride concentrations did not increase proportionately to sulfate and selenium concentrations along the hydraulic gradient. Chloride varies from a low of 189 mg/L (weephole EMW-2) to a high of 251 mg/L (weephole WEMW-weep) in the other wells and weepholes.

Hibbs and Lee (2000) speculated that groundwater evaporation alone could not explain selenium enrichment in groundwater; otherwise, chloride (the most conservative ion) in groundwater would become similarly enriched. Chloride concentrations are fairly constant in groundwater in the data set. Therefore, evaporation cannot be the primary agent enriching sulfate and selenium along the groundwater flowpath. This led to the hypothesis of selenium remobilization from reduced forms in the Swamp of the Frogs Marsh. Hibbs and Lee (2000) discuss the geologic source of selenium and sulfur in shallow groundwater in marsh sediments:

> *"During the historic period of the Swamp of the Frogs Marsh, any forms of selenium and sulfur that flowed into the marsh were probably derived from surface runoff from the highlands in the oxidized forms (SeO_4^{2-} and SO_4^{2-}). Once the oxidized forms of selenium and sulfur reached the anoxic waters of the marsh, these oxidized species were probably reduced to SeO_3^{2-}, elemental Se(0), Se^{2-}, H_2S, and HS^-. These forms would be expected to be removed from the waters in the marsh and sorbed onto solid particles, precipitated as crystalline and amorphous polymorphs, or transformed into volatile gases.*
>
> *Once immobilized in solid forms, the selenium and sulfur solids would tend to remain stable in the soil substrate as new sediments and organic matter in the marsh continued to accumulate. Cores extracted from old marsh sediments reveal sedimentary facies consistent with anoxic environments, including thick sequences of olive-gray clay, dark gray to dark brown silt and silty clay, and sandy clay and clayey sand that is usually medium to dark brown. Some of the core logs show traces of carbonized fragments indicative of decaying plant material.*
>
> *When the Swamp of the Frogs Marsh was drained in the late 1800's and early 1900's, the shallow subsurface was transformed into an oxic environment. In fact, the shallow groundwater flow system today is being recharged by oxygen-enriched water that retains some dissolved oxygen as it flows through the old marsh deposits. The groundwater data collected during this study, along with other groundwater data (Silverado, 1997) indicate that groundwater contains relatively high concentrations of dissolved oxygen (usually 0.3 to 5 mg/L), very high ratios of dissolved nitrate to nitrite, and the general absence of iron and manganese. These hydrochemical signatures indicate a highly oxic groundwater flow system.*
>
> *Oxidizing groundwaters flowing through the old marsh sediments today remobilizes the bound forms of selenium and sulfur into their oxidized and mobile forms (SeO_4^{2-} and SO_4^{2-}). Thus, we can account for high sulfate and selenium in groundwaters in large part from remobilization of reduced forms of selenium and sulfur as oxic waters flow through the historic marsh sediments."*

This primary set of observations along this channel and other sets of data collected along unlined and lined channels in the same urban catchment resulted in expanded studies in San Diego Creek Watershed. Additional studies focused on selenium and arsenic mobilized from the historic Swamp of the Frogs Marsh. Substantial external research funding was developed for the authors and others as a result. Many of our research studies in urban watersheds have been fruitful, with results identifying leakage of water main ruptures flowing into storm drains via groundwater seepage; infiltration of contaminated stormwater runoff into groundwater; and detection of groundwater mounding areas first appearing as rising groundwater at storm drains.

Safety Concerns

Because urban channels may have vertical or near vertical walls, dangerous conditions confront any person conducting studies in urban storm drains. Flood risk while working in a channel is of greatest concern. Other risks include contact with criminals, dangerous animals, and gas related toxins due to accidental or intentional releases of volatiles into storm drains. Some of these risks exist in any watershed investigation, but remain particularly acute in urban settings. Personnel should always be aware of the risks and should have safety equipment and procedures in place to deal with any possible emergency.



Figure 1. Various types of groundwater exchange points in concrete lined channels in urban catchments in southern California, including weepholes, dewatering appurtenances, and cracks and seams in grout lining near collapse features.

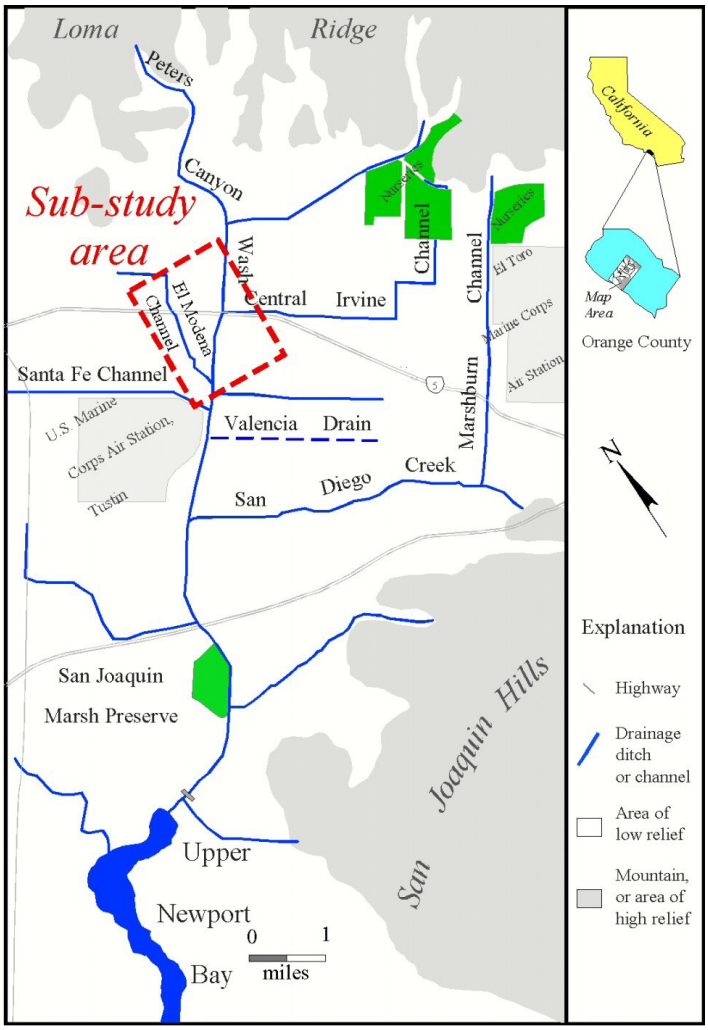
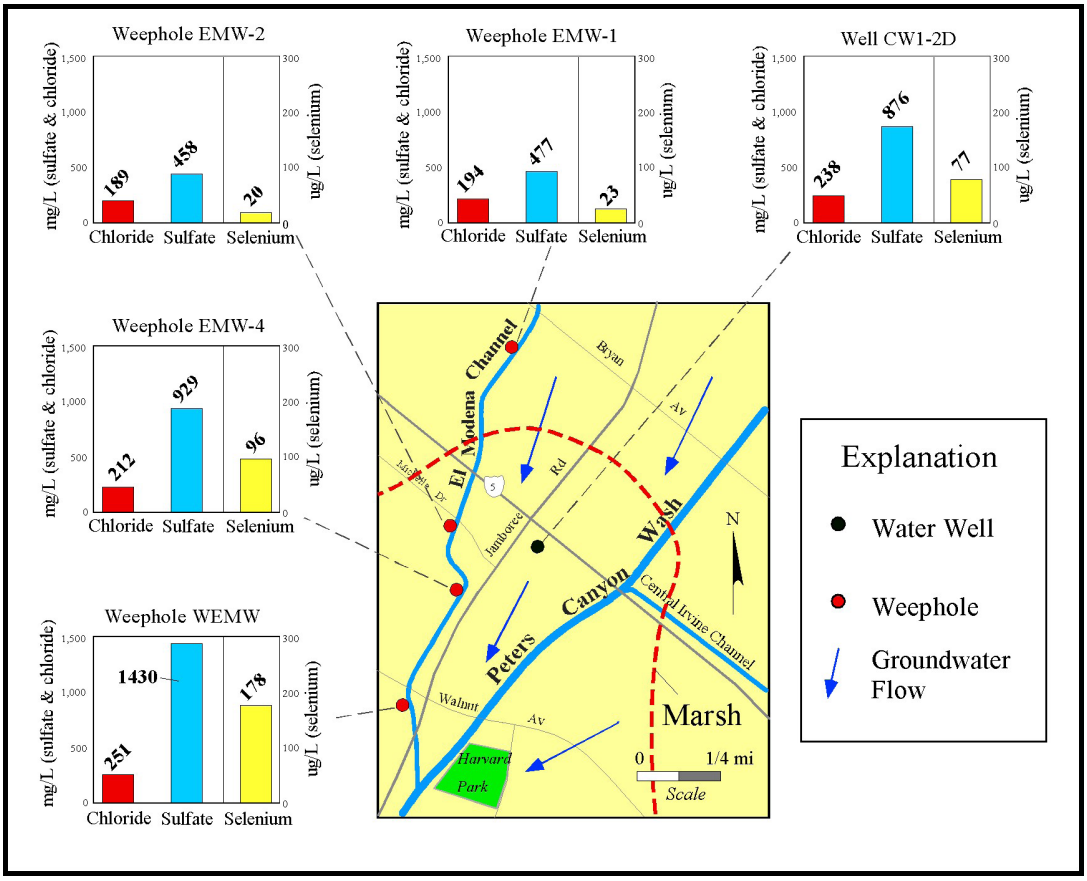


Figure 2. Location of El Modena Channel sub-study area in the San Diego Creek Watershed of central Orange County, California. Demonstration study is presented for this sub-study site.



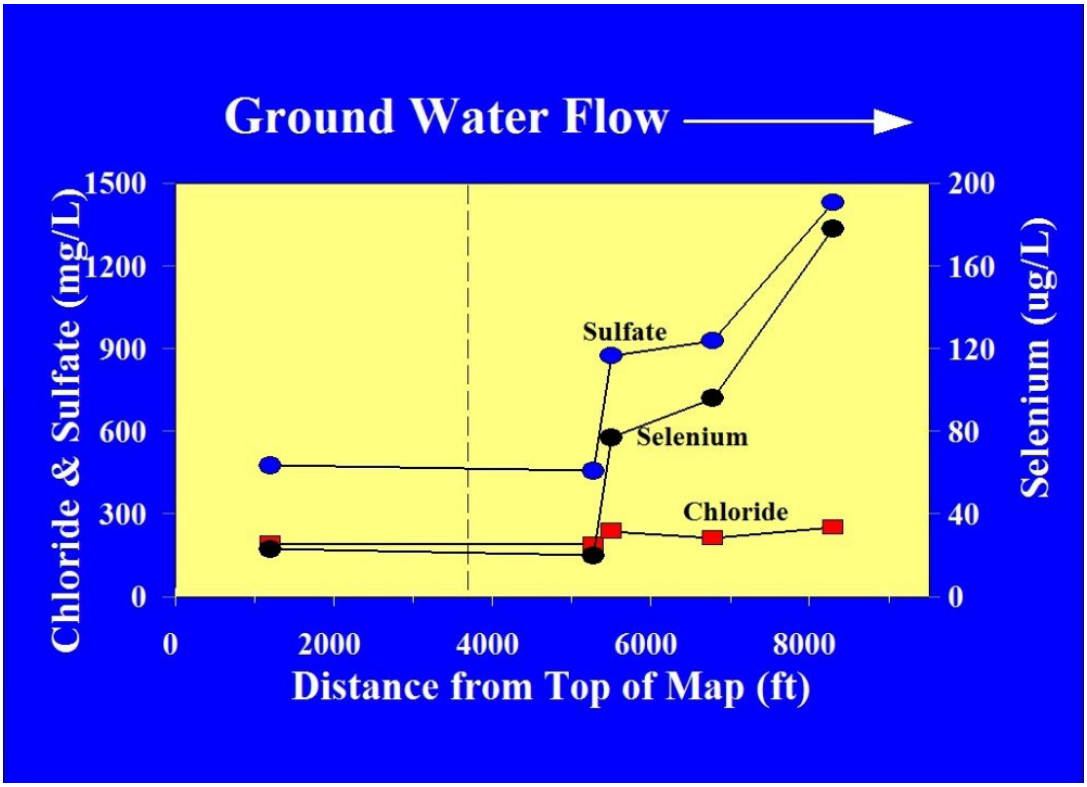


Figure 3. Graphs showing chloride, sulfate, and selenium concentrations in groundwater collected near El Modena Channel. The diagram indicates that sulfate and selenium concentrations increase continuously along the hydraulic gradient, but chloride does not increase significantly. These data suggested to Hibbs and Lee (2000) that selenium enrichment did not result from evaporation, but from a geological source associated with marsh deposits. Stippled lines in both figures show the boundaries of the historic Swamp of the Frogs Marsh.

Composite Sampling Issues

Regarding sample reliability, another concern focuses on the coarse textured material that is frequently constructed as an inert base below concrete drainage infrastructure. This material is installed to prepare a firm, non-corrosive base below the concrete lining of a channel or drain. Coarse textured material is more permeable than most shallow aquifer material and it may act as a sink to groundwater flow, creating lateral flow pathways underneath and alongside a drain or channel that is constructed (Figure 4). Composite mixing of groundwater (compositing) can occur in such instances, making it difficult to decipher hydrochemical processes developing along groundwater flowpaths. This problem is not unique to concrete lined channels, as similar issues arise in conventional hydrogeological studies where well screens of high capacity water wells penetrate multiple intervals in an aquifer. These also provide an integrated composite water quality sample. Nested monitoring wells help overcome this problem, but many groundwater basins are not instrumented with nested monitoring wells. Groundwater hydrologists often select nearly any well that is available to be sampled. In the case of concrete lined storm channels, it is necessary to determine if a composite sample might be obtained at a sample point. The chance of this happening is minimized when the water table adjacent to the concrete lined channel is more than a foot above channel grade. In our studies we have been fortunate not to have experienced many cases of severe composite sampling. Weepholes, cracks, and other groundwater sampling orifices provided water quality values that appear to be directly related to the aquifer strata in the immediate vicinity of the orifice sampled.

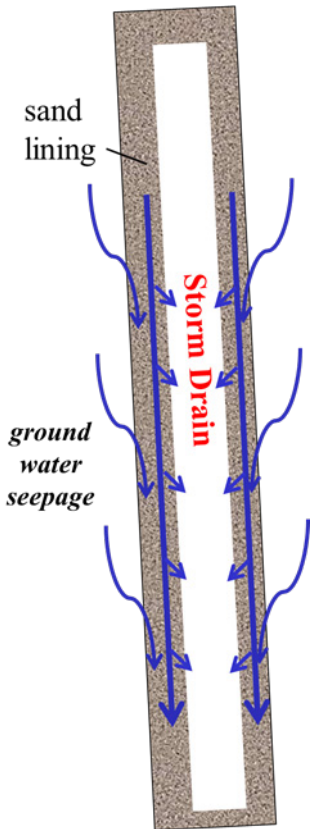


Figure 4.

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Bio: Barry Hibbs has taught at California State University, Los Angeles, since 1997, where he instructs courses in groundwater hydrology, water quality, watershed analysis, field methods, and groundwater management. Dr. Hibbs received a B.S. in Geology from Arizona State University, an M.S. in Hydrogeology from the University of Nebraska Lincoln, and a Ph.D. in Hydrogeology from the University of Texas at Austin. He is a Fellow of the Geological Society of America and a recipient of Cal-State LA's Outstanding Professor Award (2014). Dr. Hibbs' research focuses on the hydrogeology of arid basins in the Southwestern United States and Northern Mexico; stream/aquifer interactions; isotope hydrology; and trace element hydrochemistry.

Hydrologic restoration via low impact design retrofit

Tracy Fanara, University of Florida

Urban environs have historically been designed for rapid and efficient transport of stormwater runoff to protect developed areas from flooding. This design methodology leads to increased peak flows and erosion of natural landscape, as well as decreased subsurface water recharge, time to peak flow, and time of concentration. This hydrologic fraction shift from predevelopment subsurface flow to post development surface flow, coupled with high pollutant loading, can be catastrophic to receiving biomes, resulting in declination of habitat, aquatic life, and quality of drinking water sources. Due to lack of public education, government funds, or regulation, many times visible symptoms of urbanization are treated, the source of the problem remains and adverse subsurface impacts continue to escalate. In a society where population continues to increase while development design seems immutable, what can be done to protect ecosystem health and restore subsurface hydrology, and how can we influence regulation and attempt sustainability moving forward? This paper explores the impacts of LID retrofit to restore pre-development sub-surface hydrology and water quality at the University of Florida through hydrologic model forecasting, develops a Master Plan influenced by public outreach research with both EPA Rainworks Challenge national winning retrofit designs of the University of Florida campus, and concludes with development of a mobile phone application tool, TRASI (Treatment, Retention, and Sustainability Index) for site design developers and engineers to overcome LID perception obstacles with use of a simple tool which selects the most cost effective suite of low impact design techniques for a specific project. The key to a “sustainable” environment in the future is education and action today.

Bio: Tracy Fanara received her doctoral degree in Environmental Engineering, under advisement of Dr. Mark Newman and Dr. Michael Annable at the University of Florida. She has been working in the engineering field as a project engineer for eight years with some of the world’s most prestigious engineering firms (currently, CH2M Hill), specializing in stormwater design and watershed modeling and analysis, ranging from small coastal condominium developments in Sarasota, Florida to massive flood analysis and design projects in Al Kharj, Saudi Arabia. Tracy received both her Bachelor’s of Science and Master’s of Engineering degrees at the University of Florida. Tracy is an advisor to Trevor’s Eco-Education Foundation, founder of InspectorPlanet.com, on the Education Board for the Florida Stormwater Association, and was a mentor and design engineer for the nationally winning EPA Rainworks Challenge team, a competition for artful and educational low impact design retrofit Master Plans.

Water is not merely for human consumption; water is essential in the design, construction, and operation of the built environment

Nader Chalfoun, University of Arizona
(co-author: *O. Youssef)
*Presenter - Omar Youssef, University of Arizona

Energy consumption in buildings is a major environmental and sustainability concern. Arizonans spend over $9 Billion annually on primary energy consumption which is equivalent to the entire State Budget. The building sector consumes 45% of that energy. This consumption is responsible for greenhouse gas emissions such as carbon dioxide (CO_2) sulfur dioxide (SO_2) and nitrogen oxides (NO_x). Energy production also depletes water supply. In Arizona each kWh of end-use energy generated by thermoelectric power consumes 0.32 gallons of water and an extreme 64.85 gallons for hydroelectric power production. Architecture design and professional practice has the opportunity to overcome the current high consumption of energy by integrating smart water saving and harvesting techniques. At the University of Arizona College of Architecture, Planning and Landscape Architecture, a four-legged water education curriculum has been developed by the Authors and experimentally implemented in a graduate design studio. All students' projects emphasized the use of water strategies developed through the water curriculum. This paper illustrates two projects selected from two consecutive years. The first was the Engineering Innovation Building (EIB), at the University of Arizona Campus in Tucson, and the second is the Children's Museum of Tucson (CMT) in downtown Tucson. Some of the water smart strategies are a 4,500 ft² water wall that modified ambient temperatures through evaporation of pre-harvested rain water while a breezeway funneled the southeast prevailing wind across the wall and redirected to the courtyard of the building. A 1,440 ft² south oriented Bio-adaptive Algae façade was developed to generate about 9,400 kWh annually. A 400 ft long dynamic wall of discovery collected rainwater into a water harvesting tank located on site and used gray water for irrigation.

Bio: Dr. Nader Chalfoun is a Professor of Architecture and Environmental Sciences at the University of Arizona. He is regionally and internationally recognized for his work on building energy efficiency and energy performance modeling. He and his colleagues developed MRT an outdoor thermal comfort simulation model. He directs the House Energy Doctor program at the University and teaches a course sequence to architects on building energy efficiency as well as bringing these technical issues into the graduate and undergraduate curriculum. He is a prime contributor to Tucson's Sustainable Energy Standard, and a member of the Institute on Health and Wellbeing at the Arizona Center for Integrative Medicine, University of Arizona. Co-author, Omar Youssef, recently graduated with a Masters of Science in Architecture focusing on design and energy conservation. He was awarded with Best Masters Thesis for his research "Creating a Design Index for Therapeutic Architecture", and Best-in-Studio for designing the new Engineering Innovation Building. Youssef is undergoing his Ph.D. at the Arid Lands Resource Sciences as a Research Associate with a full scholarship and also the Harvill Fellowship.

Assessing urban gardening as a green stormwater management

Tolessa Deksissa, University of the District of Columbia
(co-authors: S. Tefera, Y. Assa)

Extended Abstract

As urban gardening is becoming popular in many cities worldwide, it is crucial to assess the role of home and community gardens as a way to address food security, as well as managing stormwater runoff. Urban gardening is known to have various benefits to urban dwellers, ranging from the revitalization of abandoned or underutilized urban land to providing fresh, locally produced foods and the socio-economic benefits of job creation and hands-on learning opportunities. However, if not properly managed, urban gardening may present unique challenges. The soil might be contaminated with hazardous wastes or chemicals that may pose risks to human and environmental health. Addition of excess nutrients also results in contamination of urban waterways. Urban garden soils are mostly compacted, generating relatively more urban runoff than areas with less compacted soil. The objective of this study is to assess the soil quality of home and community gardens in the District of Columbia and its potential impacts on the water quality of DC waterways. Based on soil quality data on 142 samples from community gardens and 257 samples from home gardens, eighty seven percent of the samples have medium to excessive phosphate level. Thirty percent of the community gardens and fifty two percent of home gardens have a pH level less than 7, which is acidic to neutral. Furthermore, 34% of samples from the community garden and 26% of the samples from home gardens exceeded the EPA soil screening level of 0.4 mg/kg for arsenic. To prevent urban water pollution, DC urban gardeners need to apply best management practices such as planting cover crops, mulching, reducing nutrient application, and capturing and reusing stormwater. Using rain barrels for capturing and storing stormwater for agriculture, and enhancing soil infiltration rate in mostly compacted urban gardens can reduce stormwater runoff. With proper policy and guidelines, urban gardening can improve food security, carbon neutrality, economic and social opportunity, and benefit the environment through managing stormwater and restoring urban waterways.

Introduction

The challenge of sustainable urban development in the 21st century is how to become a green city with clean waterways by implementing the green infrastructure that can addresses food security, stormwater management and heat island issues. Urban development increases stormwater runoff, which is often untreated and directly discharged to the nearest river or stream. Consequently, most urban rivers and streams remain impaired, regardless of the passage of more than 40 years since the establishment of the 1972 Clean Water Act (US EPA 1997). To address this problem, some cities have started implementing green infrastructure, including urban gardening (NGA 2009; Ackerman 2012; Whittinghill et al. 2012).

Urban gardening is known to have various benefits to the urban dwellers, ranging from the revitalization of abandoned or underutilized urban land through providing fresh, locally produced foods and other socioeconomic benefits such as job creation and hands-on learning opportunities. These benefits have resulted in the increased popularity of urban gardening in many cities. However, it is known that agricultural activity may increase non-point sources of nutrient and contaminants loading into waterways. Thus, it is crucial to assess the role of home and community gardens as a way to greening and the city and securing food while effectively managing stormwater runoff.

Urban gardening may present unique challenges. The first concern is that the soil might be contaminated with hazardous wastes or chemicals that may pose risks to human and environmental health. Second, excess addition of fertilizer or nutrients to the gardens can potentially result in non-point source pollution of urban waterways. Third, the urban gardener's knowledge and perceptions of soil contaminant risks varies (Kim et al. 2014). Finally, gardening for edible produce is not integrated in the traditional green infrastructure stormwater management.

The objective of this study is four-fold. First, the study seeks to increase awareness of soil contamination in DC urban gardens through free soil quality testing service. Second, it assesses the occurrence and extent of soil contamination with trace metals in home and community gardens. Third, the study examines the potential contamination of DC waterways by excess nutrient and trace metals. Lastly, it explores the application of urban agriculture as a green urban stormwater management strategy.

Materials and Methods

In the summer of 2014, 398 composite samples were collected from DC gardens, including 141 community garden sites and 257 home gardens (Figure 1). The soil pH was measured using 1:1 soil to water. Extractable phosphorous, heavy metals and other trace metals were determined by the Mehlich 1 method (Mehlich 1953). Mehlich 1 soil extracts were analyzed for trace

metals using a PerkinElmer's NexIon 300D Inductive Couple Plasma Mass Spectrophotometery (ICP-MS). Orthophosphate was determined colorimetricly on the Mehlich 1 extract using the Molybdovanadate method (Hach method 8114). Nitrate-N was analyzed using a 2M KCl extraction followed by colorimetric analyses using the Dimethylphenol method (Hach method 10206).

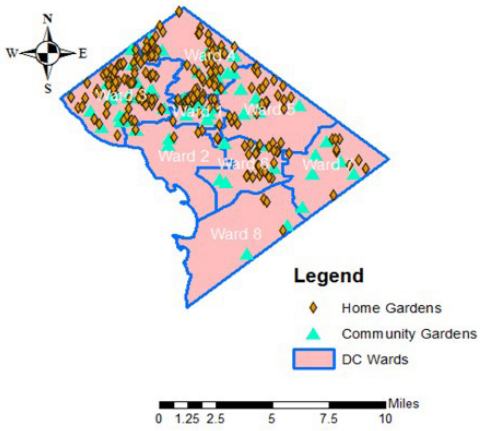

Figure 1. Sampling Location.

Results and Discussion

Major Nutrients

Based on the University of Maryland Cooperative Extension, the nutrient level in some gardens is excessive. The results show that 87% of the gardens have excess extractable phosphate, one third have excess nitrate level, and 31% have excess potassium. Gardens with alkaline pH have excess levels of calcium and magnesium. Nitrate and phosphate are the main ingredients of fertilizer, and storm runoff from the gardens with high levels of these major nutrients can potentially impair urban waterways. Furthermore, in acidic soils with excessive phosphate, both phosphate and arsenic can be more soluble (Singnes-Pastora et al. 2007). This shows that there is potential contamination of waterways through soil loss and erosion, especially from gardens near concrete sidewalks.

Trace Metals

Trace metals of concern in urban gardens, such as lead, arsenic, cadmium, copper, zinc, mercury, cadmium, chromium, nickel, and selenium were analyzed and compared with the EPA soil screening guidelines (USEPA 1996). The result shows that the highest trace metal in the studied gardens is zinc, but levels are still below EPA guidelines. Extractable arsenic level exceeds EPA soil screening limits of 0.4 ppm for residential setting (Figure 2). Other trace metals are within the EPA limits. Based on this study, the trace metal levels in urban gardens do not pose a concern with the exception of arsenic. This might be due to the fact that all the gardeners used compost for soil amendment, which might have reduced the availability of extractable trace metals (Mab et al. 2003). The contamination of community gardens is consistent with home gardens in both median and average concentrations of all 9 elements (Figure 3).

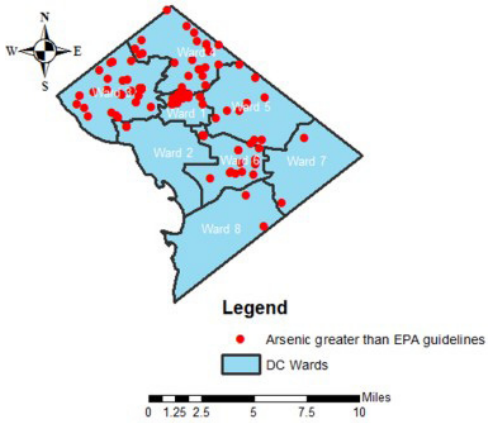

Figure 2. Locations of higher arsenic level.

The level of trace metals in urban gardens is evolving as it depends more on soil management practices than natural processes, as in a rural area. For example, Long (2012) found lead concentration above the US EPA action level of 400 ppm in the native soil of three community gardens in DC. Many sites might be highly contaminated, but there are no available test results to guide urban gardeners. The need for pre and post planting soil quality status in the urban setting is crucial as some metals can be trans-located into plant tissues. Finster et al. (2012) demonstrated how plants grown in lead contaminated soils can accumulate lead from the adherence of dust and translocation into the plant tissue. This confirms the importance of soil test prior to planting vegetables in an urban setting. Urban gardeners should test the metal levels in their soils and practice sustainable urban gardening techniques: such as raised beds. Soil quality analysis for trace metals is expensive and not affordable to all DC residents. Subsequently, during this study, we provided free soil quality testing services to about 400 gardens in DC. All participating gardens received basic information pertaining to soil contamination and level of concern regarding their soils.

Many studies have demonstrated various pathways of soil contamination in urban areas (USEPA 1980). For example, according to US Geological survey, the background concentration of lead in soil is 16 ppm, but it can reach higher levels in the residential area due to various pathways, such as peeling, chalking, or active removal of lead-based paint; and fallout from the discharge of community waste incinerators (Mielke and Reagan 1998; Gulson et al. 1995; Shacklette and Boerngen 1984). The majority of gardener believes that human exposure to lead and arsenic is due to ingestion of vegetables instead of accidental ingestion of soil particles contaminated with these elements (Kim et al. 2014). This shows the need to educate the public regarding relevant contaminants of concern and route of exposure.

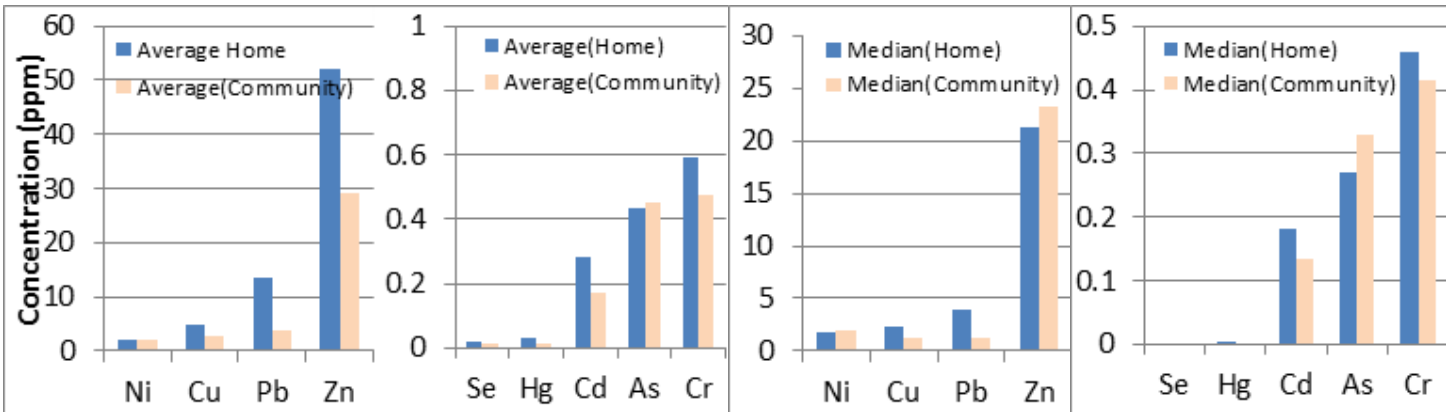

Figure 3. Trace metal analysis and location of gardens that exceeded EPA guidelines in arsenic.

Urban gardening as a Green stormwater Management Strategy

The application of urban gardening as a green stormwater management strategy needs further investigation. The two essential characteristics of green stormwater management strategy are: reduction and delay of stormwater runoff volumes, and reduction of stormwater pollutants. As a green stormwater management strategy, urban gardening for edible produce must meet these two characteristics. It also is impacted by several other factors such as soil moisture, run-off levels, erosion and sediment loss, water holding capacity of urban farm sites, using stormwater runoff for irrigation, and urban soil contaminants. In addition, urban gardening needs to possess most common characteristics of urban agriculture and green stromwater infrastructure such as reducing imperviousness and heat island effects, and increasing beautification of neighborhoods.

Community Education Need

The application of urban agriculture as a green urban stormwater management strategy needs an appropriate community education program that addresses three areas of concern. The first concern is the public perception about contaminants of concern and their route of exposure (Bellinger and Bellinger 2006; Clark et al. 2006; Gulson et al. 1995; Kim et al. 2014; Mielke and Reagan 1998). Many gardeners may not know the type of chemical contaminants and ways that humans and environments are exposed to those chemicals through gardening practices.Secondly, educating urban dwellers to integrate urban gardening for fresh produce and green stormwater management is crucial. In this study, each soil test result was discussed with each gardener. We provided guidelines both in writing and phone conversations. Thirdly, it is also important that the suitability of soil for urban agriculture and stormwater management is evaluated. If a site has soils that cannot support food production, it might be possible to use the parcel for stormwater retention and infiltration and vice versa. This indicates that proper public education can enhance the benefit of both green infrastructure and urban agriculture (Witzling et al. 2011).

Conclusion

Based on the results of soil quality analyses, we can conclude that the levels of extractable trace metals are not a concern in the studied sites, except for arsenic. More than 50% of the gardens have arsenic levels above EPA soil screening guidelines. This implies that the gardeners need to apply best management practices such as soil amendment with clean organic composts or raised beds. Without proper best management practices, gardens with excess extractable phosphate and nitrate can impair waterways. To prevent urban water pollution, DC urban gardens need to apply best management practices such as planting of cover crops, mulching and reduced nutrient application in order to reduce soil loss and erosion, and ground water contamination with nitrate. Proper guidelines and public education program can address the need to raise public perception of soil contamination issues, and how best management practices relate to the application of urban agriculture as a green stormwater management strategy. For example, urban gardens need to use rain barrels to capture and store rain water for watering their crops. Enhancing soil infiltration rate and using rain barrels can reduce stormwater runoff. With proper policy and guidelines, urban gardening can improve food security, carbon neutrality, and economic and social opportunity and benefit the environment through managing stormwater and restoring urban waterways.

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Managing potential water resource impacts from oil and gas development activities

Ayn Schmit, U.S. Environmental Protection Agency, Region 8

This presentation will provide information on potential water resource impacts associated with various aspects of oil and gas development, describe relevant U.S. Environmental Protection Agency programs and activities that address these impacts, and discuss several protective practices that can reduce the potential for impacts.

Bio: Ayn Schmit is a Water Policy Advisor for the Environmental Protection Agency's Denver Regional Office. She provides expert advise and counsel to EPA programs and partners regarding energy and water issues. Ayn has a B.S. in environmental science and a B.A. in political ecology from the University of California, Santa Cruz. She has worked for the EPA in 2 regional offices and several programs since 1983, and has spent the past 20 years managing water programs.

Groundwater quality and shale gas development

Mike Hightower, Sandia National Laboratories

Water and energy are interdependent – water is used extensively in energy development as cooling water in thermoelectric power generation; in oil and alternative transportation fuels refining, and in biofuels production. At the same time, water and waste water pumping, treatment, and distribution is one of the largest energy use sectors in many developed countries. At a time when fresh water availability is becoming limited in many regions due to changing precipitation patterns, increased ecological and environmental demands for water, and issues over sustainable surface and groundwater withdrawal and use, water consumption demands by the energy sector could expand significantly in the next two decades. The emerging water needs for the energy sector and the emerging energy needs for the water sector could significantly change how these two critical natural resources are developed and utilized.

Bio: Mike Hightower is a Distinguished Member of the Technical Staff in the Military and Energy Systems Analysis Department at Sandia National Laboratories in Albuquerque, New Mexico. He is a civil and environmental engineer with over 35 years of experience in research and development projects. His current efforts include research and evaluation of innovative environmental and energy technologies and the security and protection of critical water and energy infrastructures. He conducts research on the use of distributed and renewable energy technologies and distributed water and waste water systems to enhance sustainable economic development, global public health, and infrastructure resiliency and security. Since 2006, he has supported the US Department of Energy in developing a science and technology program for addressing energy and water interdependencies. Most recently he has supported the US Senate on energy water legislation considerations, authored a research program plan on energy and water for the National Science Foundation, and assisted the National Research Council in identifying key energy water challenges and needs. Mike holds BS and MS degrees in civil engineering from New Mexico State University.

Hydrogeologic and regulatory issues related to in-situ recovery of Uranium

Mike Wireman, US EPA - retired

In hydrogeologically favorable conditions, uranium ore can be mined using in-situ leach methods (ISL), where uranium is recovered by injecting an oxygenated lixiviant into ground water which flows through the deposit. Uranium is dissolved into the ground water / lixiviant solution and recovered by extraction wells. Uranium is removed from the solution and processed into a uranium concentrate. The uranium depleted water is refortified with lixiviant and re-circulated through the deposit for additional recovery. In-situ leaching works best for uranium deposits that occur below the water table in shallow, permeable sands and sandstones. In 2013, 47% of the world uranium production was from ISL operations. In the USA, 4.6 million pounds of U3O8 was produced in 2013 from 3 conventional underground mines and 7 ISL mining operations. At least 8 new ISL operations are currently being planned in the western USA. ISL facilities are regulated primarily by the Nuclear Regulatory Commission. The US EPA and State Mine permitting agencies also have relevant authorities. While ISL mining is considered environmentally safer that conventional uranium mining, there are significan environmental issues including: (a) hydraulic management of the lixiviant solution to prevent unwanted migration (b) disposal of radioactive waste fluids and (c) restoration of impacted groundwater to applicable water quality standards. Experience at existing ISL operations demonstrate that it is very time consuming and difficult to return the impacted groundwater to pre-mining water quality conditions. In addition large volumes of highly toxic waste fluids are generated which must be disposed of pursuant to applicable regulations. Often this is done by injection into UIC Class I wells that sometimes inject into exempted portions of underground sources of drinking water. As ISL mining of uranium increases in the US, it is important to evolve the methods for groundwater restoration and waste fluid disposal.

Bio: Mike Wireman recently retired from the US EPA where he served as a National Ground Water Expert. In this position he provided scientific support to Federal and State ground water management programs. He has extensive experience in hydrogeology of hardrock mines, mountain watersheds, DNAPL sites, nutrients in ground water, ground-water monitoring, ground-water vulnerability assessment, and source-water protection. His has worked closely with policy makers, decision makers and attorneys. He has taught classes for the National Ground Water Association, the Geological Society of America and workshops in Eastern Europe and Middle East. He serves as an advisor to the World Bank with significant international experience in Eastern Europe, the Middle East and China. He has provided expert testimony in Federal and State court, State Water Quality Control Commission and State Water court. He is past-President of the USNC-IAH, serves as a Director on the Board of the Science and Engineering Division of NGWA and is a Board member of the GWPC – Groundwater Research & Education Foundation.

Groundwater quality and shale gas development

William M. Alley, National Ground Water Association

As advances and greater use of horizontal wells and hydraulic fracturing technology has expanded natural gas and oil supplies, concerns have been raised about the possibility for contamination of shallow groundwater by stray gases, formation waters, and chemicals used in hydraulic fracturing. A lack of credible and comprehensive data and information is a major impediment to develop sound policies to minimize risks. This presentation will review the current scientific understanding of impacts and the role of research, monitoring, and baseline sampling to develop a better understanding of the connection of groundwater quality and shale gas development.

Bio: Dr. William M. Alley is Director of Science and Technology for the National Ground Water Association (NGWA). Prior to this position, he served as Chief, Office of Groundwater for the U.S. Geological Survey (USGS) for almost two decades. Dr. Alley has published over 90 scientific publications and received several awards for his work, including the USGS Shoemaker Award for Lifetime Achievement in Communication and the Meritorious Presidential Rank Award. He holds a B.S. in Geological Engineering from the Colorado School of Mines, an M.S. in Hydrogeology from Stanford University, and a Ph.D. in Geography and Environmental Engineering from the Johns Hopkins University.

The Universities WASH Network: Engaging the U.S. academic community

Braimah Apambire, Desert Research Institute
(co-author: M. Campana)

Many US colleges, universities and research institutions are involved in the WASH (water, sanitation and hygiene) sector abroad. One of the most significant barriers developing countries continue to face in realizing improved health and socioeconomic outcomes is a lack of local human resource capacity across disciplines related to WASH. Recognizing the important contributions universities can make to the international WASH sector, and to increase the visibility and effectiveness of their programs, promote coordination, innovation, and cooperation, and increase funding support, several universities founded the Universities WASH Network (previously the U.S. Universities WASH Consortium) in 2009. Activities that were untaken following the formation of the Network were 1) a survey of universities' WASH activities; 2) an event on Capitol Hill to introduce the Network; 3) presentations by various Network members at professional meetings; and 4) development of mission and vision statements. In 2013, the Desert Research Institute (DRI) was selected to host of the Network, as part of DRI's new Center for International Water and Sustainability (CIWAS). An Advisory Committee was formed to provide governance to the Network and the mission and vision of the Network was revised to more effectively capture the Network's objectives. The Network's mission is now to increase human resource capacity for WASH in developing countries through integrated education and research programs. Going forward, the Network will accomplish this by collaborating with WASH NGOs, increasing communication and coordination among universities and their external partners engaged in global WASH and provide opportunities for collaborative programming. At the WASH and Hydrophilanthropy session, we will describe the need for UWASH to be proactive in the WASH sector and outline current and planned activities of the Network.

Bio: Dr. Braimah Apambire is a Water, Sanitation & Hygiene (WASH) and development expert with extensive field, academic, teaching and grantmaking experience. He is currently the Director of the Center for International Water and Sustainability at the Desert Research Institute (DRI), Nevada. Prior to this, Braimah was a senior advisor at the Conrad N. Hilton Foundation, where he managed the Foundation's WASH grant portfolio. Previously, he was the Director of the WASH Sector at World Vision. Early in his career, he was an assistant research professor at DRI, where he conducted research on international and Southern Nevada water issues and taught numerous classes on WASH at the University of Nevada, Reno (UNR) and other universities. Dr. Apambire also founded the Students Association for International Water Issues at UNR. He received his B.S. from the University of Ghana; M.S. from Carleton University, Canada; and his Ph.D. from the University of Nevada, Reno.

Springs ecosystem ecology and climate change risk in the arid Southwest

Larry Stevens, Museum of Northern Arizona; Grand Canyon Wildlands Council

Climate change threatens biodiversity and human quality of life. Southwestern wetland-riparian and upland biota are tightly packed at springs, where many federally endangered and rare, non-listed plant and animal species occur. Springs provide unique space-for-time substitution analyses: common tree and shrub species are discretely distributed in relation to variation in elevation and aspect, with low elevation populations occurring on north-facing slopes and high elevations populations on south-facing slopes. However, some springs wetland herbs and many non-native plant species are not sensitive to aspect. Such analyses illuminate risks and introduce new questions regarding climate change impacts on biodiversity.

Bio: Larry Stevens attended Prescott College in Prescott, Arizona from 1970-1974. After working as a biological technician and a river guide, he undertook graduate studies in biology at the University of Arizona, Tucson, and at Northern Arizona University, where he received his doctoral degree in Zoology in 1989. He served as the ecologist for Grand Canyon National Park from 1989-1994, the editor for Red Lake Books, and served on many ecological councils and committees in Arizona. He teaches occasionally at both Prescott College and Northern Arizona University, and works as a whitewater rafting guide in Grand Canyon. He is presently the curator of ecology at the Museum of Northern Arizona in Flagstaff and is the senior ecologist for Grand Canyon Wildlands Council, in which he serves as a conservation representative for the adaptive management of Glen Canyon Dam and the Colorado River through Grand Canyon. Larry has authored many publications, recently including recent books on the ecology of springs ecosystems in North America and global biogeography.

Disappearing Himalayan glaciers, water security in high Asia, temples, elephants, and other wonders

Mark Williams, University of Colorado

There is considerable controversy about retreat rates and mass loss of Himalayan glaciers, and how that might affect water security for 2 billion people who rely on runoff from High Asia for their water needs. I'm part of a large project funded by USAID to answer a simple question: "How much does melting glacier ice contribute to discharge today for the major rivers of South and Central Asia, such as the Indus, Ganges, and Brahmaputra?" Our primary research tool is remote sensing of snow and ice, and melting the snow and ice using downscaled climate data to parameterize energy balance melt models. We know there is a lot of error. So, our validation is hydrochemical mixing models. My Fulbright allowed me to visit field sites and collect water samples for these mixing models. What we now know for the eastern Himalaya is that runoff at low elevations—where most of the people live—is primarily from monsoon rains with a small contribution of melting glacier ice. Groundwater inputs are important and must be included in any hydrologic investigation. Rates of glacier retreat for the Sikkim region are lower than previously thought. We'll also do a quick tour of Bhutan, the Khumbu, Annapurna Sanctuary, Langtang, and Chitwan National Park in the Terai. Bhutan was beautiful. Paintings of phalluses on houses are ubiquitous, as are "wind chimes" made of phalluses and knives. I'll explain their importance. I'll finish with tales of elephants and rhino's and other cool animals from Chitwan National Park in the Terai.

Bio: Dr. Mark Williams is Professor of Geography and Fellow at the Institute of Arctic and Alpine Research, University of Colorado, Boulder. His research on snow hydrology, surface-groundwater interactions, terrestrial-aquatic interactions and biogeochemistry has won several awards, including being elected a Fellow of the American Geophysical Union, a Senior Fulbright Scholar in Nepal for 2013-2014, the US EPA Region VIII Outstanding Environmental Achievement Award, and the Denali Award for Outstanding Recent Achievement in Mountain Geography (Mountain Geography Specialty Group of the American Association of Geographers).

Applying lessons from two centuries of experience in water resources management

Jeff Brideau, Institute for Water Resources, USACE

For over 200 years, the U.S. Army Corps of Engineers (USACE) has participated in the development and management of water resources within the United States. These Civil Works activities have paralleled and complemented the Nation's rise from an 18th century colony to a 21st century superpower. While the path forward was not always clear, there is an interesting comparison in the evolution of water resources development that can be observed when comparing USACE to a similar federal organization, the Dutch Rijkswaterstaat. The Rijkswaterstaat, which is also a little over 200-years old, has missions similar to USACE Civil Works, but applied on the European continent to an area to size of the State of Maryland, and lacking much of the geographic and cultural diversity found in the United States. Even so, the number of similarities in how the USACE Civil Works missions and Rijkswaterstaat water resources missions evolved over the same time period is informative and interesting.

Bio: Jeff Brideau is an ORAU/ORISE postdoctoral research fellow at the Institute for Water Resources, U.S. Army Corps of Engineers. Trained as a professional historian, Dr. Brideau's research explores the histories of water resources planning and development across national and disciplinary boundaries. Jeff is a graduate of the University of Ottawa – where he received his Bachelors and Masters degrees – and the University of Maryland – where he received his doctorate in environmental history. In addition to his postdoctoral work at the Institute for Water Resources, he teaches graduate courses at Virigina Tech's Science and Technology in Society Department, as an adjunct professor. Throughout his academic and professional careers, Dr. Brideau has assiduously cultivated working relationships across the disciplinary spectrum. To this end, he has actively participated in several professional associations and water resources projects set in an array of interdisciplinary contexts and configurations, including: an independent review of FEMA's National Dam Safety Program; a global survey of nature-based solutions for reducing flood risk assembled by the Nature Conservancy; as a fellow at the Northeast Consortium for Hydrologic Synthesis; and in his current position at the Institute for Water Resources. Dr. Brideau's present work on the Corps of Engineers' 308 program – which surveyed the United States' rivers for multipurpose development – is an extension of a broader agenda to bring a historically informed perspective to water resources development and planning, and to demonstrate the value of professional history for environmental decision-making.

Southern Nevada's water resource strategy: resilience, adaptation and risk management

Zane L. Marshall, Southern Nevada Water Authority

Maintaining a safe, reliable water supply to a major metropolitan area is a challenge, even in areas where source water is abundant. In the American Southwest, those challenges are exacerbated as many of the West's fastest growing urban centers are relying on a shared resource. As the agency responsible for managing Southern Nevada's water resources, the Southern Nevada Water Authority (SNWA) maintains a water resource plan that looks 50 years into the future. Southern Nevada relies almost exclusively upon the Colorado River, of which Nevada is entitled to less than 2 percent of its allocated flows. However, after a decade of drought, communities along the river system are implementing near and long-term plans to address reduced deliveries. For a long time, water agencies—including ours—focused on increasing water supplies. However, as the decade-long drought on the Colorado River demonstrated, water planners must also anticipate shortages and develop the tools necessary to meet demand even under adverse conditions. To address its immediate needs, Southern Nevada has plans to invest nearly $1.5 billion to secure access to precious Colorado River supplies. By 2021, a deeper intake will work alongside a new pumping station to access water that is currently inaccessible below 1,000 feet – even when Arizona, California and Mexico cannot receive deliveries. Ultimately, the key to long-term resource security is diversification. Addressing Southern Nevada's long-term resources requires a shared approach to resource management and cooperation among stakeholders. By developing a suite of resource options, Southern Nevada is prepared to meet the water resource challenges that lie ahead.

Bio: Zane Marshall is the Director of the Resources & Facilities Department of the Southern Nevada Water Authority (SNWA) / Las Vegas Valley Water District (LVVWD), where he has worked for the past 20 years. A Las Vegas native, Zane leads six divisions that manage water, land and environmental resources, implement water conservation programs for southern Nevada, and manage office and building infrastructure across both organizations. Zane has a Bachelor's of Arts in Environmental Studies and Biology, and a Masters of Arts in Science in Biology and Statistics from the University of Nevada, Las Vegas. He is a member of several professional organizations, including Nevada Water Resources Association and the American Water Works Association, and he has been qualified as an expert witness by the Nevada State Engineer. Zane currently serves on the Board of Directors for the Alliance for Water Efficiency and the Great Basin Bird Observatory. He served as a National Park Service volunteer member of the Devils Hole Dive Team for over 12 years, and he served in the U.S. Marine Corps Reserve from 1990 to 1998. Zane received the UNLV Outstanding Alumni Award in 2007 for leadership, contributions and dedication to improve the environment.

Causes and consequences of declining municipal demand: An unexpected water resource challenge

Gary Woodard, Montgomery & Associates / University of Arizona

Western water supplies are under siege, as prolonged drought, scant snow packs, receding reservoirs, rampant groundwater overdraft, and devastating forest fires take their toll. The sense of urgency is deepened by stories about the challenges of supplying ever-increasing water demands. Many articles describing growing populations and sprawling metropolises appear to reflect the belief that desert cities are inherently unsustainable. While supply uncertainties abound, the reality of water demand is very different. Rather than struggling to meet growing water demands, many western water providers have been surprised, perplexed, and even challenged by declines in demand. The USGS recently released "Estimated Use of Water in the United States in 2010." The report documents how growing water use outstripped population from 1950 to 1970. But then water use plateaued for a decade, and has declined briskly ever since. Between 1980 and 2010, we managed to support 85 million more people and a growing economy while reducing water use by 57 billion gallons per day. It's both a phenomenal success story, and a well-kept secret. While the declines are both wide and deep, occurring in municipal, industrial, agricultural, and power sectors across the US, this presentation addresses efforts to model and forecast municipal demand in the Southwest. Declines appear to be nearly universal, to occur in both indoor and outdoor demand, and typically exceed population growth, resulting in utilities delivering less water to more people. Because few utilities foresaw or planned on declining demand, a number of issues have arisen, including: fiscal consequences such as inadequate revenues; operational issues triggered by increased water age, inadequate residual disinfectants ,and DBPs; planning challenges such as timing of system expansion and calculating waste water system capacity; and perception issues, such as backlash against conservation programs when declining demand triggers rate increases. Detailed analysis has revealed an array of factors driving down indoor demand, including voluntary ENERGY STAR and WaterSMART standards for appliances and fixtures, and state-enacted mandatory efficiency standards. Outdoor demand has also dropped, reflecting the declining appeal of turf and backyard pools and a growing interest in sustainability. In rapidly growing areas, average residential water demand has been reduced by the addition of new, highly water-efficient homes to the housing stock. Shifting household demographics also are impacting demand, in complex ways. Water demand is no longer tightly tied to population, economic output, or quality of life, and the downward trends are expected to continue through the end of the decade and beyond.

Bio: Gary Woodard has addressed water resources issues as both an academic and a consultant for over 30 years. At the University of Arizona, he has brought a wide array of analytical skills to bear on a range of water policy issues. Gary has won several awards for creative outreach efforts, including a degree program for mid-career water professionals and citizen science programs. He also has chaired a water district, served as an elected official, founded a water conservation alliance, and served as president of the Universities Council on Water Resources. Woodard's work with two UNESCO water centers and the Army Corps has taken him to arid lands across the Middle East, North Africa and South America. He also helped draft Saudi Arabia's new National Water Act. As a senior water policy and economics consultant with Montgomery & Associates, he models water demand, evaluates utility assets, forecasts trends, and assesses conservation programs.

Assessing the risk of cryptosporidiosis in alternative potable reuse frameworks in Las Vegas

Erfaneh Amoueyan, University of Nevada, Las Vegas
(co-author: D. Gerrity)

The need for safe and accessible drinking water is a major concern worldwide. In the United States, the Environmental Protection Agency reports that water scarcity is a critical concern in nearly every state. Historic declines in water levels highlight the need for water supply augmentation, potentially through the implementation of water reuse. For example, Lake Mead, which has dropped more than 100 feet in recent years and is now at its lowest level in history, is the primary water supply for Southern Nevada. Las Vegas currently returns treated wastewater to Lake Mead in order to earn return flow credits, but other potable reuse alternatives have been proposed to reduce the cost and energy associated with this strategy. This study compares the risk of waterborne disease for the 'return flow' model against several alternative potable reuse paradigms, including direct potable reuse. The comparison was developed using a quantitative microbial risk assessment (QMRA) approach with Cryptosporidium as the target pathogen. The 'static' risk of cryptosporidiosis was estimated using Monte Carlo simulations for each alternative. The potential use of dynamic disease transmission models is also described.

Bio: Erfaneh Amoueyan earned her B.S.E. and M.S.E. in Civil & Environmental Engineering in Iran. She is now pursuing her Ph.D. degree in Civil & Environmental Engineering at University of Nevada Las Vegas. She is a graduate Assistant in the Department of Civil and Environmental Engineering and Construction at the University of Nevada Las Vegas. Her research interests focus on potable water reuse.

The influence of crystal sedimentation speed on phosphorus recovery with struvite precipitation

Mayara Aquino, Federal University of Rio Grande do Norte and University of Nevada, Las Vegas
(co-author: H. Rodrigues do Santos)

Eutrophication of drinking water reservoirs occurs due to the increase of nutrients concentrations (phosphorus and nitrogen) that typically originate from anthropogenic sources, including agricultural activities and domestic and industrial wastewater. The removal of phosphorus and nitrogen during wastewater treatment is one of the main strategies for controlling eutrophication. Specifically, the removal of phosphorus with struvite precipitation ($MgNH_4PO_4.6H_2O$) is a promising alternative because it can simultaneously recover nitrogen and phosphorus in equal molar ratios, which is important for reusing this recovered material as a fertilizer. The objective of this research was to study the influence of crystal sedimentation velocity on phosphorus recovery with struvite precipitation, aiming to obtain parameters for projects of less expensive reactors for the struvite precipitation. The velocity of sedimentation had little influence on the phosphorus removal efficiency, however contributed for the decrease of turbidity in the synthetic wastewater. It was verified an efficiency difference of 3% to 5% only between the sedimentation velocities studied. Therefore, it is not necessary the application of lower velocities on full-scale reactors. Keywords: struvite precipitation, sedimentation velocity of crystals, phosphorus recovery.

Bio: Mayara Aquino is an Environmental Engineering Student at the Federal University of Rio Grande do Norte in Brazil with partial studies at University of Las Vegas, Nevada (one year). She is currently an intern at Trussell Technologies in Pasadena, CA. During her studies at UNLV, she had the opportunity to study the metal influence in fluorescence in partnership with Dr. Daniel Gerrity.

Estrogen sulfate in soil-water systems: Is it a potential source of free estrogens?

Xuelian Bai, Desert Research Institute
(co-authors: F.X.M. Casey, H. Hakk)

Naturally occurring estrogens are known as the most potent endocrine disrupting chemicals in the environment. A sulfate conjugated estrogen, 17β-estradiol-17-sulfate (E2-17S) was hypothesized to be a precursor to free estrogens in agricultural soils. The sorption, degradation, and persistence of 14C labelled E2-17S were then delineated in various soil-water systems. The experimental results showed that soil organic carbon played a significant role in the dissipation of E2-17S from the aqueous phase. The non-linear sorption isotherms indicated limited sorption of E2-17S with moderate sorption affinities compared to other estrogen conjugates and its free counterpart. Additionally, E2-17S underwent multiple transformation pathways to release mono- and di-hydroxy-E2-17S in the aqueous phase, and free estrogens (i.e. 17β-estradiol and estrone) on the solid phase. The occurrence of hydroxylation and deconjugation under both non-sterile and sterile conditions gave evidence that abiotic processes may play a role. The conceived comprehensive model demonstrated that deconjugation of E2-17S is a minor pathway compared to hydroxylation with much lower transformation rates. In conclusion, E2-17S could be a precursor of free estrogens; however, it is not a major contributor to the total estrogen load in the environment.

Bio: Xuelian Bai, Division of Hydrologic Sciences, Desert Research Institute, Las Vegas, Nevada; Francis X.M. Casey, Dept. of Soil Science, North Dakota State University, Fargo, North Dakota; Heldur Hakk, Biosciences Research Laboratory, USDA-ARS, Fargo, North Dakota.

Rewetting of artificially desiccated soils: Effect of gravity on vapor-phase diffusion

Taylor Ball, University of Nevada, Las Vegas
(co-author: M. Nicholl)

Soil desiccation has been proposed as a means of stabilizing soluble contaminants in deep vadose zones, such as that found at Hanford, Washington. A concern with this approach is that subsequent re-wetting of the desiccated zone could remobilize the contaminants. Two processes that could lead to rewetting are vapor-phase diffusion and density-driven advection of humid air from beneath the desiccated zone. For both processes, the rising humid air is expected to adsorb onto the dry soil particles, thus rewetting them. A simple theoretical analysis suggests that in the absence of adsorption, density-driven advection is of comparable magnitude to vapor-phase diffusion. Simultaneous column experiments were used to compare the relative importance of vapor-phase diffusion and density-driven advection. One column filled with initially dry porous media was placed directly above a reservoir held at 100% relative humidity, while an identical column was placed directly beneath the reservoir. Advancement of humid air through the two columns was tracked with humidity sensors placed at regular intervals. Experiments in a variety of materials all show that vapor progresses upwards at a faster rate than downwards due to the contribution of density-driven advection.

Bio: Taylor Ball is a MS Candidate from the University of Nevada, Las Vegas Department of Geoscience. He graduated with his BS in Geology from Brigham Young University. His research focuses on vapor movement in the vadose zone. He enjoys spending time with his wife and 2 kids as well as the outdoors.

Impacts of future changes on low flow in a highly connected river-aquifer system: A case study of the Spokane River and the Spokane Valley-Rathdrum Prairie Aquifer

Heather Baxter, Washington State University
(co-authors: T. Nguyen, J. Adam, M. Barik, M. Barber, A. Hossain)

The Spokane, Washington-Coeur d'Alene, Idaho Corridor contains the Spokane Valley-Rathdrum Prairie (SVRP) Aquifer, which is a sole source of drinking water for more than 500,000 people. This aquifer is highly connected to the Spokane River, making the river relatively vulnerable to climate and anthropogenic changes such as pumping. Recent studies have found a decline in minimum daily flow in the Spokane River in the last 100 years, raising concern for the sustainability of human and ecosystem water usages in the next decades. In this research, we investigated the potential impacts of future changes in both climate and human activities on low flows in the Spokane River – SVRP system. A distributed, physically-based hydrological model, the Precipitation Runoff Modeling System (PRMS), and a Modular three-dimensional finite-difference ground-water model (MODFLOW) were used to estimate recharge into the SVRP and the interaction of surface water and groundwater. The model was calibrated and validated at a daily time-step using 16 years of both observed streamflow and observed well data from 1990 to 2005. To assess future climate change impacts, statistically down-scaled climate projections of temperature and precipitation between 2010 and 2050 from four general circulation models were used. The results from the coupled model provide insight on the interplay between climate and human activities on groundwater recharge and low flow discharge in the highly connected Spokane River – SVRP Aquifer system. Results can be used to help direct long term water resources management and planning in the region.

Bio: Heather A. Baxter, EIT, is pursuing a Masters of Science in Civil and Environmental Engineering at Washington State University . Research experience includes WISDM (Watershed Integrated Systems Dynamics Modeling) and hydrologic model development and application using MODFLOW, PRMS, and VIC.

Incorporating oceanic-atmospheric climate variability to improve the reconstructions of Sacramento and San Joaquin rivers

Saria Bukhary, University of Nevada, Las Vegas
(co-authors: A. Kalra, S. Ahmad)

Streamflow reconstruction is an important tool to understand the long term hydroclimatic changes of a region. It helps in identifying the floods and drought, their frequency, duration and intensity. Conventionally tree ring chronologies (TRC) are used for streamflow reconstruction. Studies have shown that oceanic-atmospheric climate variables of southern oscillation index (SOI), pacific decadal oscillation (PDO), and Pacific Ocean sea surface temperature (SST) affect the volume of streamflow in continental United States. This study proposes to improve the existing streamflow reconstruction methodology by incorporating the oceanic-atmospheric variables of SOI, PDO, and Pacific Ocean SST as predictors together with TRC in a stepwise linear regression analysis. Singular value decomposition was used to select Pacific Ocean SST sectors that show strong linkages with streamflow stations. The study area chosen was Sacramento and San Joaquin basin in southwestern United States, with a history of recurring droughts. Successful reconstructions were performed starting 1800-1980, with an observed period of 1932-1980 for five unimpaired streamflow gages in Sacramento basin and six unimpaired streamflow gages in San Joaquin basin. Among the pool of predictors, Pacific Ocean SST in combination with TRC showed better results for both Sacramento basin (calibration r^2= 0.72-0.77) and San Joaquin basin (calibration r^2= 0.6-0.91), compared to SOI, PDO and TRC. This work will help water managers with better estimation of drought likelihood. For future work, the methodology presented here can be applied to other watersheds by incorporating the appropriate climate drivers for the region.

Bio: Miss Saria Bukhary has a M.S. in Civil Engineering from University of Reno Nevada. She is currently pursuing her graduate studies for doctorate degree in Civil and Environmental Engineering and also working as a Research Assistant at University of Nevada Las Vegas. Her current research focuses on hydrologic reconstructions and using climate information to improve hydrologic predictions. She started her professional career as a Lecturer and then an Assistant Professor in NED University of Engineering and Technology, Pakistan.

Detection of Antibiotic Resistant Bacteria (ARB) in the Gallinas River

Laurel Carr, New Mexico Highlands University

Five sites from the headwaters to the lower Gallinas River, representing varying levels of bacteria sources and potential differences in antibiotic resistance are identified for this study. Site 1: above the Santa Fe National Forest boundary (minimal to no human influence); Site 2: downstream before the City of Las Vegas (agricultural influence); Site 3: water from water treatment plant (WTP); Site 4: above the waste water treatment plant (WWTP); and Site 5: downstream from the WWTP (reentrance into the Gallinas River). Standard filtration methods will be utilized for culture of water for gram negative bacteria. Pure cultures will be validated on a combination of differential media such as Eosin-Methylene Blue (EMB) agar. Growth characteristics of *E. coli* via EMB plate method provide a highly probable identification of *E. coli*. Antibiotic resistance of twelve (12) commonly prescribed human and animal antibiotics will be tested using the Kirby-Bauer method. I anticipate the presence of antibiotic resistant bacteria will be greater in number the further downstream the Gallinas River (human and agricultural influence) in addition to the number of multi-drug resistant bacteria.

Process-based modeling for a snow dominant watershed

Chao Chen, University of Nevada, Las Vegas
(co-authors: L. Fenstermaker, H. Stephen, S. Ahmad, Y. Gao)

Hydrologic processes in mountainous area are susceptible to the meteorological influence and geographical variation, particularly in snow dominated area. In this study, the snowmelt-dominated hydrology in Lehman Creek watershed, in eastern Nevada, was studied. As an alpine watershed, Lehman Creek is characterized with low infiltration rates by impervious quartzite and granite resulting in high snowmelt runoff. In order to evaluate future impact of global climate change, a robust model is required which could capture the characteristics of the snowmelt-dominated hydrology and reproduce the physical processes of hydrology in the study area. The Precipitation Runoff Modeling System (PRMS) - a physical process based, parameter distributed model-was applied. Daily streamflow, precipitation, temperature, and solar radiation data were collected from one USGS streamflow gaging station and four meteorological stations from 1947-2012. Using the observed data, model calibration and validation were performed on main hydrologic components- solar radiation, potential evapotranspiration and water balance under annual, monthly and daily scale. The results showed, with low winter flow and peak summer flow, the simulated streamflow successfully captured the features of the snow-dominated area by an accurate reflection of the shape and magnitude of runoff at Lehman Creek. Model calibration and validation showed adequate accuracy with less than 13% of errors in simulated streamflow except in 2011, due to the miss measurement of bypasses under high runoff generation. Model sensitivity analysis showed temperature is a critical factor and that an increasing proportion of rainfall in precipitation resulted in a change in pattern of winter and spring streamflow. The results showed a successful PRMS model application in a snow-dominated area, which can be used to estimate future streamflow in Lehman Creek in response to climate change. The model is also used to estimate contribution of Lehman Creek to the groundwater recharge in the Snake Valley.

Bio: Chao Chen has a B.S. in Water Conservancy and Hydropower Engineering from Zhejiang University of Technology, and a M.S. in Hydrology and Water Resources from Hohai University in China. Currently, she is pursuing her graduate studies for Ph.D in Civil & Environmental Engineering and also working as a research assistant at University of Nevada, Las Vegas. Miss Chen worked for China Institution of Water Resources and Hydropower Research, and assisted in water resources planning and allocation. She then worked for an Engineering Company, where she was responsible for county flood evacuation planning. Now, her main study area focuses on using distributed hydrologic models to evaluate climate change's impact on the water resource.

Collaborative tribal adaptation and resiliency to climate variability and change: Pyramid Lake Paiute Tribe

Karletta Chief, University of Arizona
(co-authors: A. Serrat-Capdevila, E.S. Chew, B. Wadsworth, K. Morgan, B. Harry)

Native American tribes throughout the Southwest are vulnerable to climate change due to intimate relationships with the environments upon which their cultures, traditions, and livelihoods depend. The Pyramid Lake Paiute Tribe in Nevada is deeply connected physically, culturally, and spiritually to Pyramid Lake, the endangered cui-ui fish (*Chasmistes cujus*), and threatened Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*). This collaborative research effort addresses the need for climate change adaptation research in the Great Basin which incorporates tribal perspectives. The objectives are to 1) determine potential for climate change adaption by understanding vulnerabilities, thresholds, and resiliencies; 2) propose collaborative tribal water management and adaptive strategies, and 3) produce a framework to support decision-making. Preliminary socio-economic data and analysis reveal that tribal vulnerability to climate change is related to cultural and economic dependence on Pyramid Lake, while external socio-economic vulnerability factors influence adaptive capacity and amplify potential impacts. Reduced water supplies as a consequence of climate change would result in a compounded reduction of inflows to Pyramid Lake, thus potentially impacting the spawning and sustenance of a cultural livelihood, endangered cui-ui. Factors that contribute to tribal adaptive capacity include sustainability-based values, technical capacity for natural resource management, proactive initiatives for control of invasive-species, strong external scientific networks, and remarkable tribal awareness of climate change. A basic mass-balance hydrologic model was developed for Pyramid Lake in order to create hypothetical projections of lake elevation under various climate change scenarios which may help to inform adaptive management planning for the Tribe. This research is funded by Department of Interior Southwest Climate Science Center.

Bio: Dr. Karletta Chief is an Assistant Professor and Assistant Specialist in the Department of Soil, Water, and Environmental Sciences at the University of Arizona. As an assistant professor, the goal of her research is to improve our understanding, tools, and predictions of watershed hydrology, unsaturated flow in arid environments, and how natural and human disturbances affect soil hydrology through the use of physically based methods. Dr. Chief research also focuses on how indigenous communities will be affected by climate change and collaborates in an interdisciplinary fashion with hydrologists and social scientists to determine how hydrological tools can be improved to identify and mitigate risks to these vulnerable populations. As an extension specialist, she works to bring relevant science to Native American communities in a culturally sensitive manner by providing hydrology expertise, transferring knowledge, assessing information needs, and developing applied science projects. Dr. Chief (Navajo) received a B.S. and M.S. in Civil and Environmental Engineering from Stanford University in 1998 and 2000. As a National Science Foundation Doctoral Fellow, Dr. Chief received her Ph.D. in Hydrology and Water Resources in the School of Engineering at the University of Arizona (UA) in 2007. She completed her post-doctorate at Desert Research Institute in Las Vegas, NV.

Regional geologic influence on the hydrogeochemistry of Santa Monica Mountains Watershed

Geza I. Demeter, California State University, Los Angeles
(co-author: B.J. Hibbs)

Extended Abstract

Shallow groundwater collected in Santa Monica Mountain Watersheds of Southern California varies in quality depending on the geologic strata the groundwater originates from. Our studies show that shallow groundwater samples collected from fine textured aquifer material formed in sedimentary marine environments tend to have the highest total dissolved solid concentrations, relative to groundwater collected in geologic strata composed primarily of lower solubility igneous rocks and sandstones. In this study, 26 groundwater samples were collected throughout the study area from groundwater springs and seeps that contribute to local perennial streams. Field index parameters (conductivity, pH, salinity, dissolved oxygen, and temperature) were obtained during sample collection, with split samples submitted to a laboratory for analysis of major ions, selenium and arsenic. Groundwater samples were also tested for hydrogen and oxygen stable isotopes to help determine the origin of the shallow groundwaters in the area. Chemical analysis show that groundwater samples collected from fine textured aquifers of sedimentary marine origins have high TDS (1,500 to 3,500 mg/L), including high chloride (250 to 500 mg/L Cl-), and very high sulfate (1,000 to 2,500 mg/L SO_4^{2-}) concentrations. Most notably, the more saline groundwater samples collected from the marine sedimentary formations were influenced by gypsum layers and calcite cements that had formed as secondary mineral precipitation products. Spatial mapping shows the highest concentrations of selenium from groundwater samples originate from one of these sedimentary marine rocks, the Miocene Monterey and Modelo Formations. Isotopic analysis of all of the samples reveals that groundwater contains the signature of mixed imported and local waters with local waters usually being more dominant (approximately >75%). Both local and imported waters have a slightly evaporative isotopic signature, synonymous with infiltrated water that had been subjected to some evaporation prior to recharge. Imported water is apparently recharging shallow aquifers in the study area, probably as a result of leakage from water pipes, sewer pipes, and urban storm drains.

Introduction

The research area is located approximately 33 miles west-northwest of the City of Los Angeles and is within a portion of Los Angeles and Ventura Counties (Figure 1). In addition, the research area encompasses the Malibu Creek Watershed (MCW) and portions of the Calleguas Creek Watershed (CCW) and Coastal Watershed (CW). The MCW encompasses approximately 109 square miles and is the second largest watershed that drains into Santa Monica Bay and includes Malibu Creek and its five tributaries: Stokes Creek; Las Virgenes Creek; Cheeseboro/Palo Comado Creek; Madea Creek, and; Lindero Creek (McCoy et. al, 2006). CCW encompasses approximately 341 square miles and is entirely within Ventura County. It drains into the Pacific Ocean near Point Magu, which seven tributaries that drain into Calleguas Creek: Arroyo Las Posas; Arroyo Simi; Conejo Creek; Arroyo Santa Rosa; Arroyo Conejo; Revolon Slough, and; Beardsley Wash. The CW is located in the southern windward side of the Santa Monica Mountain. Most of the Santa Monica Mountains and surrounding hills within the research area is composed of Tertiary-aged igneous and sedimentary rock, with the exception of the Cretaceous-aged Chatsworth Formation, which outcrops near the ridgeline of the Simi Hills (Table 1).

Groundwater in the research area occurs both in alluvial sediments within stream channels and local valleys, and within fractured and weathered bedrock. Groundwater is encountered between approximately 5 and 40 feet below ground surface. This groundwater is a source for many local perennial creeks and streams in the study area. Groundwater is made available to these creeks and streams by ways of springs, seeps, and weep holes.

Methods

A total of 26 groundwater samples were collected from various seeps and springs within the research area (Figure 2). These streams and creeks include Arroyo Conejo Creek, Arroyo Sequit, Cheeseboro/Palo Comado Creek, Cold Creek, Lang Creek, Las Virgenes Creek, Lindero Canyon Creek, Medea Creek, Pavement Creek, and Solstice Canyon Creek. Groundwater sample locations were chosen on the premise that they are easily accessible and would best represent the geologic formations within the research area. Samples were collected in clean, unused high-density polyethylene (HDPE) bottles by either grab method or by using a peristaltic pump. Each sample was immediately labeled and placed in a cooler filled with ice. Water quality field parameters such as pH, salinity, temperature (°C), dissolved oxygen (DO), and conductivity were collected using a YSI multi-parameter water quality meter, and a YSI DO meter. Groundwater samples submitted for cation analysis were filtered using a 0.45 micrometer (μm) filter.

Split groundwater samples were submitted to a California State-approved laboratory for analysis of major ions, including sodium, potassium, calcium, magnesium, nitrate, orthophosphate, sulfate, bicarbonate, chloride, fluoride, and bromide. Groundwater samples were also analyzed for alkalinity, arsenic, and selenium. The laboratory used the United States Environmental Protection Agency (EPA) Method 6010B and 6020 for cation and metals analysis, EPA Method 300.0 for anion analysis, and Standard Method (SM) 2320B for alkalinity. In addition, groundwater samples were submitted for isotopic analysis for oxygen and hydrogen isotopes. The results of each analysis were used to compare water quality data based on the geologic environment where the sample was collected.

Table 1. Geologic units in Upper Malibu Creek Watershed (modified from Hibbs et al, 2015, Dibblee, 1992).

Location in Watershed	Geologic Time	Formation	Description
Stream channel	Pleistocene/ Holocene	Superficial and Older Superficial Sediments	unconsolidated alluvium; poorly bedded, poorly sorted to sorted sand, gravel, silt, and clay with some cobbles and boulders
Upper (northern) section	Miocene	Lindero Canyon Formation	massive to crudely bedded sandstone, semi-friable, some areas with calcite veins
	Cretaceous	Chatsworth Formation	clay shales and arkosic sandstones
Middle section	Miocene	Monterey Formation	brittle, silicious, white, punky, diatomaceous shales; oil bearing
Lower (southern) section	Miocene	Conejo Volcanics	extrusive volcanic rocks, andesitic breccia, basaltic flows
	Miocene	Upper Topanga Formation	thin sandstone, clay shale and siltstone

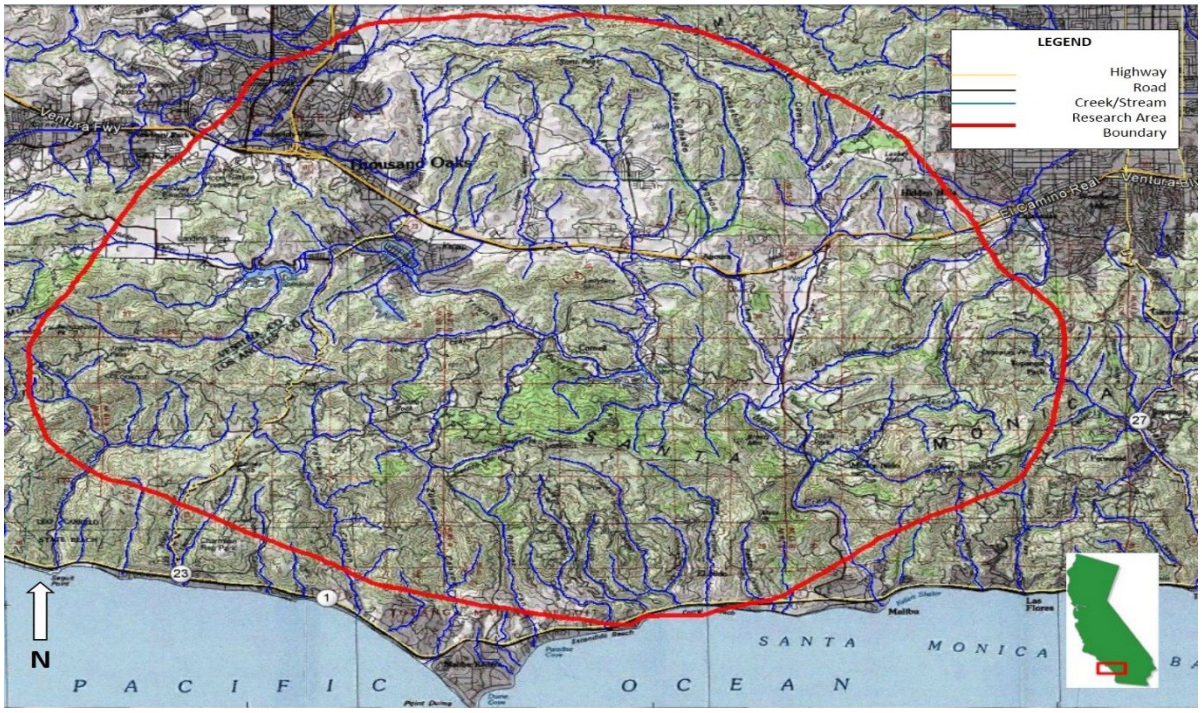

Figure 1. Research Area Location Map (modified from USGS, 1979).

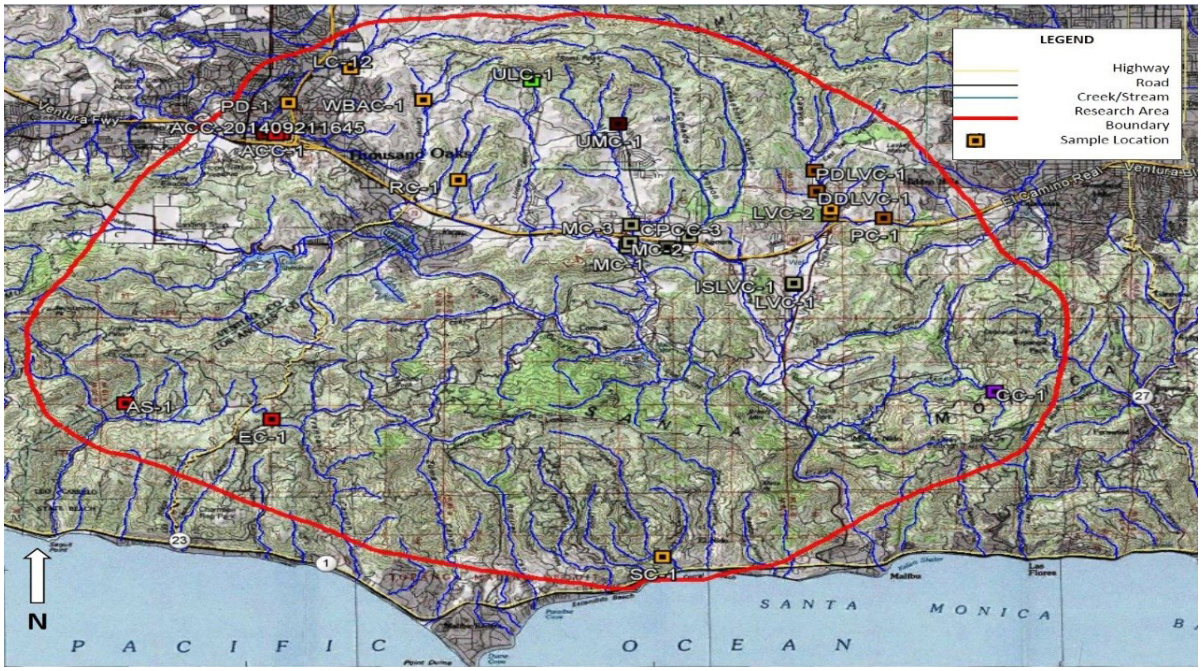

Figure 2. Site Map with Sample Locations (modified from USGS, 1979).

Results

Groundwater samples collected where base flow drains from sedimentary rocks contain relatively high specific conductance, with an average specific conductance of 3,400 micro Siemens per centimeter (µS/cm), indicative of relatively saline base flow, particularly in sedimentary rocks with marine origins (Monterey, Modelo, Upper and Lower Topanga, Lindero Canyon, and Chatsworth Formations). Lower specific conductance was identified were groundwater base flow drained from igneous rocks (Conejo Volcanics Formation), with an average specific conductance of 1,407 µS/cm, indicative of slightly saline waters due to less available soluble minerals in volcanic strata and weathered residuals. When specific conductance is compared to sulfate values, groundwater is separated based on the geologic material the water was in contact with (Figure 3). Specific conductance of groundwater originating from sedimentary marine strata is more dependent on sulfate values than groundwater originating from igneous strata. Average sulfate concentrations for groundwater originating in marine sedimentary strata within the study area is 1,383 milligrams per liter (mg/L), versus sulfate concentrations of 262 mg/L for groundwater originating in igneous strata. Average chloride and selenium concentrations for groundwater originating in marine sedimentary strata within the study area are 247 mg/L and 20 micrograms per liter (µg/L), respectively, versus chloride and selenium concentrations of 115 mg/L and 5 µg/L respectively, for groundwater originating in igneous strata.

Isotopic analysis of the groundwater samples collected in the study area show a mixture of both local and imported water. However, local waters appear to be more dominant than imported waters. In addition, $\delta^{18}O$ values appear to vary, depending on where the sample was collected. Groundwater samples collected closer to the ocean have an isotopic signature that is indicative of heavier water, i.e. a higher concentration of $\delta^{18}O$ than samples collected more inland (Figure 4).

Discussion and Conclusion

Results of this study show that groundwater base flow originating from marine sedimentary strata have high specific conductance and sulfate concentrations, including high chloride and selenium concentrations. Specific conductance and sulfate concentrations are particularly high from groundwater collected in sedimentary strata with an abundance of secondary precipitate minerals, such as calcite and gypsum, as evident from samples collected within the Monterey, Modelo, and Upper Topanga Formations, with the highest concentrations detected in groundwater samples collected from the Upper Topanga Formation (Figure 3). Secondary gypsum and calcite minerals have been suggested to have originated from the oxidation of pyrite, originally formed during the initial deposition of the formation sediments (Hibbs, 2014). In addition, high concentrations of chloride and selenium appear to have high concentrations from groundwater samples collected in the Monterey, Modelo, and Upper Topanga Formations, with the highest concentration of chloride and selenium detected in groundwater samples collected from the Modelo Formation. The origin of dissolved selenium

concentrations has been suggested to be the result from the oxidation of pyrite minerals (Hibbs, 2014). The origins of chloride concentrations are unknown at this time. Sulfate and total dissolved solids in groundwater originating from igneous strata are much lower due to the availability of soluble minerals.

Isotopic analysis of the groundwater samples indicate that the signature of the groundwater samples are representative of both local and imported water, with the local waters being slightly more dominant at approximately 75%. Both local and imported waters have a slightly evaporative isotopic signature, synonymous with infiltrated water that had been subjected to some evaporation prior to recharge. It is evident that imported water is recharging shallow aquifers in the study area, probably as a result of leakage from water pipes, sewer pipes, and urban storm drains. In addition, groundwater samples collected closer to the Pacific Ocean, as those samples collected on the windward side of the Santa Monica Mountains, appear to have a slightly heavier isotopic signature than samples collected further inland, such as the samples collected within the Simi Hills (Figure 4). This suggests that the Santa Monica Mountains are producing a local orogenic effect on precipitation originating from the Pacific Ocean (Hibbs, 2014). The local orogenic effect causes the heavier $\delta^{18}O$ isotope precipitation to fall first over the Santa Monica Mountains, while precipitation with lesser amounts of $\delta^{18}O$ isotopes to fall out near the Simi Hills (Figure 5).

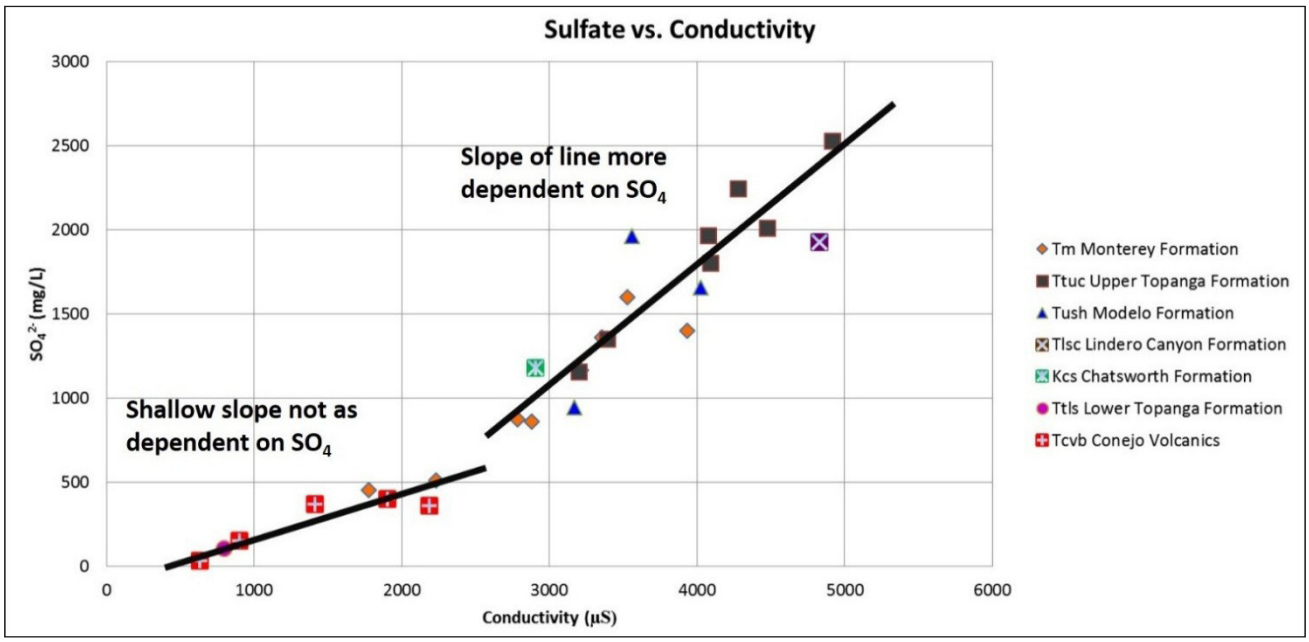

Figure 3. Sulfate values versus Conductivity values.

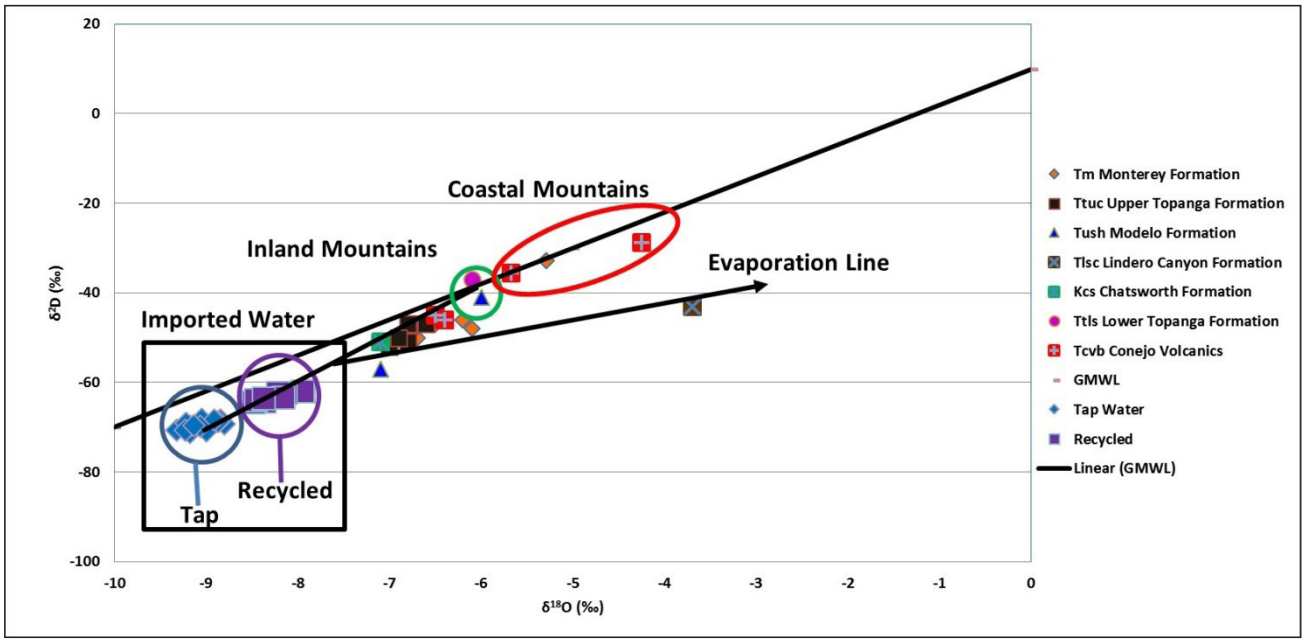

Figure 4. Graph showing mixing line of isotopes and origin of groundwater samples.

This research project would benefit from additional studies regarding the influence of seasonal groundwater fluctuations and evapotranspiration data from local flora and shallow groundwater conditions. The study would also benefit from additional groundwater sample from igneous and sedimentary sources that are located in undeveloped areas, which would least likely be influenced by imported water.

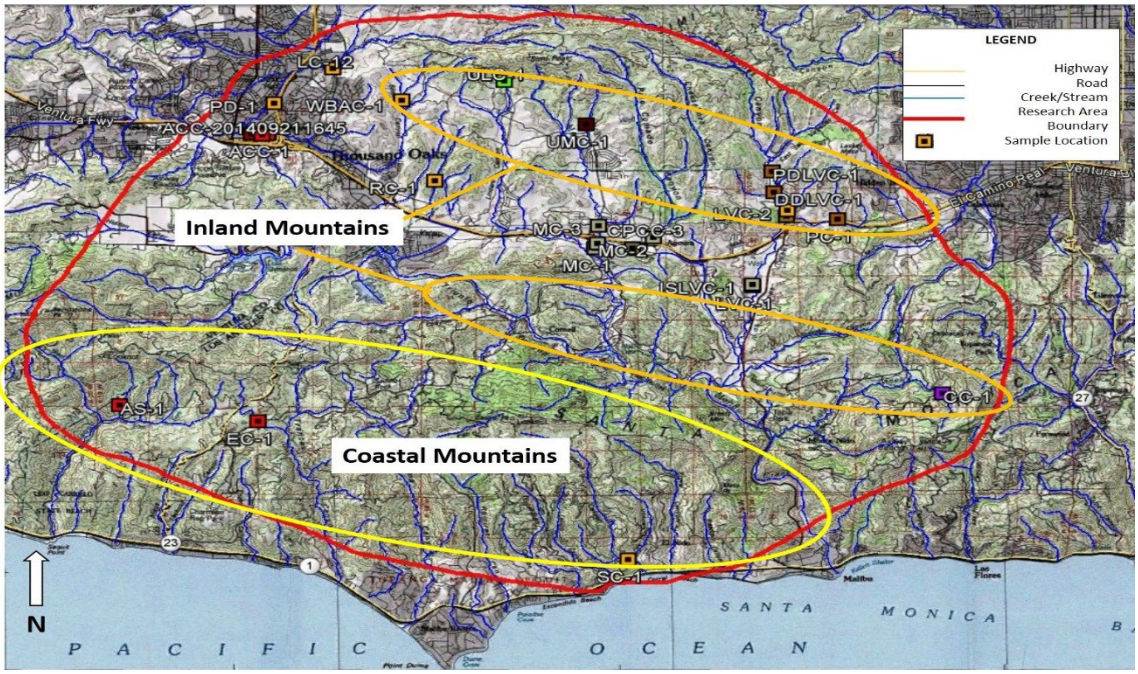

Figure 5. Map showing isotope orogenic effect of precipitation in the Santa Monica Mountains (modified from USGS, 1979).

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Bio: Geza Demeter graduated from San Francisco State University with a Bachelor's of Science degree in Geology in 2006. Since then, she has been working as an environmental geologist for approximately 8 years in the environmental consulting industry, with the last four years as a registered professional geologist with the State of California. Since the Fall of 2012, she has been working towards her Masters degree in hydrogeology at the California State University, Los Angeles.

Assessing the impacts of concentrated flow paths on crop yield and horizon depth in southern Illinois agricultural fields

Matt Enger, Southern Illinois University
(co-authors: J.E. Schoonover, K.W.J. Williard, R. Cook)

Sediment loss from agricultural landscapes is a key contributor to water quality impairment and has the potential to impact crop yield. Riparian buffers and grassed waterways have proven to be effective best management practices (BMPs) to protect water quality and minimize soil loss. However, concentrated flow paths (CFPs) are often overlooked and can limit the effectiveness of BMPs. Conventional management of CFPs is to fill and grade them; however, this provides a short term solution leading to their reformation. The objectives of this study are to assess the impacts that CFPs have on soil properties, horizon depth (A-horizon), and crop yield within six small agricultural catchments. Catchments and CFPs were delineated using ArcGIS and LiDAR data from the Illinois State Geological Survey (ISGS). Following the 2014 harvest, three of the six CFPs within each catchment were filled with soil from the site and graded (treatment). Depth of A-horizon and penetration resistance were recorded along fixed transects perpendicular to CFPs prior to 2015 crop and will be repeated following the 2015 harvest. Water quality will also be assessed via automated samples across all treatments during major rain events (i.e., precipitation exceeding 2.5 cm). Soil fertility and crop yield will be analyzed within each catchment to develop a fertility map in relation to CFPs. We anticipate that the annual grading of CFPs increase sediment loss, impair water quality, and reduces crop yield. These data will provide farmers and land managers critical information for the management of CFPs.

Bio: Matt Enger is currently pursuing a M.S. degree in Forestry focusing on hydrology and soil science at Southern Illinois University, where he also earned a B.S. in 2014.

Bringing safe drinking water to Africa: A comparative study of water treatment technologies for communities within the Sahel

Nichole Francis, University of Nevada, Las Vegas

According to UNICEF, 1,800 children under the age of 5 die every day in the world from diarrheal diseases. Of these deaths, 90% could be prevented by having access to clean water and sanitation. Out of the 88 million people in the world without improved drinking water sources, Africa accounts for a third (WHO/UNICEF, 2010). In an effort to reduce deaths and illnesses due to the consumption of unsafe drinking water in the Sahel as well as provide a practicable alternative for safe drinking water while on the move due to climatic and societal conditions, I investigated drinking water technologies that are best suited for communities in Chad and Sudan located within this region. In order to do so, a comparative study was conducted on literature published on drinking water treatment techniques on the basis of treatment efficacy, capacity (volume/day), and viability. Multi-Criteria Analysis was then performed in order to make a final recommendation. Results indicate that chlorination is one of the most effective water treatment technologies for communities within Chad and Sudan with the highest score of 95%, when compared to technologies with e .coli, virus, reliability (quality/time), portability, power required, level of difficulty, suspended sold removal, maintenance required and flow rate data available. With the capability of removing over 99% of viruses and bacteria, its ease of use, no maintenance required, and portability of solution required for treatment, chlorination appears to be the most useful for the treatment of water within this region. Although found most effective, pretreatment is required for waters of high turbidity and further or alternative treatment is recommended for waters contaminated with nitrates, arsenic, or lead.

Bio: Nichole Francis is a graduate student at the University of Nevada, Las Vegas in the Water Resources Management Program, where she also obtained her Bachelor's Degree in Chemistry and Minor in Sociology. Her interests are developing African communities and improving their self sufficiency.

Role of thermal cycling on coupled heat and moisture transfer in shallow desert soils

Sara Gedo, University of Nevada, Las Vegas
(co-author: M. Nicholl)

In arid climates (< 250 mm yr^{-1}), solar controlled thermal cycles may be an important mechanism for near-surface moisture transfer. The lack of atmospheric water vapor in arid regions intensifies thermal fluctuations at both the diurnal and seasonal time scales. Dry soils exhibit a low thermal conductivity, which restricts the depth that is affected by fluctuations in soil air temperature. Diurnal warming at the land surface results in strong near-surface temperature gradients that are capable of inducing thermally driven expansion and contraction of the soil air as it warms and cools, resulting in a convective transport of water vapor in shallow desert soils (< 50 cm). It is expected that seasonal warming causes steeper thermal fluctuations and thus increase convection. The objective of this research is to better understand the affects of thermal cycling on the movement and distribution of moisture in shallow desert soils.

In this study, we will conduct small-scale (15-20 cm) experiments to explore the impact of thermal cycling on moisture distribution. Columns will be filled with homogeneous soils packed to a uniform bulk density and moisture content. Heat plates, placed on either end of the column will be used to induce a controlled temperature gradient. Chloride, a conservative tracer, will be added to help determine the phase of moisture movement (liquid vs. vapor). Once equilibrated, the column will be deconstructed and measured for moisture content, chloride concentration, and temperature profiles. Measurements will be used to interpret moisture flux for both vertical and horizontal conditions.

Bio: Sara Gedo received a B.S. in Geology from University of California, Riverside in 2012. For the past year, she has been a graduate student at UNLV working on a master's project in vadose zone hydrology. In addition, she is working part-time at the US Geological Survey as a hydrologic technician.

Assessing the Challenges and Limitations of Reclaiming Altered and Endangered Northern Prairie Streams

Philip J. Gerla, University of North Dakota

Wetlands and streams of the Midwest U.S. tallgrass and Northern Plains prairie have been altered thoroughly since the beginning of agricultural development approximately 150 years ago. Although restoring upland prairie is difficult, expensive, and time-consuming, prairie stream restoration presents even greater challenges. Changes in watershed land cover, water balance, channel morphology, and regional climate often create altered and potentially irreversible hydrological conditions that are complicated to assess. Targeted reconstruction along selected stream reaches, however, can often greatly enhance lotic and riparian ecosystem function and services. Three examples of prairie stream projects demonstrate a restoration continuum from moderate success to complete failure. These case studies, two from the Glacial Ridge National Wildlife Refuge in northwestern Minnesota and one from southeastern North Dakota's Sheyenne Grasslands, include 1) modification of a ditch system to resemble more closely a natural prairie stream environment, 2) integration of large agricultural surface-water drain within a glacial paleochannel, and 3) attempted mitigation of incision along an irreversibly degrading, out-of-control groundwater-dependent stream. The contrasting results of reclamation show the importance of looking beyond the channel. Understanding thoroughly the groundwater-surface water interaction, watershed conditions, and dynamic channel processes is essential in designing successful prairie stream reclamation and restoration.

Bio: Philip J. Gerla came to University of North Dakota in 1988 after working for two years for a groundwater - environmental consulting firm in Milwaukee, Wisconsin. He holds a PhD degree from University of Arizona, an MS from University of New Hampshire, and a BS from Oregon State University, all in geology. Phil teaches courses in hydrology and environmental geology at UND, with research interests in wetlands and groundwater - surface water interaction. From 2003 through 2013, Phil was employed part-time as a regional conservation hydrologist for The Nature Conservancy.

Cover crop and tillage impacts on nitrogen leaching from row crop agriculture in southern Illinois

Brooke Hagarty, Southern Illinois University

A major global challenge of our generation is to minimize the environmental impacts of increased agricultural production to supply a growing world population. Excess nitrate leaching from agricultural areas can have detrimental effects on aquatic ecosystem and human health. The objective of this research is to find effective methods to reduce nitrate leaching without reducing corn and soybean yields. Cover cropping systems have shown promise as a way to minimize nitrate leaching, but more research is needed to understand how cover crops coupled with tillage systems (conventional-till vs. no-till) influence nitrate losses. This project will examine four treatments: cover crop/no-till, no cover crop/no-till, cover crop/till, no cover crop/till. The crop rotations for year 1 will be cereal rye followed by soybean and no cover crop followed by soybean. The crop rotations for year 2 will be hairy vetch followed by corn, tillage radish and spring oat mix followed by corn, no cover crop followed by corn. Four tension lysimeters will be installed in early spring 2015 at a depth of 24 inches within each of the 12 treatment plots. Lysimeters will be measured every 2 weeks and following significant (>1 in) rain events, throughout the year to estimate nitrate leaching below the root zone. The mass water balance equation will be used to estimate the amount of water draining below the root zone. Soil nitrate-N concentrations will be coupled with drainage volumes to estimate nitrate-N loads exiting the rooting zone. Lastly, grain yield will also be measured to assess impacts of cover crops and tillage on corn and soybean production. More knowledge on practices that increase crop production while decreasing nitrate leaching will be useful to growers, industry, commodity groups, and the scientific community.

Bio: Brooke Hagarty is currently pursuing a M.S. degree in Forestry focusing on hydrology and soil science at Southern Illinois University, where she also earned a B.S. in 2014.

Isotopic and hydrochemical identification of source waters and pollutants in Malibu Creek Watershed, CA

Michael Harrison, California State University, Los Angeles
(co-author: B.J. Hibbs)

Extended Abstract

The Malibu Creek Watershed is located within Los Angeles and Ventura County (Figure 1). Malibu Creek Watershed covers 109 square miles and contains five main feeder streams (Stokes, Las Virgenes, Palo Camado, Medea, and Lindero Creek) that drain into the Santa Monica Bay at Malibu Lagoon (Owens 1998).

The Miocene Monterey-Modelo Group lies predominately within the upper-middle Malibu Creek Watershed and covers all of El Camino Real Creek (Figure 1). The Monterey-Modelo Group is described as oil bearing, brittle, white, siliceous, punky, and diatomaceous shale (Bramlette 1946). The Monterey-Modelo Group is commonly noted as one of California's most important petroleum resources enriched with various trace elements such as selenium (USGS 2002). The Monterey-Modelo Formation has also been noted for its contribution of high selenium, metals, phosphate, nitrogen, salinity, and heavy metal content in the Malibu Creek Watershed (LVMWD n.d.). It is interpreted that high phosphorus content in particular is due to groundwater leaching of the formation, but there is some doubt about phosphate and nitrogen being largely elevated from this geologic source (Hibbs 2014).

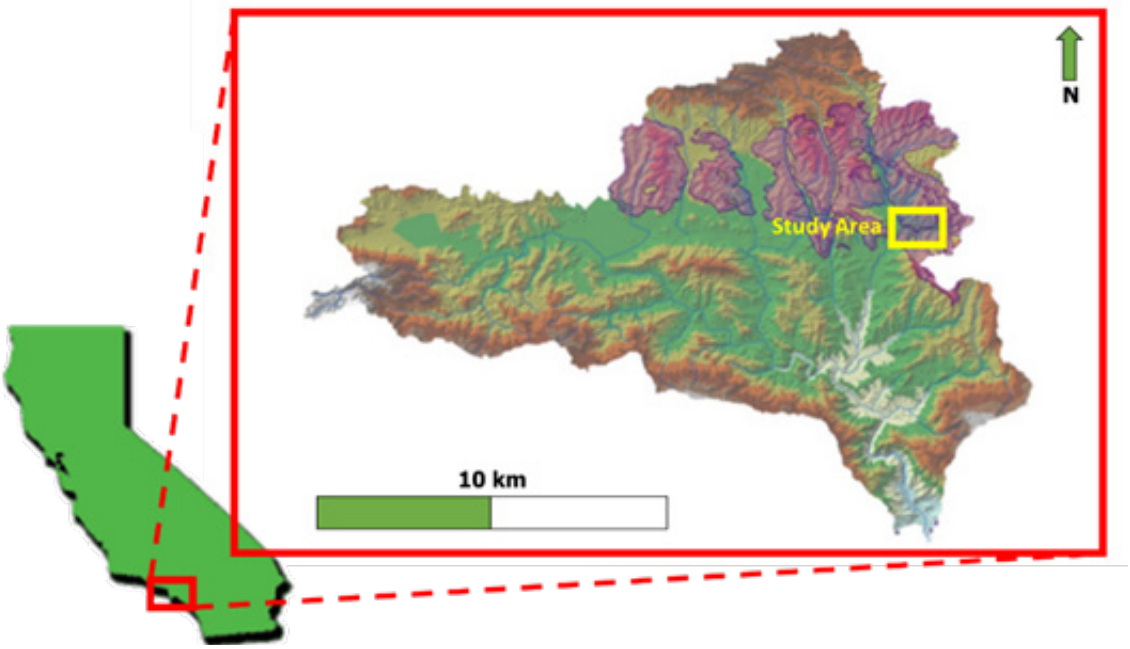

Figure 1. Location of the Malibu Creek Watershed and study area. The Monterey-Modelo Formation lies on the upper portion of the watershed and is shaded pink (modified from Las Virgenes Municipal Water District n.d.).

Due to the increase of development in the area, an increase of imported water (tap and recycled wastewater from tap water use) may be contributing to El Camino Real Creek, primarily from an urban storm drain at the head of the creek (Figure 1). Recent studies have illustrated that high phosphorus and nitrate content is also a result of dry weather runoff of recycled water that contributes an important percentage of these nutrients in nearby creeks (Hibbs 2014).

This study examines the hydrochemistry and source waters in El Camino Real Creek throughout a one year period (Figure 2). The investigation determines the source flow using stable water isotopes compared to hydrochemical parameters. Stable water isotopes determine if the source is from imported water or locally recharged water. The hydrochemical parameters examined include conductivity, sulfate, chloride, phosphate, and nitrate. This investigation considers the geology within and surrounding El Camino Real Creek and its effect on the local ground and surface water. This investigation also considers anthropogenic contributions to the creek which might include local runoff through drainages.

Methods

Several stations along El Camino Real Creek were sampled repeatedly in time. Samples were collected approximately every 6 weeks within a year period to understand the seasonal hydrochemical differences throughout the creek. Each station

was measured for temperature, conductivity, and dissolved oxygen on site. Collected samples were tested for stable water isotopes, chloride, sulfate, nitrate, and phosphate, and other water quality parameters.

Samples for hydrochemical data were collected as grab samples along designated stations in El Camino Real Creek. Stations were tested on site with a Hach water quality probe to measure pH, conductivity, salinity, and temperature.

Sulfate, chloride, phosphate and nitrate tests were conducted using standard wet lab methods with titration or/and spectrophotometer. Anion nutrients (phosphate and nitrate) can be the result of natural or anthropogenic sources. Phosphates are necessary for aquatic plants while nitrate is needed for animals and plants to synthesize amino acids (Vernier 2007). However excess phosphate and nitrate can result in excessive growth of algae and aquatic plants. Levels of phosphate in freshwater are typically less than 0.1 mg/L while levels of nitrate in freshwater are typically less than 1 mg/L. When levels are much higher, this might indicate an anthropogenic source. Sulfate and chloride are distinct in Monterey-Modelo sourced baseflows compared to imported water sources (tap water and recycled tap waters) and can be effective in discriminating between local and imported sources through mixing analysis (Hibbs 2014).

Stable water isotopes allow an estimation on the source water. The global meteoric line uses stable water isotopes to display signatures that represent the water source or its developmental process and is used to determine whether the water source is local or imported. Using hydrochemical mixing equations and anions as endmember mixing sources, scatter plots, and integration of stable isotopes, it was possible to determine the sources of nutrients and standard anions in surface flows. This was achieved by defining endmembers (pure imported and pure local) and finding out where waters plot in the mixing analysis. Several months of study have been completed to date and initial interpretations are presented in this paper.

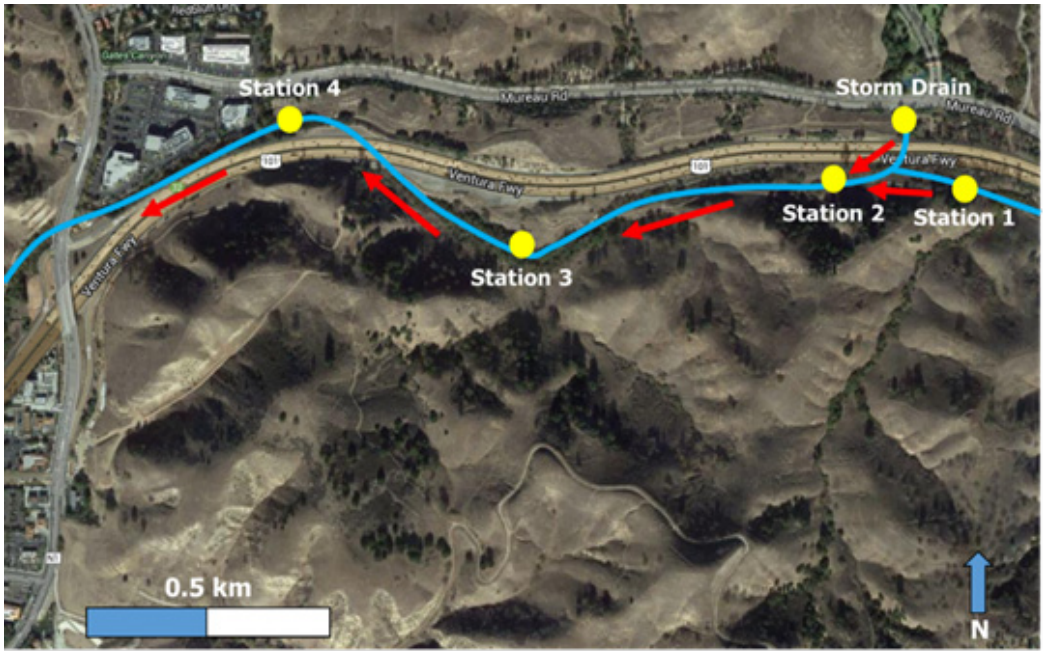

Figure 2. Satellite map of study area and sampling stations.

Results

The study results to date show a decrease in nitrate and phosphate concentrations downstream from the storm drain (Figure 3 and 4). From an initial input at the storm drain where dry weather flows consistently contain more than 1.5 mg/L NO_3-N and an average of 1.5 mg/L PO_4, values decrease to concentrations averaging 0.25 mg/L NO_3-N and 0.63 mg/L PO_4 where El Camino Real Creek converges with Las Virgenes Creek at its most downstream station. An additional source flow (station 1) developed during the winter season via an upstream tributary that began to flow into El Camino Real Creek (Figure 2). It hadn't flowed prior to January 2015 during this study. Station 1 flows have significantly low concentrations of PO_4 that are less than 0.075 mg/L and NO_3-N values less than 0.4 mg/L. Station 1 has the highest levels of conductivity throughout the creek with values greater than 4000 µS. Below station 1, conductivity increases from less than 2750 µS at the storm drain to over 3500 µS at the most downstream station (Figure 5).

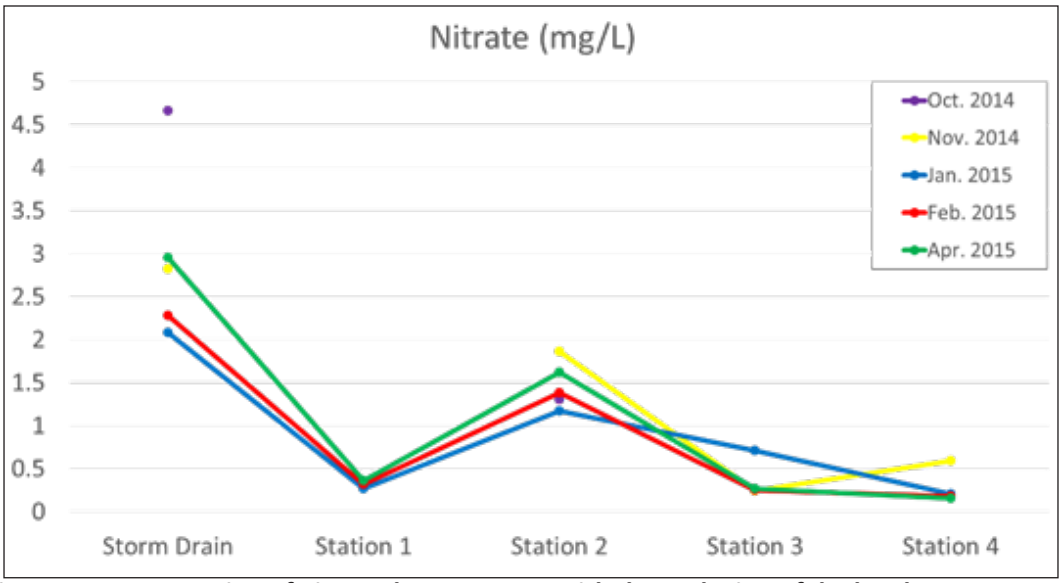

Figure 3. Concentration of nitrate downstream. With the exclusion of the local water source (Station 1) nitrate concentration generally decreases downstream from the storm drain.

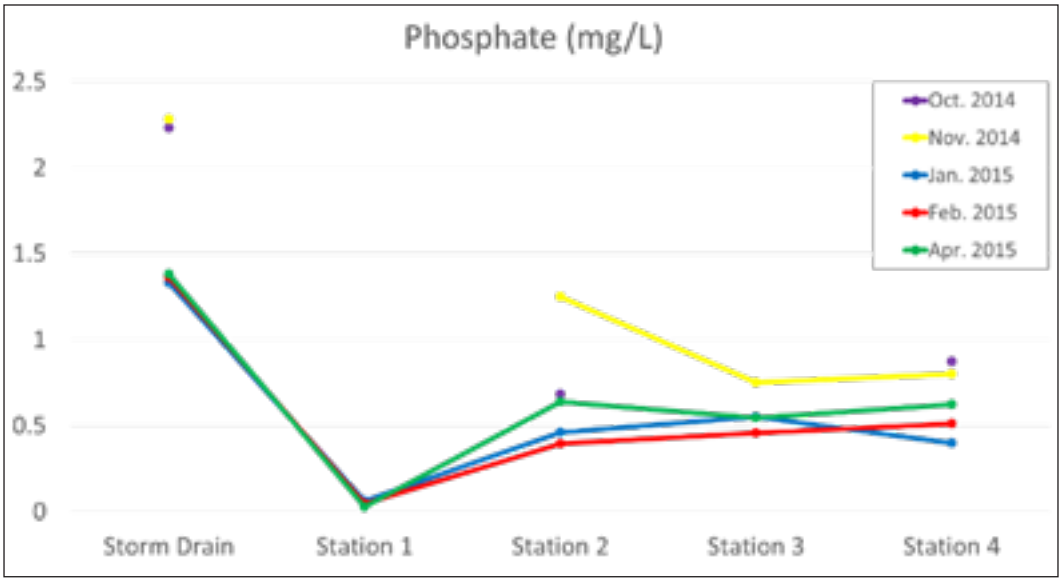

Figure 4. Concentration of phosphate downstream.

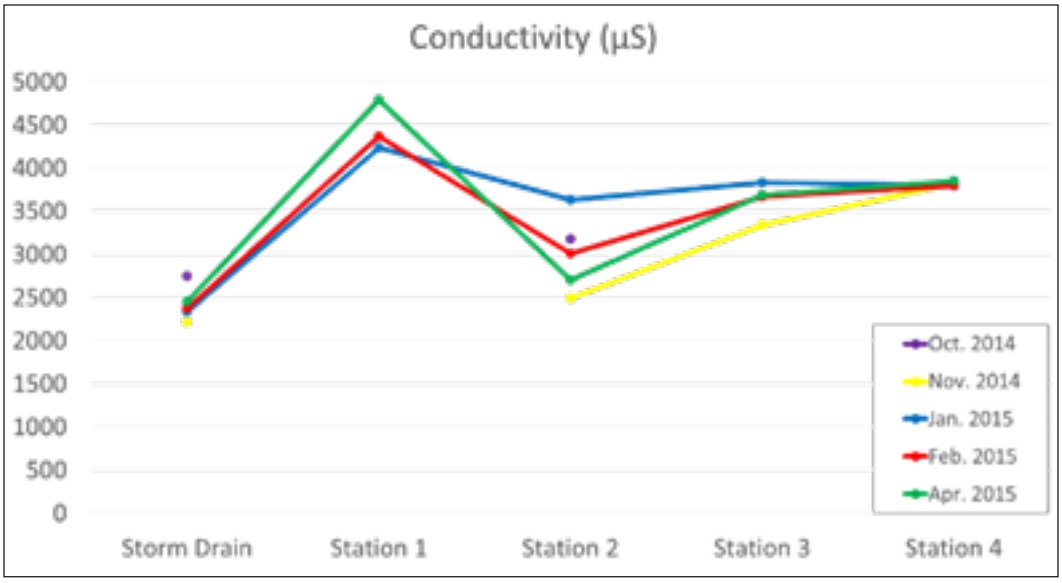

Figure 5. Conductivity downstream.

Local samples of recycled and imported water were established as endmembers for stable water isotope mixing analysis. Imported water includes tap water and recycled wastewater. Both are used for urban water applications in the entire study area. Recycled water and tap water have relatively light isotope values compared to local water derived by precipitation recharge. Native water is identified at the station 1 tributary because it drains undeveloped areas of the watershed (Figure 6).

The average isotope values for the recycled and imported endmembers are -9.1 ‰ $\delta^{18}O$ and -73 ‰ δD. The average isotope values for the samples collected at the storm drain are -6.6 ‰ $\delta^{18}O$ and -60 ‰ δD. Samples from the upstream tributary (station 1) have stable isotope values of –5.8 ‰ $\delta^{18}O$ and -41 ‰ δD. The average isotope values for the samples collected along station 2 through 4 are -6.5 ‰ $\delta^{18}O$ and -50 ‰ δD. Samples downstream from the storm drain (stations 2 through 4) along El Camino Real Creek fit along a mixing line of the plotted stable isotope data (Figure 6), with samples collected closest to the storm drain containing the most imported water.

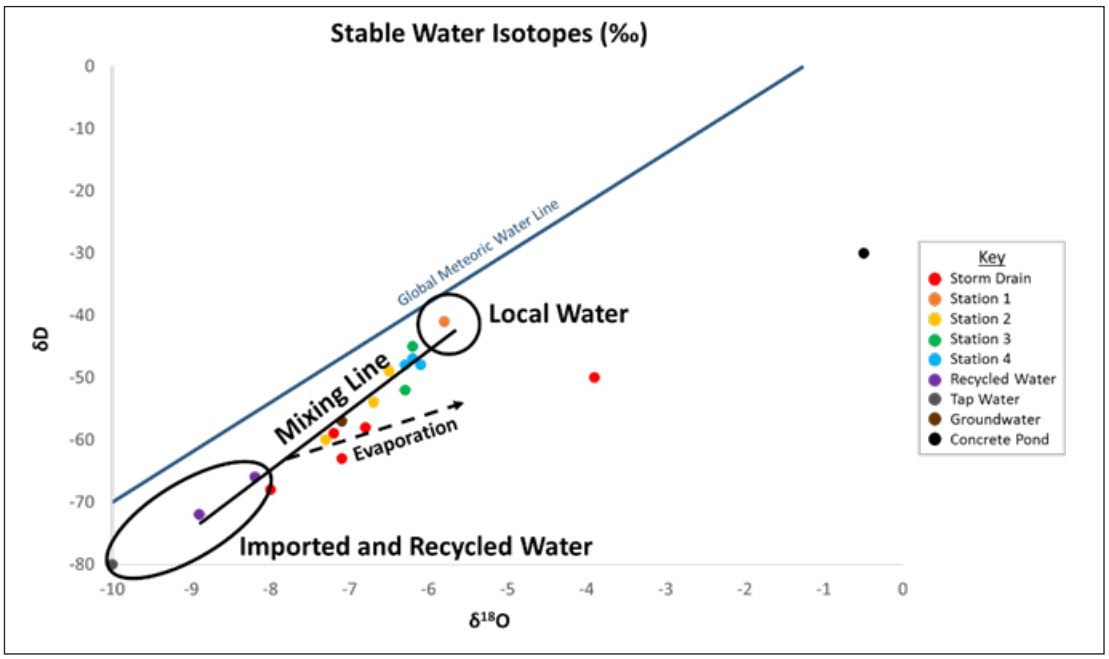

Figure 6. Graph displaying the variation of hydrogen (deuterium) and oxygen isotopes of samples collected in El Camino Real Creek and local area. Imported and recycled water have a lighter isotopic signature than local water. Mixing between imported/recycled and local water is seen downstream with some evaporation.

Discussion

Downstream from the storm drain, El Camino Real Creek has a trend of decreasing NO_3-N and an initial decrease before stabilization of PO_4 values. Decreases in nitrate and phosphorus are due to transformative process such as denitrification and vegetation uptake, along with some mixing and dilution with groundwater baseflow that has ambient concentrations of nutrients. Stabilization of phosphorus may be a result of groundwater leaching from phosphatic bearing strata in equilibrium with vegetation uptake. The increase of conductivity is likely a result of excess salt byproduct from evapotranspiration in the riparian zone, and/or mixing with saline groundwater baseflow.

Stable isotopes of hydrogen and oxygen show mixing of recycled water with local groundwater downstream, which demonstrates that nutrients in this creek are not strictly dominated by geologic sources (Figure 6). Isotope data also shows a strong correlation between high concentrations of NO_3-N and PO_4 with imported water fractions, probably due to recycled wastewater use for urban watering (Figure 7 and 8). Stations that have a percentage of imported (most likely recycled wastewater runoff augmented with some tap water runoff) have generally higher values of NO_3-N and PO_4. This correlation strengthens the point that high nutrients from the storm drain are mixing with the natural tributary and groundwater downstream.

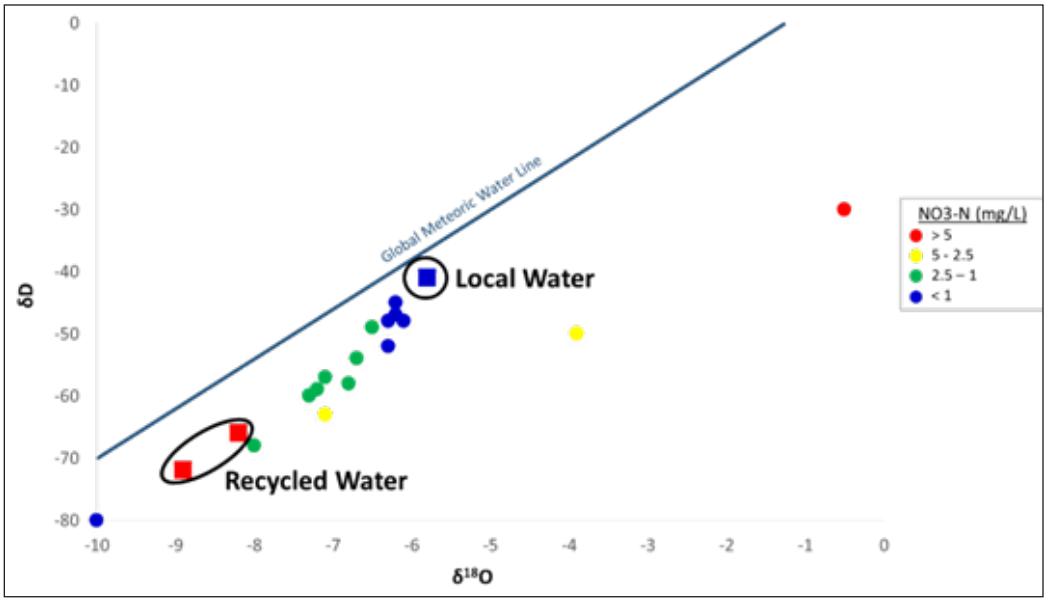

Figure 7. Graph displaying the correlation between lighter isotopic signatures with high NO_3-N concentrations with heavier isotopic signatures with lower concentrations of NO_3-N.

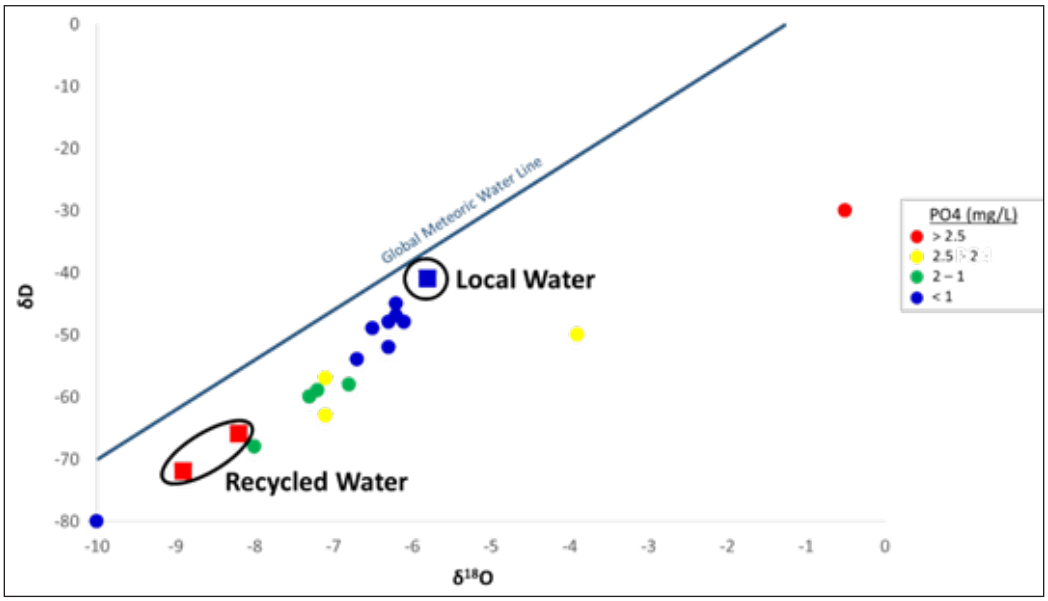

Figure 8. Graph displaying the correlation between lighter isotopic signatures with high PO_4 concentrations with heavier isotopic signatures with lower concentrations of PO_4.

Conclusions

Further study is needed in several areas. Mass balance analysis of flows and conservative solutes (e.g., chloride) will be conducted to quantify the nutrients variabilities and sources/sinks throughout the streams. Special studies of the hyporheic zone will be conducted to understand effects of groundwater baseflow mixing. Diurnal studies of the flows of the storm drain will also be conducted to understand the diurnal changes of source flow and water chemistry from the storm drain. Nitrate isotopes will be tested and compared in creek and recycled water to try to determine if recycled water is the source of elevated nitrate.

This investigation is relevant because streams within the Malibu Creek Watershed contain pollutants that have not met water quality standards set by regulatory agencies such as the U.S. Environmental Protection Agency. This project is furthering our understanding of the geologic and anthropogenic controls of nutrients, salts, and source flows in the watershed. Being able to identify source flows and the seasonal hydrochemical changes is necessary before future regulatory action can be considered.

Acknowledgements
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Unsaturated flow in fractured rocks: Effects of matrix-matrix contacts on capillary-driven flow across a fracture

Jeevan Jayakody, University of Nevada, Las Vegas
(co-author: M. Nicholl)

Under unsaturated conditions, open fractures can act as partial barriers to water flow between adjoining matrix blocks. Matrix to matrix contacts points and/or liquid bridges formed due to spatial heterogeneity within a fracture aperture create local hydraulic connections to facilitate inter-block flow. Bench-scale experiments were conducted to explore the influence of inter-block connections on capillary-driven, two-dimensional flow between adjoining matrix blocks. We considered: 1) the cross-sectional area (A) of the connection relative to that of the block; and 2) the position of the connection relative to edges of the block. Imbibition into a 10x6x2 cm block of dry sandstone was measured as a function of time for 240 hours under isothermal conditions. The fraction of the 10x2 cm face in hydraulic connection with an adjacent saturated block of sandstone was varied between 20 and 100%. The location of the connection was varied for each value of A. The rate of imbibition into the dry block varied with both A and the location of the inter-block connection. At A = 100%, measured imbibition was comparable to 1D absorption-based predictions, but deviated substantially as A decreased. At constant A, imbibition rate decreased as the inter-block contact shifted closer to edges of the block. For all values of A, and positions of the connection, imbibition rate decreased significantly as the wetting front reached the edges of the block. Saturation (S) of the block at this stage (0.53±0.03) was insensitive to A or location of the connection. For $S < 0.53$, cumulative flow into the block showed a dependency on A, position of the contact and square-root of time that can be fitted to a linear equation with empirical constants. These results show that the individual hydraulic connections place a first-order control on the evolution of flow fields in unsaturated fractured rocks. The observed relationships may be incorporated into continuum-based models to improve predictions of unsaturated flow and solute transport in fractured rocks.

Bio: Jeevan Jayakody is a PhD student at the Department of Geoscience, University of Nevada, Las Vegas. His current research is focused on understanding fluid flow processes and mechanisms in unsaturated dual-permeability media. Jeevan received his Bachelor's degree in Geology from University of Peradeniya, Sri Lanka in 2005 and Master's degree in Geoscience from University of Nevada, Las Vegas in 2010.

Changing storm properties and their impacts on the flood frequency in southern Nevada

Peng Jiang, Desert Research Institute
(co-authors: L. Chen, Z. Yu, K. Acharya)

Precipitation storm properties, such as intensity, frequency, duration, and event pattern are changing due to the increases in Green House Gases, transition of ocean oscillation phases, and etc. These changes in storm properties will further impact on the flood frequency. In this study, we investigate the trends and changing temporal variabilities of storm properties include storm duration, interstorm period, average storm intensity, and within storm pattern due to both large-scale ocean oscillations and anthropogenic activities in southern Nevada. Based on the changing characteristic of storm properties, a stochastic precipitation model is developed which incorporates the human and natural climate change impacts on nonstationary precipitation prediction. The precipitation outputs are used to drive a hydrological model (HEC-HMS) to examine the changes in future flood frequency in Las Vegas urban area. Results of changes in storm properties, flood frequency, and their links will be presented in the meeting.

Bio: Peng Jiang earned his MSc degree in Hydrology and Water Resources from Hohai University, China in 2009. He received his Ph.D degree in Geoscience in 2013 from University of Nevada Las Vegas. In 2014 he worked as postdoctoral fellow in Desert Research Institute Las Vegas. Peng Jiang's research focuses on hydroclimatology, surface water hydrology, and large-scale hydrologic modeling. His hydroclimatology research includes assessing current GCM/RCM datasets, analyzing the trends of hydroclimatic variables, and developing precipitation models to generate nonstationary future precipitation scenarios. His surface and near-surface hydrology research includes assessing changes in precipitation properties, connections with ocean oscillations, and relations to warming trends. His large-scale hydrologic modeling research includes the spatial-temporal distribution of hydrologic variables under climate change and future water assessment. Some of Peng Jiang's research has also been on climate change and how it will affect Colorado River flows.

Identification of key features in hydrologic models by a new method

Dong Ha Kim, Georgia Department of Natural Resources

Local population and economic growths, together with climate change, have added more stress on already scarce water resources than ever before. Ever-increasing demands from neighboring local governing entities (i.e., county or municipality) for securing water to assure their own population and economic growths has been calling for temporally and spatially fine-scale estimation of hydrologic response to varying degree of natural and human inputs. As a result, hydrologic models of fine spatial and temporal scales with relatively small spatial extents are required to address various local water resource management questions as raised by considering the subtleties of potential management actions. Estimating of watershed runoff and streamflow, among other hydrological responses, can be the first and most important step for water managers to achieve equitable and sustainable resources planning. Most existing hydrologic routing models assume that the storage-discharge relationship follows a certain mathematical form, usually a linear or a power function, with parameters calibrated based on existing inflow-outflow data. Likewise, most conceptual rainfall-runoff models presume that vertical or lateral flow in soil follows a power or an exponential relationship with soil moisture. These assumptions simplify the model calibration process but also constraint model performance in simulating runoff or streamflow throughout the corresponding flow ranges, which can add more uncertainty into making management decisions in a finer-scale framework since errors associated with the hydrologic variable estimation generally propagate more substantially through a fine-scale model than through a coarse-scale model within the same spatial extent. These relationships in a new nonlinear hydrologic river routing and a new conceptual rainfall-runoff models, however, are only required to be nondecreasing and subsequently the relational functions, including storage-discharge and storage-loss/gain functions in the routing model and soil moisture-water flow and soil moisture-loss/gain functions in the rainfall-runoff model, are identified by a novel parameter estimation approach within a dynamic optimization framework. The previous applications of the new river routing model to the Equatorial Lakes in East Africa and to the Nile River indeed identified these functions exhibiting different functional forms at different regions of their active range. In this study, the rainfall-runoff model with North America Land Data Assimilation System Phase 2 (NLDAS-2) precipitation and evapotranspiration data as its inputs has been developed and the resulting runoff time series is fed into the river routing model to predict downstream hydrographs for a watershed in the Southeast of the U.S. that covers several places with conflicting water demands within a relatively small spatial extent. This set of tools can also be applied to other watersheds due to the available high resolution gridded climate time-series dataset and streamgage data, which can be easily retrieved by HydroDesktop application, throughout the USA. Finally, the accuracy of the simulated watershed hydrology in terms of its magnitude and timing demonstrates that this suite of hydrologic models can be a strong alternative method for providing reliable answers to fine-scale hydrologic response questions as raised by uncertain ramifications of potential water resources management actions.

Bio: Dong Ha Kim is a River Basin Modeler for the Georgia Environmental Protection Division, Georgia Department of Natural Resources in Atlanta, GA. He received his Ph.D. in Civil Engineering (Environmental Fluid Mechanics and Water Resources) from Georgia Institute of Technology in 2011.

Estimating urban evapotranspiration for water conservation: Make it simple and direct

Roger Kjelgren, Utah State University
(co-authors: L. Hipps, R. Beeson, D. Pittenger, A. Torres-Rua)

Irrigated urban landscape water conservation is urgent for much of the U.S. Key to water conservation is some measure of evaporation and transpiration (ET) fluxes to estimate actual landscape water use over a period of time for replacement by irrigation. Currently, water use is estimated by using local weather data (radiation, wind, temperature, humidity) to calculate reference ET (ETo) for a standardized large, hypothetical turf surface. ETo measured over large, oasis urban turf areas is then loosely tethered to ground-level reality with adjustment factors to correct ETo, generally downward, for plant type. The current approach uses ad-hoc species-level adjustment factors to account for the built and biological mosaic of urban landscapes, but is overly complex, unwieldy, ad-hoc and not user friendly. The American Society of Agricultural and Biological Engineers is developing a national ANSI standard for urban landscape water use with simple adjustment factors (Plant Factors, PF) that correct local ETo for broad plant types of turf, non-turf, and desert plants. These PF's are justified based on science showing that variation in daily water use within a species is as great as among species so that species-specific adjustments are not meaningful. Turfgrass and non-turf plants have two subdivided PF's based on turf photosynthate metabolism, C4 and C3, and non-turf (woody plants) that separate based on transpiration (sto-matal) sensitivity to dry air (vapor deficit) that varies between humid and arid climates. Satellite-based estimates of actual urban ET for large, oasis turf areas can potentially replace the ETo x PF approach. A preliminary 2014 study at a golf course near Salt Lake City used Landsat thermal and multispectral data to estimate water use that was compared to water use with eddy covariance over, then compared to ETo x PF estimates from a nearby weather station. Satellite and ETo estimates were both within 5% of measured eddy covariance water use, suggesting actual oasis turf water use can be estimated from satellite data.

Bio: Roger Kjelgren is a professor of Plant Science in the department of Plants, Soils, and Climate at Utah State University. His academic expertise is in water use and water stress physiology ap-plied to landscape water conservation and tree-ring reconstructions of paleo climate.

A feasibility study for seeding snow from winter storm clouds in southern Nevada

Casey Korby, University of Nevada, Las Vegas

Several papers, including those of the Desert Research Institute, have studied the efficacy of Weather Modification (WM) to enhance orographic snowfall in mountainous regions. These papers have shown cloud seeding has varying success, but none of these studies have addressed the potential for WM in the mountains of Southern Nevada (e.g. the Spring Mountains and Sheep Mountains outside Las Vegas, Nevada) or of its potential to increase the groundwater recharge of nearby aquifers. The geographic and meteorological suitability for a cloud seeding program is based on the data available for the remote and mountainous terrain from weather stations and previous studies. Literature on seeding clouds for snow with silver iodide indicates that temperatures must not be any warmer than -5° C within 3 hours of seeding to produce snowflakes. The meteorological parameters of temperature, wind direction, and cloud moisture content are critical to the success of any cloud seeding program and must be established to warrant further investigations into a WM program in southern Nevada.

Bio: Casey Korby a student in UNLV's Water Resources management program. He has previously lived in Minnesota and Alaska, but now calls Las Vegas home. In his spare time he enjoys hiking and skiing in the mountains surrounding the Las Vegas Valley.

Intercomparison of satellite precipitation products using an object-based evaluation approach

Jingjing Li, California State University Los Angeles
(co-author: Y. Ding)

Extended Abstract

An object-based evaluation approach is utilized to verify two satellite-based precipitation products including Integrated Multi-satellitE Retrievals for GPM (IMERG) and Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN). The ability of these two satellite-based precipitation products to depict the spatial and geometric characteristics of precipitation structure against Stage IV ground observations are demonstrated in this study. The precipitation objects derived from two satellite-based precipitation products and ground observations well represent the closely spaced, but separable storm systems in the original precipitation fields. The results indicate that IMERG possesses the similar spatial pattern of local-scale precipitation areas against stage IV observations. In addition, IMERG depicts the sizes and locations of precipitation areas more accurately against stage IV, while PERSIANN tends to overestimate the coverage of localized precipitation areas.

Introduction

Precipitation is a crucial hydrologic variable that links the atmosphere with the surface land processes. It is commonly measured by ground instruments (e.g. radar or rain gauges). Such instruments can provide true precipitation measurements, which, however, are sparse in time and space and are even nonexistent in many populated regions. With the advances in remote sensing technology, satellite-based precipitation products provide precipitation estimates with high spatial and temporal resolutions that are suitable for hydrologic modeling and watershed management, such as Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN), Climate Prediction center MORPHing technique (CMORPH), and TRMM Multi-Satellite Precipitation Analysis (TMPA). In addition, the recently launched Global Precipitation Measurement (GPM) mission provides a new precipitation product: Integrated Multi-satellitE Retrievals for GPM (IMERG), utilizing several existing algorithms to estimate precipitation.

However, satellite-based precipitation products are prone to errors and need to be evaluated using the ground observations. Many verification activities have been established to evaluate the accuracy of satellite precipitation estimates (e.g. Sapiano and Arkin 2009). These activities employ pixel-based verification measures, such as bias, root mean square error, probability of detection, and false alarm ratio, to summarize pixel-to-pixel differences between satellite precipitation estimates and ground observations. While providing valuable information, these measures do not explicitly quantify errors associated with spatial and geometric patterns, structures, and placement of precipitation, which are essential for hydrologic applications.

On the other hand, spatial verification methods have been developed to evaluate the simulated precipitation fields focusing on the spatial pattern, intensity, and location of precipitation entities (see Gilleland et al. 2010, and references therein). One group of spatial verification methods is feature/object-based approaches, where the properties of precipitation objects obtained from simulated precipitation fields are verified by those from observations. A new object-based method has been developed to identify the local-scale precipitation objects using an image processing technique termed watershed transform. This object-based approach allows the evaluation of closely spaced, but separated localized precipitation areas because each localized precipitation area possesses different spatial characteristics, such as size, shape and orientation (Li et al. 2015).

The overriding goal of this study is to use the newly developed object-based approach to reveal the spatial and geometric errors in satellite-based precipitation products over continental United States (CONUS) during the summer season. A secondary goal is to investigate the possible performance changes in satellite-based precipitation products from PERSIANN to IMERG compared with ground observations.

Methodology

The object-based evaluation approach was developed by Li et al. (2015) with the aim of verifying to what extent the simulated precipitation estimates depict the spatial and geometric characteristics of the observed precipitation. The object-based approach defines the local-scale precipitation objects using an image processing technique referred to as watershed transform (Meyer 1994). This algorithm partitions precipitation intensity images into segmented precipitation areas based on storm centers. Watershed transform is capable of detecting the closely spaced, but separable local-scale precipitation areas both in the precipitation estimates and observations. To avoid over-segmentation in the images, the object-based approach employs another image processing technique termed H-minima transform. The H-minima transform suppresses

the minor fluctuations in the images by increasing the local minima with the merge threshold. A minimum size threshold is used after applying the watershed transform to decide the lower bound coverage of precipitation objects. The precipitation objects that are above the threshold will be further considered in the evaluation. The same merge and minimum size thresholds are used on satellite-based precipitation estimates and observations to examine their similarities. In this study, a merge threshold of 15 mm/day is used for a local-scale evaluation of satellite-based precipitation products, based on the methodology used in Li et al. (2015).

After the precipitation objects are identified, the next step is to evaluate the estimated objects against observed objects. Precipitation objects obtained from estimates and observations are categorized into matching objects and unmatching objects based on overlapping criteria. For the unmatching objects, object-based false alarm ratio and missing ratio are computed to represent the falsely detected objects proportion in the satellite precipitation field and missed objects proportion in the observation field, respectively. For the matching objects, four geometric attributes, including centroid location distance, object area ratio, intersection area ratio, and orientation difference, are selected. To obtain commensurable measures, these attributes are converted to interest values (ranging from 0 to 1) through different interest functions. The interest value of 1 represents a perfect performance of the estimated object for a specific attribute, while the value of 0 represents no skill. An overall interest score is summarized from the interest values and assigned weights, which reveals the quality of the estimated data in an aggregated sense. In general, a small centroid distance, a large intersection area ratio, a small object size difference, and a small orientation difference result in a high overall interest score.

Data

The two satellite-based precipitation products used in this study are IMERG and PERSIANN. IMERG is a global precipitation system based on the three prior algorithms including TMPA, CPC Morphing-Kalman Filter (CMORPH-KF), and PERSIANN-Cloud Classification System (PERSIANN-CCS). IMERG utilizes various satellite passive microwave sensors to compute the precipitation estimates. These precipitation estimates are then inter-calibrated, morphed and combined with geostationary infrared fields. They are further adjusted by monthly precipitation gauge analysis data to provide precipitation estimates at each 0.1° by 0.1° every 30 minutes (Huffman et al. 2014). PERSIANN computes the precipitation estimates from geostationary long-wave infrared imagery using the artificial neural networks approach. The precipitation estimates are then corrected by passive microwave information. PERSIANN data are available at 0.25° by 0.25° every hour (Hsu et al. 1997). NOAA stage IV Multisensor Precipitation Estimation rain analysis is used as the ground-observation reference. Stage IV data aggregates the ground radar precipitation measurements from the National Weather Service (NWS) River Forecast Centers (RFC) over CONUS. It is adjusted by rain gauge measurements and has manual quality control to provide hourly precipitation data at 4 km spatial resolution (Lin and Mitchell 2005). Here, the evaluations were conducted at 0.25° by 0.25° on a daily scale in the summer of 2014 over CONUS. IMERG and the stage IV data were averaged to 0.25° by 0.25°.

Results

The object-based approach described above is implemented on two satellite-based precipitation products against ground radar observations. Figure 1(a), (c) and (e) demonstrate the precipitation distribution obtained from the stage IV, IMERG and PERSIANN at a daily accumulation of rainfall intensity on August 23rd, 2014, over CONUS. The structure of convective storm systems is clearly presented in these figures. In general, the spatial pattern of IMERG precipitation is similar to that of stage IV data, while PERSIANN data tends to produce larger storm systems than stage IV. PERSIANN uses the cloud-top brightness temperature to estimate the precipitation intensity, which leads to the tendency of obtaining precipitation systems with larger coverage. On the other hand, IMERG was developed based on the three existing precipitation algorithms and adjusted by rain gauge analysis, which allows more accurate detection of precipitation coverage and convective storm systems. It is expected that IMERG performs better than PERSIANN. Figure 1(b), (d) and (f) illustrate the precipitation objects derived from the stage IV observation and two satellite-based precipitation products using the watershed transformation. The closely spaced, but separable local-scale precipitation areas are well represented by the precipitation objects in these three datasets. The resulting precipitation objects are well-delineated storm systems that a human expert would likely see from the precipitation fields. The distribution of IMERG precipitation objects well matches that of stage IV precipitation objects, while PERSIANN precipitation objects are larger in size compared to stage IV objects. Both IMERG and PERSIANN have some missing objects over New Mexico State. In addition, PERSIANN misses several objects in northeastern US against the stage IV, while IMERG does not.

The precipitation objects obtained from IMERG and PERSIANN are evaluated against the precipitation objects obtained from stage IV. Figure 2 illustrates the normalized histograms of the interest values of four geometric attributes in the

summer of 2014 for IMERG and PERSIANN. For the area ratio, IMERG has a higher averaged interest value than PERSIANN, which indicates that the sizes of IMERG precipitation objects are closer to sizes of stage IV precipitation objects than those of PERSIANN. For the centroid distance, IMERG possesses a larger portion of the interest values (above the value of 0.8) compared to PERSIANN. This demonstrates that IMERG objects are placed closer to the correspondent stage IV object. There is a shorter distance between IMERG object centroid and stage IV object centroid. IMERG is more likely to detect the localized precipitation areas at the correct locations. For the intersection area ratio and orientation difference, IMERG shows the similar pattern as PERSIANN in the histograms. In sum, IMERG outperforms PERSIANN in the attributes of area ratio and centroid distance, while keeping the similar performances as PERSIANN in the attributes of intersection area ratio and orientation difference. This demonstrates the improved skill of IMERG in estimating the sizes and locations of localized precipitation areas against stage IV.

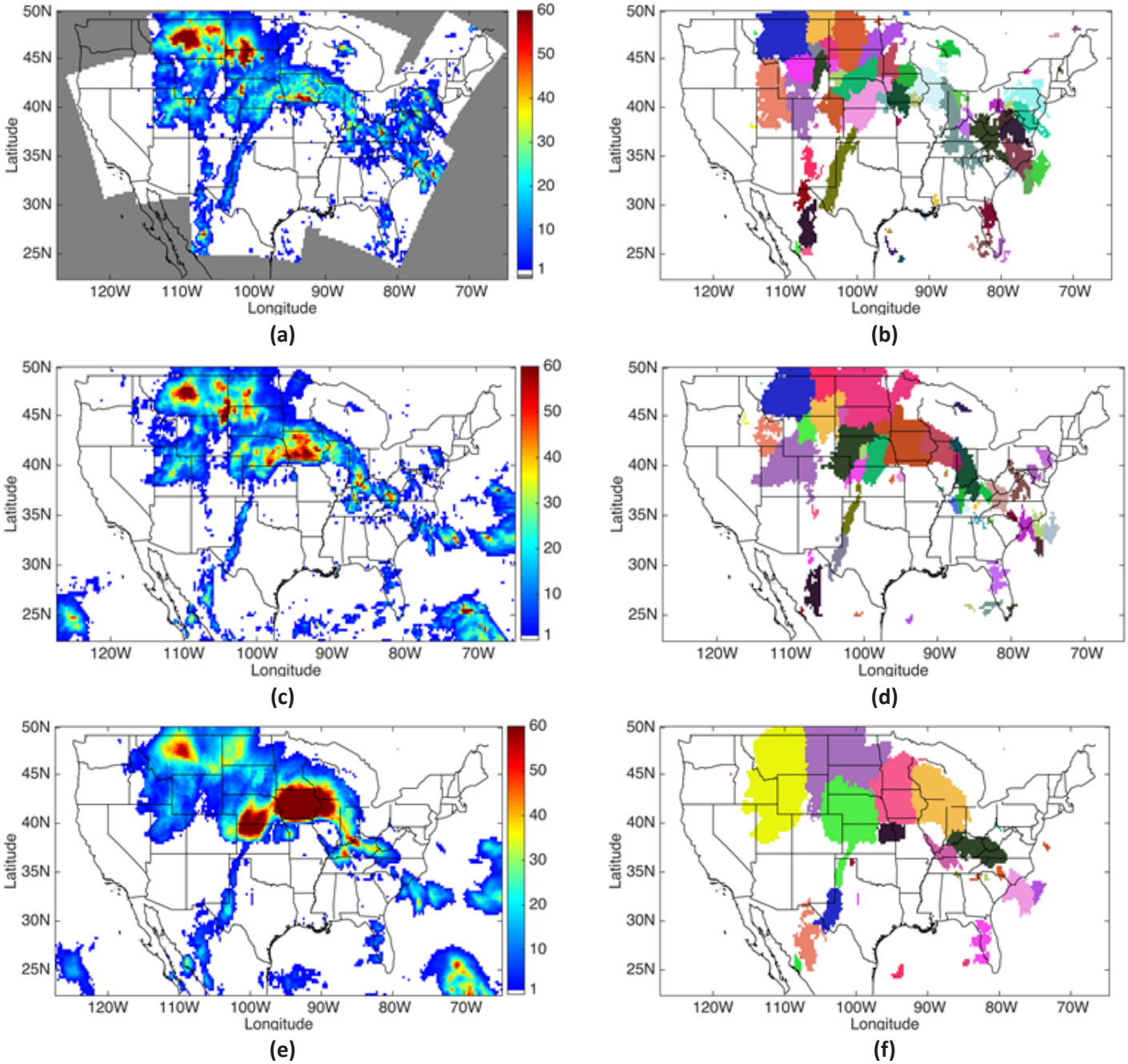

Figure 1. (a), (c) and (e) Precipitation distribution in mm/day obtained from stage IV, IMERG and PERSIANN, at 0.25° by 0.25° over CONUS on August 23rd, 2014. White background represents rainfall intensity below a threshold of 1 mm/day. Grey area represents no data. (b), (d) and (f) Distribution of precipitation objects after applying watershed transform on original precipitation data shown in (a), (c) and (e). Different colors represent different precipitation objects.

Figure 3 depicts the time series of three verification scores, including object-based false alarm ratio, object-based missing ratio and overall interest score, for IMERG and PERSIANN in the summer of 2014. The object-based false alarm ratio and missing ratio are mostly below a value of 0.1 for both satellite-based precipitation products. This indicates that IMERG and PERSIANN both have the abilities to detect the correct occurrences of the local-scale precipitation areas when compared to stage IV. The overall interest score derived from the four attributes and assigned weights shows that IMERG performs better than PERSIANN in an aggregated sense. In short, both IMERG and PERSIANN have the skill to depict the spatial and geometric characteristics of precipitation structure in the local scale against stage IV observations.

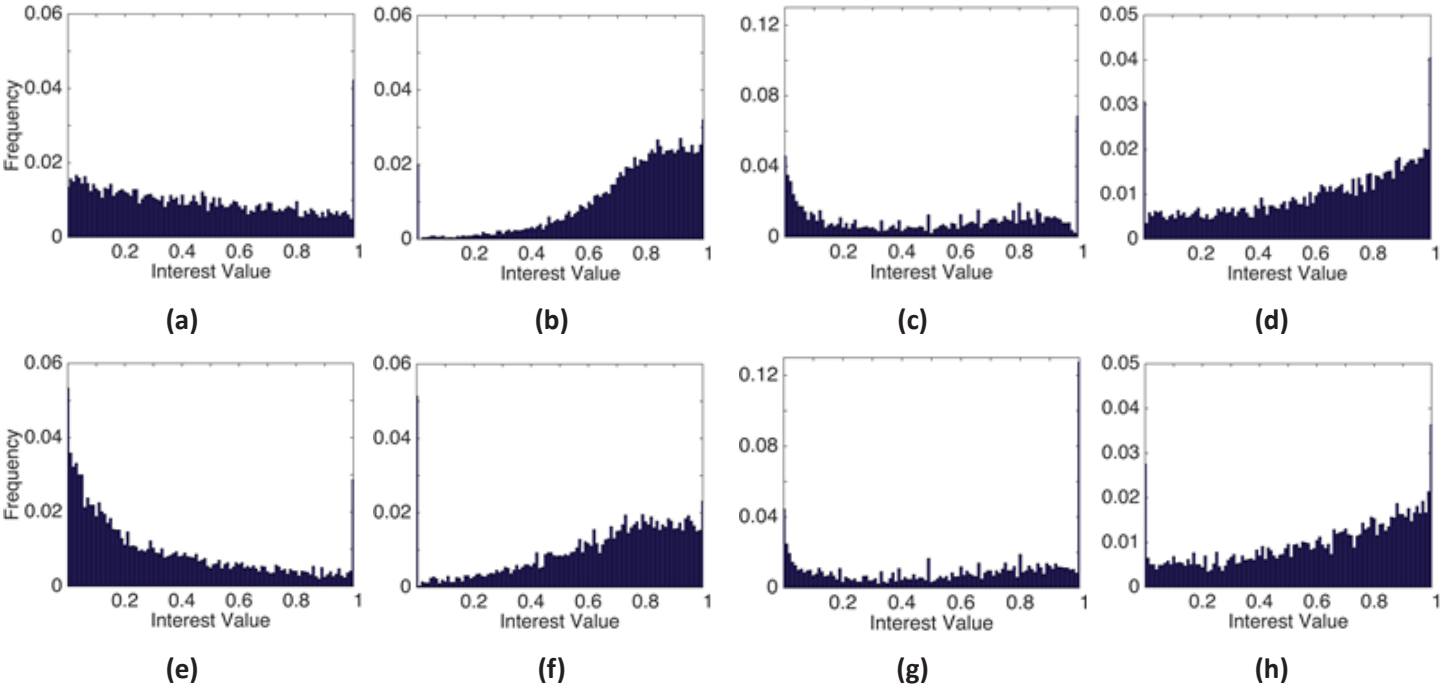

Figure 2. Normalized histograms of four attributes including (a) and (e) centroid distance, (b) and (f) area ratio, (c) and (g) intersection area ratio, as well as (d) and (h) orientation difference for IMERG and PERSIANN, respectively, in the summer of 2014.

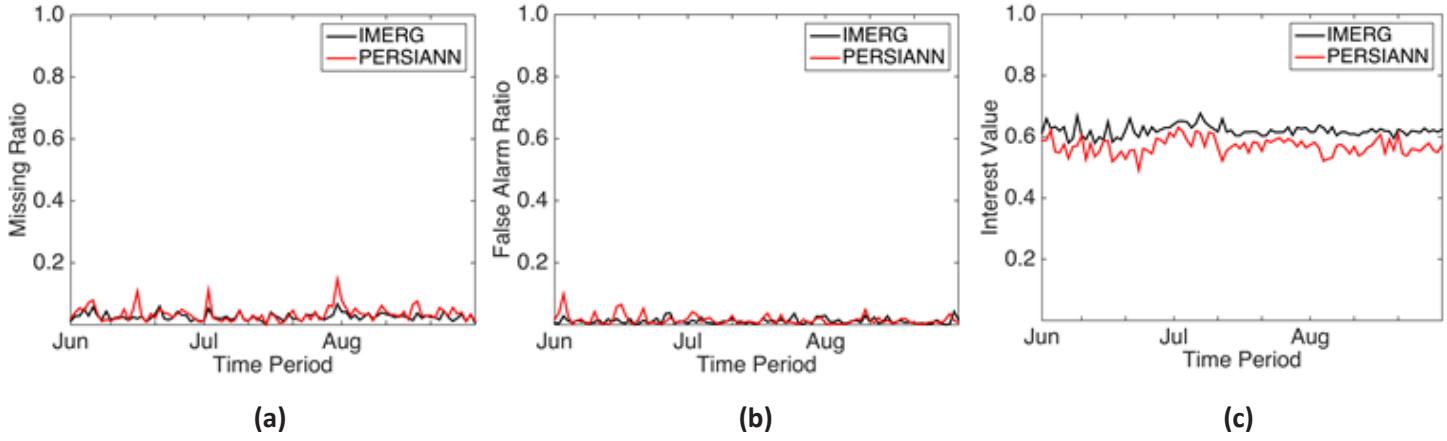

Figure 3. Time series of three scores including (a) object-based false alarm ratio, (b) object-based missing ratio, and (c) overall interest score for IMERG and PERSIANN in the summer of 2014.

Summary and Conclusion

Two satellite-based precipitation products IMERG and PERSIANN are evaluated against stage IV ground observations using an object-based verification approach. This object-based approach verifies the precipitation products based on the spatial and geometrical characteristics of the precipitation structure against the observations. The precipitation objects derived from the three datasets well represent the localized storm systems in the original precipitation fields. The object evaluations results demonstrate that IMERG and PERSIANN have the skills of identifying the local-scale precipitation areas correctly

with small false alarm and missing objects proportions. Meanwhile, IMERG outperforms PERSIANN in depicting the sizes and placement of matching precipitation areas against stage IV observations. The further object-based evaluation study will include the evaluations of other satellite-based high-resolution precipitation products. A comprehensive evaluation will be performed for the different seasons to understand the skills of satellite-based precipitation products in depicting the spatial and geometric features of different precipitation systems.

Acknowledgement
The authors would like to acknowledge NASA/Goddard Space Flight Center's Mesoscale Atmospheric Processes Laboratory and PPS for providing IMERG data. The authors would also like to thank Hao Liu for his assistance with the stage IV data preparation.

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Bio: Dr. Li is an assistant professor in Department of Geosciences and Environment, College of Natural and Social Sciences at California State University, Los Angeles. She received her B.S. in Environmental Engineering from Fuzhou University, China in 2007, M.S. in Environmental Engineering and Ph.D. in Civil Engineering from University of California, Irvine (2008 and 2012). Her research interests include remote sensing, precipitation error analysis, GIS-based modeling of watershed-scale processes, hydrologic modeling, and image processing. Her research has been published in literature journals such as Journal of Hydrometeorology and the International Journal of Remote Sensing. She has presented her work at various conferences and research centers, including NASA JPL, NASA GSFC and AGU.

Enhanced photocatalytic water treatment using immobilized nanocomposite thin films

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(co-author: P. Xu)

An innovative photoreactor was designed, characterized and investigated for degrading organic contaminant in water. Photoreactor used Fe doped TiO_2 nanocomposite thin films coated on side-glowing optical fibers (SOFs) as a means of light transmission medium. Polymer assisted hydrothermal deposition method was employed to coat TiO_2 and Fe-TiO_2 films on SOFs. The photocatalyst films were characterized using scanning electron microscope, energy-dispersive X-ray spectroscopy, and X-ray diffraction. The photocatalytic activities of the catalysts coated SOFs were first studied by the degradation of Rhodamine B, a dye of which the concentration can be quickly quantified by a spectrophotometer. The results showed that 5% Fe-TiO_2 thin films, mixtures of anatase and rutile phases, achieved the highest photocatalytic activity under the irradiation of ultraviolet and visible light. The coupled adsorption and photocatalytic degradation of Rhodamine B by the SOFs coated with photocatalysts nanocomposite thin films follows the Langmuir-Hinshelwood kinetic model. To investigate the long-term sustainability of the synthesized photocatalysts for water treatment, the method for reactivation of the used catalysts was studied. Based on the results of batch experiment, an innovative continuous-flow photoreactor for water treatment using solar energy was developed to degrade environment contaminants (e.g., pharmaceuticals) from reclaimed water. This type of photoreactor will be suitable for arid and semi-arid regions because the solar resources are abundant, and the closed compact reactor developed in this project is particularly appealing for reducing water loss that occurs in an open system.

Bio: Lu Lin is a master student from New Mexico State University studying Environmental Engineering. Her bachelor degree was obtained from Beijing Normal University in China. Her research focuses on desalination concentrate treatment, including heavy metals removal and organic contaminants degradation.

Biological treatment (aerobic bacteria) of wastewater with high organic matter

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The quality of water resources depends on both, natural factors and human actions. Water quality is determined by comparing the physical, chemical and biological levels of a sample of water to water quality guidelines (WQG) or standards. These WQG or standards are based on scientifically acceptable studies that assure human or environmental health. The objective of this study was to determine de decay of COD (chemical oxygen demand). Wastewater with high organic matter content (8,000 mg/L) was treated with 500 g of aerobic bacteria in a period of 10 days in a 100,000 L batch reactor. Significant reduction of COD was achieved (380 mg/L) and therefore the permissible limit for discharge to the municipal sewage system was target (440 mg/L). The study demonstrates that wastewater high in pollutant load of COD can be treated with a minimum load of aerobic bacteria, to be managed in an environment with controlled aeration, and its quality be improved. This treatment reduces the treatment costs by not being required one installation of conventional treatment with activated sludge rector.

Bio: Edgar Raul Lom Arredondo is a student of the Environmental Engineering Master Program, at the Universidad Autonoma de Ciudad Juarez, México. He obtained his bachelor degree in Ecology in 2004. SInce 1992 he has been working for industry in the Safety, Hygiene and Environmental Area.

Water infiltration into arid soil – Experiments and numerical modeling

Yuan Luo, University of Nevada, Las Vegas

Nevada enjoys abundance of sunshine days and could potentially produce a huge amount of electricity power by photovoltaic facilities to meet the nation's energy needs and diverse the local economy. Yet, the developing of solar energy must be tempered by concerns about required water use and environmental impact. Due to the fragile ecosystem in Nevada, environmental impact researches and evaluations are needed before constructing the photovoltaic facilities. Every living thing is dependent on water, so hydrologic cycle is important to the ecosystem. Infiltration is a critical part of hydrologic cycle, especially for desert environment, because the groundwater mainly recharge from infiltrated precipitation.

Soil water infiltration process has been studied since last century. There are many widely applied models have been developed to analyze the soil water infiltration process, they are mainly into three categories: (1) physically based, (2) empirical and (3) numerical. Hydrus-1D is a numerical model based on Richard's equation for simulate one dimensional vertical movement of water, heat and multiple solutes in variably-saturated media by using finite element method. Many applications of soil water infiltration have been conducted by using Hydrus-1D since the first version the software package developed.

However, the suitability of these models is not fully understood about their suitability in arid areas, especially the extreme condition, desert soil. The suitability of these models were evaluated statistically and compared using data collected from a large weighing lysimeter facility built in Boulder City, NV.

Bio: Yuan Luo is currently a PhD Graduate Research Assistant in the Division of Hydrologic Sciences at the Desert Research Institute.

Ozone-reactive N-nitrosodimethylamine (NDMA) precursors: Yields, factors affecting formation and implications for water reuse

Erica Marti, University of Nevada, Las Vegas
(co-authors: A. Pisarenko, E. Dickenson, J. Peller, J. Batista)

N-nitrosodimethylamine (NDMA) is a probable human carcinogen and may be a regulated drinking water contaminant in the future. Although there are some industrial sources, the main process for this contaminant to enter the water is as a disinfection byproduct. Substantial research has focused on NDMA formation with chloramination, but recent studies show direct formation during ozonation of surface water and treated wastewater. NDMA formation may be a significant barrier to ozonation in water reuse applications, particularly for potable reuse. This research focused on identifying a set of model compounds or precursors that form NDMA with high yields. Several factors affecting formation were investigated, including: bromide presence, ozone dose, and addition of hydrogen peroxide. Comparisons in NDMA formation were made between: formation associated with molecular ozone vs hydroxyl radical, formation in ultrapure water vs wastewater, and formation due to chloramination vs ozonation. Results show that bromide concentration was significant for some model compounds, but did not enhance NDMA formation for the other precursors. This suggests that different pathways may be involved in NDMA formation. Molecular ozone is the dominant oxidant leading to NDMA formation for the model compounds and the presence of hydroxyl radical scavengers could lead to increased NDMA concentrations. Formation due to chloramination was minimal compared to formation due to ozonation. Pre-chlorination was investigated as a mitigation strategy. Initial results suggest that it may be highly effective at reducing NDMA formation due to ozonation or chloramination. However, trade-offs in disinfection byproducts must be evaluated.

Bio: Erica Marti is a Ph.D. student in Civil & Environmental Engineering at the University of Nevada, Las Vegas and a Graduate Intern in the Water Quality Research and Development division at the Southern Nevada Water Authority. She has 5 years of experience in water-related research and holds a Master of Science in Engineering. Both her Master's research and Ph.D. research are in the area of emerging contaminants in water and wastewater. She recently conducted research at Curtin Water Research Centre in Perth, Australia through the NSF East Asia and Pacific Summer Institute.

Fate of antibiotic resistant bacteria in wastewater treatment processes

Majid Neyestani, University of Nevada, Las Vegas
(co-author: D. Gerrity)

The invention of antibiotics is considered a turning point among all health-related events. However, the intensive use of these "wonder drugs" has led to the development of antibiotic resistance. Wastewater treatment plants seem to be among the hot spots for the development of antibiotic resistance; specifically, the biological treatment process may be a suitable environment for resistance development. In spite of growing interest in the fate of AR in biological treatment processes, the effects of operational conditions are still unknown. In this research, the fate of antibiotic resistant bacteria was evaluated in wastewater treatment processes. A local wastewater treatment plant was selected for sampling purposes. Tetracycline and ampicillin were selected as the antibiotic agents. R2A agar supplemented with antibiotic was utilized in order to count the resistant bacteria. Sampling was performed on raw wastewater, activated sludge basin, filtration effluent and disinfection effluent. The results showed that the wastewater treatment plant can effectively decrease the amount of resistant bacteria.

Bio: Majid Neyestani earned his M.S.E. in Civil & Environmental Engineering at the Isfahan University of Technology. He is a Ph.D student in the Department of Civil and Environmental Engineering and Construction at the University of Nevada Las Vegas where his research interests focus on wastewater treatment processes.

Near-continuous water-quality: Lake Mead National Recreation Area

Erin Orozco, US Geological Survey

The U.S. Geological Survey, in cooperation with the National Park Service, Southern Nevada Water Authority and Clark County Water Reclamation District, collects near-continuous depth-dependent water-quality data on Lake Mead and Lake Mohave within Lake Mead National Recreation Area (LAKE), Arizona and Nevada. The data are collected as part of a multi-agency monitoring network to collect basic water-quality data to provide resource managers with a better understanding of the hydrodynamics of LAKE. Monitoring stations on Lake Mead and Lake Mohave collect water-quality data using automatic profiling systems equipped with multi-parameter sondes. The sondes have sensors for temperature, specific conductance, dissolved oxygen, pH, turbidity, and depth. Data are collected every 6 hours at 5-meter depth intervals (Lake Mead) and 2.5-meter depth (Mohave) beginning at 1 meter below water surface. The water-quality station located on Lake Mead also is equipped with meteorological equipment that measures wind speed and direction, relative humidity, air temperature, solar radiation, and barometric pressure. Meteorological data is collected on a continual basis and averaged hourly. Continual monitoring of vertical and temporal changes, water quality, and meteorological changes provide benefits to ongoing interpretive studies and programs concerned with natural or anthropogenic change, public education, or recreational activities.

Bio: Erin Orozco is a Hydrologist for the US Geological Survey. She received a B.S. in Geology from University Nevada, Las Vegas.

Spatial-temporal patterns of hydrological drought indicators in major U.S. river basins

Maryam Pournasiri Poshtiri, University of Colorado Denver
(co-author: I. Pal)

Climate non-stationarity affects regional hydrological extremes. This research considers extreme low streamflow and deficit characteristics, which are important indicators of water scarcity within the broader context of hydrological droughts, and assesses their spatial temporal trending patterns using various approaches. The initial results indicate general drying monotonic trending patterns of indicators for the conterminous U.S. (CONUS), particularly in the last four decades, as opposed to wetting trends reported in the previous studies. Regional differences in trending patterns are marked, which echoed the climatic changes synthesized in the recent National Climate Assessment report. Reversal of trends is also noted for certain northern regions of CONUS after 1980s. Changes in return periods and corresponding return values of low flow characteristics are also informed, implying a changing risk condition relevant for water-resources and engineering decision-making. Monotonic temporal trending patterns for different regions of CONUS are also compared with the evolution of trends of hydrological drought indicators using a spatial-temporally multidimensional ensemble empirical mode decomposition method. Persistent hydrological drought conditions and their drying patterns can lead to chronic water scarcity—a main driver of societal and cross-boundary conflicts. Thus, the research outcomes are crucial for developing suitable adaptive management measures at the locations of need.

Effect of soil texture and slope on concentrated flow path formation in agricultural watersheds

Prabisha Shrestha, Southern Illinois University
(co-authors: K.W.J. Williard, J.E. Schoonover)

Sediment is the second major source of agricultural water pollution in the United States. Best management practices such as riparian buffer zones have been recommended to trap nutrients and sediment from agricultural runoff. However, sediment deposited in buffers can eventually form berms that can contribute to concentrated flow path (CFP) formation. This study investigates the effects of field characteristics such as soil texture and slope on the frequency and occurrence of CFPs in southern Illinois. The research will be conducted in five counties: Alexander, Jackson, Johnson, Pulaski and Union. Digital Elevation Models (DEMs) created using Laser Detection and Ranging (LiDAR) point data will be utilized to investigate the occurrence of CFPs. Watershed delineation at each CFP will also be used to estimate the percentage of agricultural fields drained by CFPs. Although existing literature highlight the prevalence of CFPs in agricultural fields and riparian buffers, results from this study is expected to provide insight into influence of soil texture and slope on CFP formation. This understanding can be helpful in designing riparian buffers based on field characteristics to increase its effectiveness in addressing non-point source agricultural pollution.

Bio: Prabisha Shrestha is a Forestry graduate student in the Department of Forestry at Southern Illinois University Carbondale. She received her undergraduate degree with a major in Environmental Science and a minor in Public Health from Asian University for Women. Her graduate works involve investigating the impacts of berms and concentrated flow paths on efficiency of riparian buffers.

Can industrial wastewater (Unilever, Ocean spray and Biodiesel) generated in Nevada be used as carbon source in place of conventional carbon sources to treat groundwater contaminant-perchlorate?

Sichu Shrestha, University of Nevada, Las Vegas

Biodegradation of perchlorate using a fluidized bed reactor (FBR) has shown remarkable results in treating water contaminated with perchlorate. In a biological treatment process, bacteria reduce perchlorate to chloride and oxygen using a carbon source such as ethanol and acetate. These chemical carbon sources are expensive to treat huge volume of water. The objective of this study was to evaluate wastewater from the industries in Nevada as a suitable alternative to those commonly used carbon sources to reduce the operating cost. This study was conducted with commonly used carbon sources- Acetate, Ethanol, Glucose, and Lactate, and the wastewater from Glycerol, Ocean spray, and Unilever. The bacterial growth rate was observed higher in the reactors with lactate, glucose, and glycerol than with other carbon sources. Perchlorate degradation was the highest for acetate (98%), 21-45% for other commonly used carbon sources, and 25-36% for industrial wastewater. Based on this study, the perchlorate degradation rate in reactors using industrial wastewater was similar to degradation rate for Ethanol, Glucose, and Lactate. The higher degradation rate with acetate might be because the perchlorate degrading culture used in this study was enriched in acetate. This suggests that use of bacterial culture enriched in the industrial wastewater might enhance the perchlorate reduction. Further study is recommended to operate FBR inoculated with bacteria enriched in the industrial wastewaters.

Issues associated with the use of untreated roadside springs as a source of drinking water

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Roadside groundwater springs are frequently used as a source of drinking water across Pennsylvania. A survey of approximately 1,000 Pennsylvania residents in 2014 found that 33% had consumed water from a roadside spring at least once and 9% consumed water routinely (weekly to monthly). The most common reasons for the use of roadside springs were better tasting water and the perceived "natural" qualities of spring water. State and local policy makers have debated the potential risks and regulation of roadside springs in the early 1990's but no scientific data has ever been collected to document the potential water quality risks from these springs. Samples were collected during 2013 from 35 major roadside springs with easy access from public road rights-of-way and were analyzed for 20 inorganic and microbiological water quality parameters. Nearly all (34) of the springs failed at least one health-based drinking water standard with the most common problems being coliform bacteria and *E. coli* bacteria. Spring waters were also generally soft, acidic and corrosive with low levels of total dissolved solids. A follow-up study during 2014 on a subset of eight springs which previously contained *E. coli* bacteria looked at the seasonal variability of water quality in the springs along with additional water quality parameters. This study found some seasonal variations in water quality along with the presence of *Giardia* and *Cryptosporidium* spores in 50% of the springs. These scientific data are critical to better communicate the health risks associated with the use of roadside springs to both the general public and the various agencies and/or municipalities that control access to these water supplies.

Bio: Bryan Swistock is a Water Resources Extension Specialist in the College of Agricultural Sciences, Department of Ecosystem Science and Management at Penn State University. He received a bachelor's degree in Environmental Health from Indiana University of Pennsylvania and a master's degree in Environmental Pollution Control from Penn State University. For the past 27 years he has conducted research, teaching and extension programs on emerging water resources issues throughout Pennsylvania. Over the past ten years, Bryan has focused on projects related to the proper construction, testing and management of rural drinking water supplies. He has authored numerous referred journal articles and presented hundreds of educational programs on drinking water issues.

Annual and seasonal fluxes of particulate matter from atmospheric deposition to Lake Tahoe: Assessment from a long-term passive monitoring program

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Lake Tahoe, an oligotrophic lake largely appreciated for its water clarity and geographic setting, has been reported of its deteriorating water clarity over the past few decades due to nutrient and sediment particle inputs. Contributions from atmospheric deposition of particulate matter (PM) have been suggested to be substantial, yet inadequately quantified. This study established three long-term monitoring sites (7/18/2013 – 8/19/2014) in the Lake Tahoe Basin to investigate dry and wet PM deposition for 1) offshore/background, 2) near-shore, and 3) upper watershed conditions. Dry deposition was quantified on passive substrates using a scanning electron microscope, while wet deposition was based on particles suspended in rain and/or snow water and analyzed by a laser diffraction spectrometer. Size-resolved (1-64 μm for dry deposition; 0.5-20 μm for wet deposition) particle fluxes were attained with 24-hr resolution. During August 2013 – February 2014, monthly averaged daily number fluxes by dry deposition (DNFdry) exhibited a bi-modal size distribution with maximal and second modes in the 1-2.5 μm and 4-10 μm bins, respectively. The near-shore site showed twice as much DNFdry as that at the upper-watershed site, suggesting impacts by tourist activities. DNF due to wet deposition (DNFwet) showed a skewed size distribution with fine-mode PM (0.5-1 μm) accounting for 75% of DNFwet. One average, DNFwet is 6 to 9 times higher than DNFdry, though only 9% of days recorded detectable precipitation. The normalized total DNF is estimated to be 1.73×10^4 # $cm^{-2}day^{-1}$ (DNFdry: 7.88×10^3; DNFwet: 9.43×10^3) if only PM of size 1-64 μm is considered. Total DNF agreed with the Lake Tahoe Total Maximum Daily Load (TMDL) estimate within a factor of 3. This suggests a significant contribution of precipitation to the PM flux. Annual and seasonal PM loads via atmospheric deposition will be presented and their implications for the Lake Tahoe water clarity will be discussed.

Bio: Ya-Chun Tai, nicknamed "Anna", is a graduate research assistant studying atmospheric sciences in a joint program between the University of Nevada, Reno, and Desert Research Institute. She received her B.S. in Atmospheric Sciences at Florida State University in 2012 and worked one year in the Cloud and Aerosol Research Laboratory/Group as a research assistant at the National Taiwan University, Taipei, Taiwan. Ya-Chun's research interest lies in understanding the relationship between aerosols and mesoscale weather events, as well as their combined effects on air quality. In her spare time, Ya-Chun enjoys playing badminton and learning Thai. Ya-Chun is currently working towards her master's degree focusing on the impact of atmospheric deposition on the water clarity in Lake Tahoe.

Evaluating the effects of time-scales on long-term changes in streamflow

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Change in climatic conditions as a result of global warming has become one of the most crucial issues of the present time. Climate variability is causing many changes in the natural environment including the hydrologic cycle, which influences the inadequate water resources. Meeting the demand of limited water resources with the increasing population has become a big challenge for water resource managers. Analyses of trends in hydrologic variables (i.e., temperature, precipitation, streamflow etc.) have been helpful to deduce changing patterns in global and local climate. This study focuses on detecting long-term (gradual) and short-term (abrupt) trends in streamflow pattern of the continental USA. The study also analyzes the effect of climate change on the seasons and different time-scales. The spatiotemporal distributions of these patterns were also assessed. Discrete Wavelet Transform (DWT), which is a relatively new technique used in spectral analysis, has been used in this study to analyze the streamflow of time-series data. DWT has been used to decompose the data into lower resolutions which were then analyzed with statistical tools. Modified Mann-Kendall (MK) trend tests were used to analyze long-term trends whereas Pettit test was used to analyze abrupt shifts or steps. Records from 237 unimpaired streamflow stations with 62 years (i.e., 1952-2012) of continuous data were collected and the streamflow patterns were analyzed for water-year, four seasons (Fall, Winter, Spring and Summer) and three different dyadic scales (i.e., 1 year, 2 years and 4 years). Both gradual and abrupt changes were analyzed for different time-scales and their spatial distributions were evaluated. The results of this study may assist water managers to efficiently plan and manage the water resources under changing climatic conditions on different time-scales.

Assessing simulated transmissivity in flow models with complex hydrogeology

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Transmissivity within an aquifer is directly proportional to the aquifer thickness and the estimated aquifer conductivity. Accurately simulating transmissivity in numerical models poses a significant challenge when modeling complex groundwater systems. With complex geology (especially in fractured systems) and multiple hydrogeologic units, transmissivity can vary over several orders of magnitude in relatively short distances. To test methods for computing simulated transmissivity from a numerical model, a five-layer MODFLOW model will be constructed with known hydraulic conductivities assigned to each layer. Each layer will be pumped in a simulated pumping test and analyzed using Cooper-Jacob straight-line method. A pumping well will be placed in each layer and a simulated aquifer test will be conducted to assess the effect of multiple layers with varying hydraulic conductivities on simulated transmissivity. This will be an aid in assessing how multiple layers of various transmissivities in complex hydrogeologic settings are affecting each other in the aquifer test analysis. Additional work will compare simulated transmissivity values from complex regional groundwater models to field-estimated transmissivities. Field-estimated values from single well aquifer tests will be compared against; a summation of transmissivities of multiple hydrogeologic units in a model cell, a weighted arithmetic mean of hydraulic conductivity over the model layer thickness, simulated hydraulic conductivity over the entire thickness of an HGU represented in the model, and simulated hydraulic conductivity over the real-world tested interval of the pumping test. This comparison will be used to assess the accuracy of transmissivity calculations in groundwater models.

Bio: Afan Tarar is a graduate student attending UNLV, where he also received a B.S. in Cellular and Molecular biology. The focus of his graduate studies is primarily groundwater and hydrology. Currently, he is working with the USGS NVWSC, where he has accumulated 534 hours of volunteer service and hands on experience. Mr. Tarar volunteered with the USGS over the summer and was offered a temporary position there having helped with some ongoing USGS projects. Through the USGS, Mr. Tarar was able to start work on his thesis, Assessing Simulated Transmissivity in Flow Models with Complex Hydrogeology, with Dr. Wayne Belcher and Dr. David Kreamer, with the ultimate goal of becoming a modeler using a variety of different software.