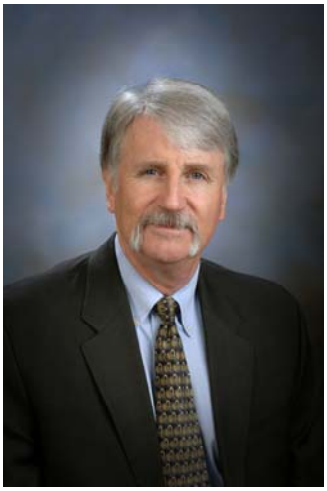
Colorado State University



2008 Research Colloquium

Global Water: From Conflict to Sustainability Challenges and Opportunities in an Interdependent World

Welcome and Thank You for participating in the Global Water Research Colloquium!

These are exciting times at Colorado State University as we position ourselves to address globally important research questions.

Virtually all world development and governmental organizations agree that adequate supplies of clean water is one of the most critically important issues facing the world if we are to thrive in the 21st Century. CSU has a long history of engagement in international and domestic water research, going back to the very beginning of this University in 1870. To meet the future challenges of water resources research, teaching and outreach we must engage across all of CSU's Colleges, academic departments and special units.

The Global Water Research Colloquium is one step in communicating our successes and vision for water research. This Colloquium is a tribute to the many outstanding water research faculty at CSU and we anticipate that this is just a starting place for more communication and collaboration among the faculty that apply their disciplines to water. We are pleased to link this event to Hydrology Days and the 50th Anniversary of Watershed Science at CSU to create a week-long dialog on water at CSU for our faculty, students, research partners and alumni to look forward future challenges and continued successes in water research.

Sincerely,

William H. Farland
Vice President for Research
Colorado State University

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VPR Global Water Colloquium

Global Water: From Conflict to Sustainability

Challenges and Opportunities in an Interdependent World

Tuesday, March 25, 2008 - Hilton Fort Collins

Opening Remarks 8:30am	**Topic**: Water: Past, Present and Future at CSU – Where have we been, where are we going? **Speaker**: Bill Farland (VPR)
Introduction 8:45am	**Topic**: Global Water: Challenges and Opportunities in an Interdependent World **Speakers**: Evan Vlachos (Sociology), Neil Grigg (Civil & Env Eng)
9:15am	Introduce Research and Art Posters
9:30am	Refreshments and Poster Session
1st Session 10:00am	**Topic**: Water Supply for Human Systems **Moderator**: Neil Hansen (Soil and Crop Sciences) **Speakers**: Jorge Ramirez (Civil & Env Eng), Valerie Assetto (Political Science)
2nd Session 11:15am	**Topic**: Health, Sanitation and Infectious Diseases **Moderator**: Jay Nuckols (Veterinary Medicine & Biomedical Sciences) **Speakers**: Pieter Johnson (UC Boulder), Dan Gould (Vet Medicine)
Lunch 12:15pm	**Introduction**: Jim Cooney (International Programs) **Keynote Speaker**: Brian Richter (TNC) **Topic**: Global Water Opportunities from a Practical Ecological Perspective
3rd Session 1:30pm	**Topic**: Adaptation to Changing Hydrologic and Climate Regimes **Moderator**: LeRoy Poff (Biology) **Speakers**: Ellen Wohl (Geosciences), Graeme Stephens (Atmospheric Sciences)
2:45pm	Poster Awards
3:00pm	Refreshments and Poster Session
4th Session Panel 3:30pm	**Topic**: Where are the coming opportunities for the Land Grant University to engage in global water issues? **Moderator**: Melinda Laituri (Forest, Rangeland and Watershed Stewardship) **Participants**: Eugene Stakhiv (IWR, Army Corps of Engineers), Brian Richter (TNC), Pierre Julien (Engineering), Ellen Wohl (Geosciences), Valerie Assetto (Political Science)
Conclusion 4:45-5:00pm	**Topic**: Closing Remarks **Speaker**: Evan Vlachos (Sociology)
Reception 5:30pm	**Master of Ceremonies**: Luis Garcia (Civil and Env Eng) **Topic**: Global Dimensions of Watershed Science **Speaker:** Jim Meiman (Warner College of Natural Resources)

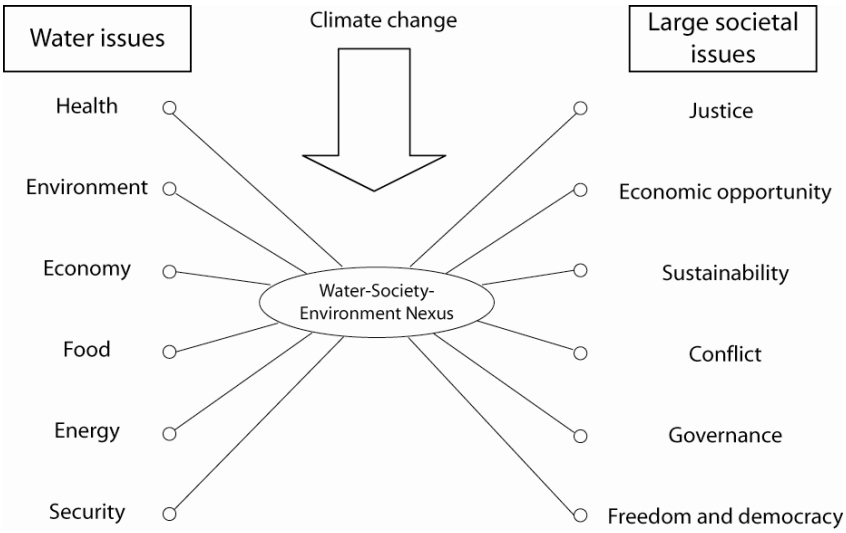
Presentation Abstracts

Global Water: Challenges and Opportunities in an Interdependent World
Neil S. Grigg and Evan Vlachos - March 25, 2008

Abstract:

While the 2008 election focuses on war, the economy, and gas prices, a global water crisis continues to build. Evidence includes climate change, pollution, flooding, and the losses and suffering they cause. Because water issues involve all scales from local to global, these issues are seen in different ways by different groups.

Much of the water crisis is caused by humans who decide how to manage water and create impacts on it. Problems such as water scarcity, water conflict, habitat loss, and flood disasters are all within our ability to solve, but institutional barriers block us. The discussion can be framed in different ways, and the one adopted for this paper is shown below:



On the left of the diagram are issues that are affected directly by water services such as water supply, wastewater, flood control, water for food and energy, and so on. On the right are larger societal issues, which become inputs and outputs of the water management equation. For example, water decisions can create just outcomes and help alleviate poverty, while injustice can lead to distorted water allocation and management

outcomes. The water-society-environment nexus shown illustrates why, although water issues may be local and solvable, they are inextricably linked with larger societal issues.

The grand objective of water management is sustainability, but what will it take to achieve it? Most people recognize that there is no magic bullet or super technology waiting in the wings, but it will take wise actions at many scales, locales, and times. The central questions are: what are these actions; who defines them; and how can they be encouraged and caused to happen?

Answers to these questions have been developed by the international community through the paradigm of "Integrated Water Resources Management" (IWRM), which is essentially a way to balance all viewpoints to achieve wise water management. Its principles can be presented in different ways, such as this list:[1]

- Effective policies
- Effective planning, decision making, and monitoring on watershed basis
- Shared governance with clear roles and relationships
- Coordination mechanism and rules for consensus and conflict resolution
- Transparency and accountability
- System to allocate water efficiently and equitably
- Incentives for conservation and best management practices
- Shared economic, environmental, and social goals
- Assessment and triple bottom line reporting on watershed basis
- Corporate social responsibility programs for water utilities
- Effective regulation
- Enabled water workforces and public

IWRM can be interpreted as the practice of effective governance on a public-private issue with high scientific and technical inputs. Many disciplines at Colorado State can contribute to advancing its agenda. While the biggest issues seem to involve politics and governance, science and engineering problems loom large, and practical disciplines such as business education have major roles as well.

To illustrate the roles of disciplines in IWRM, consider three objectives of higher education: preparing graduates for useful and satisfying occupations, to contribute to the solution of important societal problems, and to add to the body of fundamental knowledge about natural and social phenomena. These three objectives can be seen at work in global water issues such as water and sanitation, scarcity, water quality, and organization of the water industry.

Water supply and sanitation is recognized as an essential factor in overcoming poverty and improving life in lower-income countries. The occupations involved include environmental health and engineering and the knowledge required focuses on systemic and institutional issues, rather than on new scientific breakthroughs. Therefore, policy and behavioral disciplines share responsibility with science and engineering to make improvements in villages and cities across the developing world.

[1] The list is from a forthcoming book entitled "Total Water Management: Leadership Practices for a Sustainable Future" by Neil S. Grigg (American Water Works Association, 2008). The book explains the principles required for a sustainable water future in some detail.

With world population moving toward the seven billion mark and with migration to cities continuing, climate change threatens to exacerbate drought and water scarcity in many places. Just this year we have seen severe drought in normally-humid Atlanta, and National Geographic magazine has just published an alarming view of the West without adequate supplies in the Colorado River. These problems of water security require not only the best thinking of engineers; they will require the best actions that our public institutions can deliver to bring harmony and equity into transparent negotiations that occur in frameworks of shared governance.

While in the United States the Clean Water Act did much to solve the worst problems of municipal and industrial wastewater, more subtle but insidious problems of water quality remain. Locally, even our seemingly-pristine supplies seem threatened by nutrients and even toxic algal blooms. These local problems can escalate to the point where even large oceanic systems are threatened, such as we see in the expanding dead zone of the Gulf of Mexico.

Water problems such as these do engagement of diverse stakeholder groups and application of the principles of IWRM. However noble these intentions, decisions and actions occur within the framework of the water industry, where designated groups exercise much of the control over water management actions. As these groups organize to confront the issues facing them, they do so in a climate of incentives and limited funding that can shackle innovation and positive stewardship. Therefore, another area of required advancement in water management is organizational improvement among utilities, agencies, and other institutions. This can involve proposals such as privatization or cooperative public-private arrangements. These can be fraught with difficulty, as in the case of Cochabama, Bolivia, where a water privatization plan triggered social unrest that threatened the stability of government. Therefore, business proposals for water improvement must be scrutinized by policy and social scientists to assure their viability in the context of culture, as well as for pure efficiency.

Our greatest challenges at Colorado State are to organize and find support for our programs that confront the global water crisis. The knowledge to solve water problems must come through interdisciplinary approaches. Yet, research financing and university incentives do not promote these interdisciplinary approaches and the university must find the direction and the will to offer solutions. Given Colorado State's historical record in water management, we are positioned well to lead with new program areas that address basic needs across the planet. These can help alleviate poverty, end flood disasters and waterborne diseases, and motivate land and water management toward a green Earth.

Achieving such worthwhile results will not be easy, but it is a noble mission for the public university. Solving the vexing problems of program organization and support will not be easy, given the many demands on the university. However, we can succeed if Colorado State affirms anew that water issues define a large part of its continuing mission. Then, we must organize programs to confront the larger interdisciplinary questions, seek out research funding from diverse sources, and take a leadership role in solving global water issues. Work on global water problems offers Colorado State a chance to prepare students and create new knowledge in a central arena of the 21st Century. Giving attention to these critical issues will demonstrate the vitality of higher education as a relevant institution to prepare graduates to tackle tough issues while adding knowledge that can create resilient and successful future societies.

Dr. Neil Grigg
Biographical Sketch

Dr. Grigg has been a Professor of Civil Engineering at Colorado State University since 1982 and served as Department Head of Civil Engineering since 1991. He has published five books, three of which are textbooks in the general field of public works and water resources infrastructure. He developed several graduate courses related to public works management including: Infrastructure and Engineering Management, Urban Systems Engineering, Urban Water Management, and Water Resources Planning. Dr. Grigg made contributions to both the public and private sector of water resource management. In 1968, he co-founded Sellards & Grigg, Inc., a Denver-based civil infrastructure engineering firm. From 1979-1982, Dr. Grigg was Assistant Secretary for Natural Resources, State of North Carolina, where he was responsible for the state agencies of Environmental Management, Water Resources, Marine Fisheries, Forest Resources, Soil and Water Conservation, Parks and Recreation, and Coastal Resources. During this time, he reorganized the state water resources program and led an effort to create a Division of Water Resources. In 1981, Dr. Grigg was awarded the North Carolina Governor's Award for Environmental Protection. In 1998, Dr. Grigg received the Warren A. Hall Award, bestowed by the Universities Council on Water Resources.
In the international arena, Dr. Grigg served as Director of Office of the International Education and Director of the International School for Water Resources at Colorado State University. He was also a member of the steering committee for the World Congress on Engineering Education. As a former member of the American Public Works Association's Council on International Collaboration, he helped organize a fellowship program that brought foreign students to the Congress. In addition, he developed a UNESCO program of cooperation with UFRGS (Brazil) and directed a US-Italy videotape course in water systems management. He has led professional delegations to South Africa (1996), Vietnam (1993), Japan (1992), and China (1987).

Dr. Evan Vlachos
Biographical Sketch

Dr. Evan Vlachos is Professor of Sociology and Civil Engineering at Colorado State University, Fort Collins, Colorado, where he is also Associate Director of the International School for Water Resources. He holds a Law degree from the University of Athens (1959), and M.A. (1962) and Ph.D. (1964) degrees in Sociology from Indiana University. Dr. Evan Vlachos has worked on a variety of projects in the United States and abroad on aspects of urban planning, water resources planning and management, forecasting and futurism, technology assessment and demography. He has served in a variety of US and international commissions, especially on water resources and the environment. Dr. Vlachos has served as Member and Chairman of the Environmental Advisory Board, U.S. Army Corps of Engineers between 1982 and 1987. He has been a member of the Advisory Panel on Environmental and Earth S&T in NATO, Brussels (Eastern Europe and Russia) between 1993 and 2000. Dr. Vlachos is also a member of UNESCO's Committee on "Water and Civilization." Dr. Vlachos is the recipient of the Army's Outstanding Civilian Service Medal (1987), the CSU Oliver Pennock Distinguished Service Award (1988), and the American Water Resources Association's Icko Iben Award (1993).

Session I

Topic: Water Supply for Human Systems
Moderator: Neil Hansen (Soil and Crop Sciences)
Speakers: Jorge Ramirez (Civil & Env Eng), Valerie Assetto (Political Science)

Addressing Water Needs for Human Systems Through Interdisciplinary Efforts at Both Global and Local Levels

Dr. Neil Hansen
Dept. of Soil and Crop Sciences, Colorado State University

Abstract:

Irrigated agriculture is a vital part of global food production and food security and is responsible for nearly 90% of global water consumption. Consideration of water for human systems must address the importance of irrigated agriculture and its role in food supply, economic activity, and environmental sustainability. The ability to develop, maintain, and expand irrigation is vital to much of the developing world.

Many of the global water challenges surrounding irrigation are also being faced within Colorado. For example, unsustainable irrigation practices that cause waterlogging and soil salinization occur in the major irrigated river valleys in Colorado. A myriad of factors including water rights, water policy, and hydrology slow the adoption of more sustainable approaches. Another pressing issue is competition for water between rapidly growing urban population centers and agricultural users. For example, in the Colorado-Big Thompson Water Project, ownership of water shares has shifted from 90% agricultural to being 60% owned by municipalities and industry. In the next twenty-five years, Colorado's population is expected to exceed 7 million. A statewide water supply survey predicts that the South Platte Basin will experience a 60 percent increase in water demand by 2030 and it is expected that significant areas of irrigated farmland will dry up to help supply water needs. Solutions to these complicated issues require a highly interdisciplinary effort. For example, development of new agricultural systems that increase irrigation and crop water use efficiency needs to be coupled with the establishment of successful water organizations that interface between agricultural and urban water users. Similarly, engineering needed for new water conveyance, storage, and monitoring needs to be coupled with economic and political analysis at multiple scales. All of these issues must consider environmental and ecological issues as well as the potential influence of the changing climate.

Colorado State University has long been recognized as a leader in international irrigation development, with notable accomplishments in Pakistan and Egypt, among others. The model for past success wasbased on cooperative efforts of interdisciplinary teams that addressed social, organizational, legal, economic, productivity, water management, and technology areas of need. There is a great opportunity to continue successful water projects both locally and globally through interdisciplinary teams and efforts originating from CSU.

Dr. Neil Hansen
Biographical Sketch:

Neil Hansen is an Associate Professor of Soil Science at Colorado State University with specialization in soil and water conservation in both dryland and irrigated crop production systems. Dr. Hansen earned his Ph.D. degree from the University of Minnesota. He leads a field oriented research program to develop cropping systems that conserve soil and water resources. Specific research areas include soil erosion, soil carbon dynamics, managing agricultural phosphorus to protect water quality, deficit irrigation practices for grain and forage crop production, and iron deficiency chlorosis in soybean. He is currently evaluating irrigated cropping systems that reduce consumptive water use in order to make water available to meet growing demand by urban users. Dr. Hansen leads an active outreach education program involving farm producers, agricultural professionals, and staff from federal and state agencies on topics related to soil and water conservation and management. He also had international outreach work including agricultural projects in Russia and Australia.

Global Hydrologic Cycle and World Water Resources Vulnerability: Scientific Challenges and Opportunities

Jorge A. Ramírez
Department of Civil and Environmental Engineering, Colorado State University

Abstract:

Global population and economic growth has resulted in a tremendous increase in water use worldwide. The demand for water is expected to continue increasing in the foreseeable future. Simultaneously, although global water supply may be considered constant, its temporal and spatial distributions are changing dramatically as a result of natural and anthropogenic climate variability and change. Therefore, the uncertainty in global water supply availability to meet human needs is increasing. The natural variability of hydrologic processes coupled to the uncertainty in our understanding of future hydrologic, climatic, social, and political drivers changeboth the vulnerability of human systems to water supply and our ability to sustainably manage those resources. In order to effectively manage our available water resources, we must quantify the vulnerability of the coupled hydrologic–climatic–ecologic–socio-political system.

The water research programs at Colorado State University have had a world-renowned history of significant contributions to hydrologic science, atmospheric science, and water resources management. In this presentation we will examine the global and local scientific challenges posed by the hydrologic, atmospheric, ecologic, and socio-political drivers of that vulnerability, as well as the opportunities for interdisciplinary research that those challenges present to scientists and engineers at Colorado State University.

Biographical Sketch:

Dr. Jorge A. Ramírez is professor of Civil and Environmental Engineering at CSU since 1990, with a focus on water resources, hydrologic, and environmental sciences and engineering. He received a Doctor of Philosophy in hydrometeorology from MIT in 1988, a Master of Science in hydrology and water resources from MIT in 1982, and a BS in civil engineering from the School of Mines of the National University of Colombia in Medellin in 1981. Dr. Ramírez has consulted for United Nations Development Programme at the National Institute of Hydrology in India, the Korean Water Resources Corporation, the hydroelectric power sector of Colombia, and has vast international experience, holding positions most recently with renowned institutions such as the Swiss Federal Institute of Technology in Switzerland and the Center for Environmental Research and Monitoring (CIMA) in Italy. In 2005 he was honored with the George T. Abell Outstanding Mid-Career Faculty Award at CSU and has served on science and technology committee panels for the National Science Foundation. On campus, Dr. Ramírez teaches both undergraduate and graduate courses in Engineering and Physical Hydrology and organizes Hydrology Days, the internationally recognized conference on the latest research regarding scientific and technological advances in hydrologic science and engineering.

Effective Management Strategies for International Fresh Water Supply Disputes: Bringing Politics Back Into the Equation

Dr. Valerie J. Assetto
Dept. of Political Science, Colorado State University

Abstract:

International fresh water supply disputes engage a myriad of political concerns and factors that often make long-term management and resolution especially problematic. Failure to address the political dimension of fresh water disputes often predisposes an otherwise effective management agreement to failure in the long term. A small number of political science scholars have applied the two levels analysis approach to analyze international disputes that resonate at both the international and national levels to understand what factors predispose a conflict to intractability. This is particularly effective in highlighting the role of political rivalries and interests in such a conflict.

The first part of this talk will examine the domestic political variables that most often impact long-term international conflicts over water. These include historical factors present in the establishment of the state, current rules and political dynamics, and group conflicts within the state that may fracture stakeholders even further. The salience of the water dispute to domestic groups, economic health, and politics will also be examined.

International variables will then be explored. Historical and contemporary rivalries, the role of third party actors, and the nature of trade and finance relationships as they impact water disputes will be illuminated.

Finally, the domestic and international factors discussed will be linked to demonstrate how failure to account for these can predispose a management solution to suboptimal outcomes and even failure.

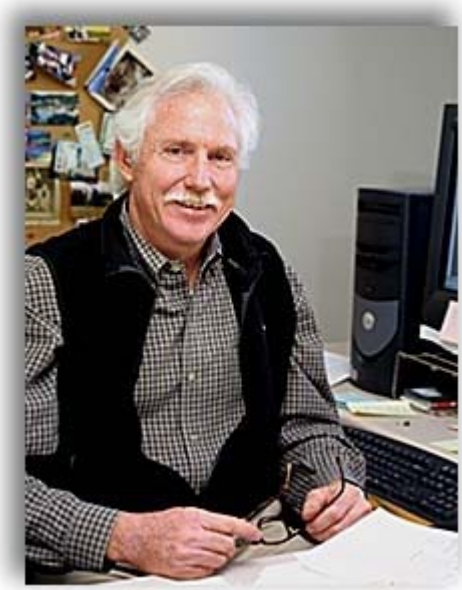
Biographical Sketch:

Before coming to CSU in 1981, Dr. Assetto earned her B.A. *summa cum laude* from Lehigh University and her M.A. and Ph.D. from Rice University. Valerie Assetto's greatest service contributions have been in advancing the international mission of the University. Commitment to international understanding has marked her entire career, as illustrated by her teaching, mentoring, and scholarship. In 2004 Dr. Assetto was awarded the Oliver P. Pennock Service Awards for her leadership role in the International Studies Association and the American Association for the Advancement of Slavic Studies. On campus, Dr. Assetto has been central to the Russian and East European Interdisciplinary Studies Program. Specifically, Dr. Assetto was instrumental in establishing the student exchange program with the Technical University of Budapest.

Session II

Topic: Health, Sanitation and Infectious Diseases
Moderator: Jay Nuckols (Veterinary Medicine & Biomedical Sciences)
Speakers: Pieter Johnson (UC Boulder), Dan Gould (Vet Medicine)

Jay Nuckols
College of Veterinary Medicine and Biomedical Sciences, Colorado State University



Abstract:

Non pathogenic and non toxic water supply is essential to all life forms. There exists global disparity in whether one or both of these causal factors are more highly associated with water supply related diseases. In geographic areas such as the United States where pathogens in water supply are "in check", the emphasis of field research (including epidemiology) has generally shifted from pathogens to toxic chemicals and their association with chronic diseases such as cancer. For example, it was reported by the World Health Organization in 2000 that at least two million deaths per year, mostly young children, were attributable to water supply related diarrheal diseases. Most all of these deaths occur in 3rd world countries, and most are considered preventable. Therefore, the priority for research spending in those countries is, and should be, field-oriented and application based - "how can we rid the water supply of pathogens that are taking these young lives?" In contrast, the U.S. National Cancer Institute is currently conducting a multimillion dollar study with a primary objective to determine the extent to which naturally occurring arsenic in the water supply can explain the excess incidence of bladder cancer in New England (where it is definitely an "old person" disease; average age of diagnosis of around 65 years). Likewise for both pathogens and toxic compounds, laboratory based research on waterborne disease has generally shifted to molecular based research in order to elucidate the mechanisms of disease causation. The research emphasis in the former region is on saving young lives, the emphasis in the latter is on extending older lives. Both research quality of life issues. Both are justified by the degree to which the water supply is non pathogenic and non toxic in each respective geographic region.

It has been my observation over the past 15 years that water related research concerning environmental health and infectious disease in the College of Veterinary Medicine and Biomedical Sciences at Colorado State University has mirrored this global pattern by a shift in research emphasis from field studies of water borne pathogens and infectious disease epidemiology to a focus on chronic disease epidemiology concerning water borne toxic contaminants, and on molecular level mechanisms related to causation of water supply related diseases. In both cases, public health scientists are working to save lives and improve quality of life; but the extremes in emphasis are important when we discuss the best course to take in research directions and opportunities for the Water Resource Research Program at Colorado State University.

The objective of our session on Health, Sanitation and Infectious Diseases is to present examples of water resource related research being conducted by Colorado based health scientists. We have invited two very distinguished health effects researchers. Both research topics fit the paradigm of field oriented applications based research, but lend themselves to more mechanistic study of exposure and causation of disease. Perhaps most importantly for the purpose of this colloquium, these research programs demonstrate an opportunity and essential need for integration with water resource research.

Dr. Jay Nuckols
Biographical Sketch:

John R. Nuckols holds degrees in Engineering from Texas A & I University (BS, 1973), Northwestern University (MSCE, 1975) and the University of Kentucky (PhD, 1982). Dr. Nuckols is trained as an environmental engineer and hydrologist, and has over 25 years of experience in the field of applied environmental sciences, including fate and transport modeling, environmental health assessment, and exposure assessment for epidemiological studies. In 1992, Dr. Nuckols established the Environmental Health Advanced Systems Laboratory at Colorado State University, with a mission to conduct research in the development and application of computer-based technology for exposure assessment in environmental epidemiological studies. Since September of 2000, Dr. Nuckols has served as a consultant to the Occupational Epidemiology Branch of the National Cancer Institute on exposure assessment in environmental epidemiology studies, including the application of GIS.

Linking Nutrient Enrichment and Disease Emergence in Aquatic Ecosystems

Pieter Johnson
Ecology and Evolutionary Biology, University of Colorado

Abstract:

Worldwide increases in the number of human and wildlife diseases have challenged ecologists to understand how large-scale changes affect host-parasite interactions. Aquatic ecosystems represent a nexus between habitat alteration and disease emergence, and we focus here on how human-mediated changes to aquatic environments affect parasites and pathogens. We explored interactions between a particularly widespread form of anthropogenic change (aquatic eutrophication) and the incidence of disease in marine and freshwater environments. We considered the consequences of eutrophication on macroparasitic-, microparasitic- and infectious and non-infectious diseases of humans and wildlife, including cholera, West Nile virus, malaria, harmful algal blooms, coral reef diseases and amphibian malformations. The objectives were threefold: first, to examine broad-scale patterns in the types of parasites and pathogens favored under eutrophic conditions and how these patterns vary with environment, degree of eutrophication, and type of disease. Second, we examined evidence for the ecological mechanisms underpinning relationships between nutrient enrichment and disease. While parasite abundance is often correlated with nutrient pollution, the mechanisms responsible for these patterns are frequently confounded, and we therefore focused on recent experimental studies examining this issue. And finally, we explored how forecasted changes in nutrient deposition are expected to affect the levels of pathogenic disease. Results derived from published and unpublished research indicate that nutrient enrichment has diverse effects on disease that depend on the type of pathogen, host species and condition, attributes of the aquatic system and the degree of enrichment. Nutrient enrichment can alter disease dynamics by changing host density, host distribution, infection resistance, pathogen virulence or toxicity, or by causing disease directly. While low to moderate levels of nutrients can increase species richness and parasite abundance, higher levels often lead to a decline of parasite species richness. However, even as parasite richness declines, pathology and disease sometimes become more severe. Eutrophication also causes pronounced shifts in the types of parasites and pathogens in aquatic environments, favoring generalist or opportunistic parasites with direct or simple life cycles. Collectively, these pathogens may be particularly dangerous because they can continue to cause mortality even as their hosts decline, potentially leading to sustained epidemics or extirpations. Given that nutrient-loading will almost certainly become more severe and widespread in the coming decades, eutrophication will continue to be an important factor in the etiology of human and wildlife diseases. We emphasize the importance of studies integrating experiments and ecological modeling to identify mechanisms and feedbacks in the interactions between nutrient-loading and host-pathogen dynamics.

Dr. Pieter Johnson
Biographical Sketch:

Dr. Johnson received a Doctor of Philosophy from the University of Wisconsin, Madison in Zoology with a minor in Ecological Statistics. He was the recipient of a National Science Foundation Graduate Research Fellowship. Upon completing his Postdoctoral work at the Center for Limnology, he serves at the University of Colorado, Boulder as Assistant Professor in the Ecology and Evolutionary Biology Department. Research conducted in the Johnson Lab focuses on two pervasive and inter-related forms of biological change: disease emergence and species invasions. Both have important consequences not only for individuals and populations, but for entire ecological communities and ecosystem processes. Invasions and disease also have costly economic and health repercussions for human societies. Most recently, Dr. Johnson has been recognized by the larger scientific community for his findings linking runoff with high levels of farm nutrients to parasite infections causing frog deformities in ponds and lakes across North America.

Ruminant Livestock Production Problems Caused by High-Sulfate Water

Dan Gould
College of Biomedical Sciences and Veterinary Medicine, Colorado State University

Abstract:

Domestic ruminant animal species serve a valuable role in sustainable agricultural systems. The ruminant advantage is the ability to convert the renewable resources of rangeland, pasture, and crop residues or other by-products into food that can be consumed by humans. Water represents an essential nutrient for livestock, and compromised water quality can interfere with livestock health and productivity. Anti-quality factors that can affect water are numerous. Some simply reduce water intake because of poor palatability. Others produce nutritional imbalances, and some have toxic effects. This presentation focuses on the adverse effects of high sulfur intake in cattle. These studies were initiated as a result of disease investigations by Colorado State Veterinary Diagnostic Laboratory personnel and collaborators in the CSU Integrated Livestock program, USDA/APHIS, and the USEPA. Additional collaborators included investigators in Canada, Argentina and Chile.

Many areas of the world have naturally high levels of sulfate in water. Consumption of high-sulfate water by humans, and other animals with simple stomachs, is associated with diarrhea that subsides after acclimation. The situation is much different in ruminant animals. When cattle ingest excessive amounts of sulfur in water and/or feed, sulfate-reducing bacteria that are a normal part of the stomach fermentation microflora reduce the sulfur to highly toxic hydrogen sulfide. In its most severe form, toxicity is manifested as irreversible injury to areas of the cerebral cortex of the brain. The disease is called polioencephalomalacia (PEM) or more colloquially, blind staggers. Hot weather tends to increase the risk of PEM because cattle drink more water, thus increasing the intake of sulfur. In addition, the concentration of sulfate in surface water increases as a result of evaporation.

Lesser amounts of ingested sulfur produce imbalances in copper nutrition. Copper and other metals react with sulfide to form insoluble complexes that are poorly absorbed. The resulting copper deficiency interferes it growth and reproduction. Dairy cows with modest increases in sulfur intake have reduced milk production.

Mitigation approaches need to be economically viable and of appropriate scale and complexity to fit the type of livestock production operation. Ranches probably represent the most difficult situations because the forage resources are spread over large areas, and local water sources must be used. More detailed understanding local geological and hydrological characteristics could aid in developing the most advantageous livestock water sources. Simple, inexpensive purification systems using chemical, microbial or other processes could possibly be developed for reducing sulfate content of water from wells or ponds. Larger, livestock operations, like feedlots and

dairies, could use more complex, centralized systems, but economic viability would always an important consideration.

Dr. Dan Gould
Biographical Sketch:

Dan Gould, Professor and Associate Department Head for Professional Veterinary Medicine and Clinical Service, received his BS and DVM (with high distinction) from CSU. He obtained his PhD from UC Davis in Comparative Pathology while studying brain lesions induced by Clostidium perfringens toxin. Board certified by the ACVP in 1974, Dan was an Assistant Professor at the Ohio State University before joining the CSU faculty in 1980. He was promoted to Professor in 1992. Dan has truly made major contributions to the Department throughout his career, earning his place in the Glover Gallery of Contemporary Distinguished Faculty to which he was named in 2004. Over the years, Dan has provided effective and indefatigable administrative service to the Department, serving as Chief/Section Head of Necropsy/Surgical Pathology since 1985 and Associate Department Head since 2002. Dan's research interests are extensive and varied, but primarily revolve around neuropathology, toxicology and metabolic/nutritional diseases.

Keynote Speaker: Brian Richter (TNC)
Introduction: Jim Cooney (International Programs)
Topic: Global Water Opportunities from a Practical Ecological Perspective

Global Water Opportunities from a Practical Ecological Perspective

Brian Richter
Co-Director, Global Freshwater Program, The Nature Conservancy

Abstract:

Water managers and engineers around the world are struggling to meet rapidly growing needs for water in cities, industries, and farms, and for producing hydro-electric power. Presently, more than two billion people lack electricity in their homes, and more than a billion lack access to clean drinking water. One of the tragic consequences of this dire situation is the ongoing death of a child every eight seconds from water-borne diseases. Fortunately, national governments around the world have pledged to tackle this tragedy head-on. The United Nations' Millennium Development Goals, created in 2000, include ambitious targets for the year 2015 that address poverty and hunger, child mortality, drinking water supplies, and sanitation. Unprecedented sums of money are being directed toward this global mission. History suggests that these development activities could also generate some very serious unintended consequences. The common response to water development needs has been heavily centered on the construction of new dams, water diversions, groundwater well fields, and other infrastructure. During the latter half of the 20th century, an average of two large dams were built somewhere in the world each and every day, resulting in more than 50,000 large dams, including 5,000 here in the United States. These dams and large water diversions block the pathways used by migrating fish, reduce and rearrange the patterns of flowing water that have choreographed aquatic life cycles for millennia, and change water quality. As the health of the world's freshwater ecosystems have declined, so too have their ability to support both biodiversity and human needs. These changes can have significant effects on the social fabric and economic well-being of affected people and communities, particularly among those whose livelihoods are still closely connected to nature. In the effort to provide new benefits such as water supply and electricity, the abundance of natural benefits provided by healthy freshwater ecosystems has been squandered too often, in too many places.

In the rush to further develop water resources for human purposes, we must fully apply recent advances in science and technology and be ever-mindful of unintended consequences of our development activities. Today, nearly 400 new dams are planned or under construction in Central America, more than 250 in Ecuador and 200 in Brazil, hundreds more in Ontario, and in China, nearly 50 in the Yangtze River basin alone. The degree of ecological damage and social disruption resulting from these new dams will depend largely upon the degree to which sustainability principles and practices are applied.

This presentation will highlight efforts by environmental and social interest groups to re-direct future water development toward a more sustainable path. It will touch upon recent progress being made in designing and operating dams for ecological sustainability, regional planning approaches that can help avoid areas of critical social or environmental concern, and the development of new "green certification" programs that could provide incentives for development interests to implement sustainable practices.

Brian Richter
Biographical Sketch:

Brian Richter has been involved in river science and conservation for more than 20 years. As co-leader of The Nature Conservancy's Global Freshwater Team, he leads a staff of hydrologists, aquatic ecologists, policy specialists, educators and communicators that support conservation projects across the Americas, Asia and the Pacific region.

Working with public agencies, academic institutions and other private organizations, Brian's work is focused on the global challenges of meeting human needs for water while keeping fresh water ecosystems healthy.

Brian has developed numerous scientific tools and methods to support river restoration efforts, including the *Indicators of Hydrologic Alteration software* that is being used by water managers and ecologists worldwide. He has published many scientific papers on the importance of ecologically sustainable water management in international science journals and co-authored a book with Sandra Postel entitled *Rivers for Life: Managing Water for People and Nature* (Island Press, 2003).

Brian has provided scientific or technical consultation on more than 90 river projects worldwide. His travels have taken him to the Yangtze River in China, the Paraguay River in Brazil, and the Sabie River in Africa, but the Moormans River in Virginia is home.

Session III

Topic: Adaptation to Changing Hydrologic and Climate Regimes
Moderator: LeRoy Poff (Biology)
Speakers: Ellen Wohl (Geosciences), Graeme Stephens (Atmospheric Sciences)

Modeling the Future of Aquatic Ecosystems?

LeRoy Poff
Department of Biology, Colorado State University

Abstract:

Freshwater ecosystems (streams, rivers, lakes, ponds, wetlands, riparian zones) are highly valued by society both for the many goods and services they provide and for their numerous other cultural and aesthetic amenities. For these systems to be sustainable and resilient to changing environmental conditions, they require adequate water of good quality at particular times of the year. Arguably, managing freshwater resources to allow for both direct human uses and ecosystem needs is one of the great challenges facing society in the coming decades. Currently, ecologists and river scientists have a robust understanding of the dependence of riverine ecosystems on natural hydrologic variability and how human modifications of natural flows alters them. There is an increasing urgency to transfer this general knowledge to useable models so that ecosystem needs can have a "place at the table" in the process of integrated water resources planning for various regions around the world. This urgency is amplified by anticipated increases in human demand for water and the uncertainties of future water supply.

As coupled ecological-social systems, aquatic and riparian ecosystems exhibit great complexity, which makes modeling their response to natural ranges of environmental variability and to human alteration of natural flows an imprecise science. These dynamics are further complicated by the fact that these systems occur in a spatial context, that is any particular aquatic or riparian ecosystem represents an integration of numerous upstream and upgradient processes at the whole watershed (network) scale. Clearly, understanding and modeling the dynamics of these ecosystems to natural and human changes in environmental regimes requires an interdisciplinary approach combining ecology, hydrology, geomorphology, engineering, management and social sciences.

Given the intrinsic complexity of these ecosystems, coupled with the urgent need to foresee avoidable negative consequences of future water resources development, creative modeling approaches are needed to account for the relative risks to human and ecosystem users of water associated with different modes of water resources development or water availability. Robust, risk-based modeling approaches are needed that can provide society and managers with decision support tools to better balance the overlapping needs of humans and ecosystems for fresh water under a range of possible futures.

I will briefly outline an EPA-funded research project that addresses the question of how likely the invasive Eurasian saltcedar (Tamarix) is into new regions that will warm under prospective

climate change. This interdisciplinary research couples precipitation forecasts from GCMs with a rainfall-runoff model that incorporates reservoir management operations, with artificial neural network models that generate flow regimes at the subkilometer scale, with an ecological response model that describes current distribution of saltcedar as a function of flow regime and channel geomorphology across the western US. Our aim is to provide a decision support tool that can allow evaluation of different scenarios of climate change and water management strategies/responses on the invasion success of saltcedar at the subkilometer scale throughout entire river networks at a large regional scale. Such multi-scale, multi-process modeling efforts reflect good opportunities to bring diverse disciplines together to address pressing social-environmental problems in water resources.

Dr. LeRoy Poff
Biographical Sketch:

N. LeRoy Poff, who received his doctorate in 1989 at Colorado State, took postdoctoral and Research Scientist positions at the University of Maryland before joining Colorado State's biology department faculty in 1997. He is considered a pioneer in the field of hydroecology. Poff's seminal research in riverine and freshwater ecology focuses on testing how the structure and functional organization of biological communities (invertebrates and fish) are shaped by the natural, dynamic variation in patterns of water flow characteristic of streams and rivers. The research provides a basis for predicting how species populations and whole aquatic communities respond to landscape-scale alterations of the hydrologic cycle, such as land-use change and damming of rivers, as well as to regional climate changes. He is a frequent speaker and presenter at national and international meetings, including the Plenary Presentation at international conferences in Korea and Spain last year.

Last year, Poff was inducted as an Aldo Leopold Leadership Fellow by the Ecological Society of America, a prestigious honor he shares with scientists from Yale, Stanford, University of California-Davis, Northern Arizona University, the University of Colorado-Boulder and other universities. In 2004, he was also awarded a Land & Water Australia fellowship for a sabbatical visit to Griffith University, and he was selected a Kaesar Visiting Scholar by the Center for Limnology at the University of Wisconsin. He is a noteworthy contributor to National Research Council reports on U.S. water use and river science and has been a panel member for the National Science Foundation in addition to serving as a consultant, board member and editor for several national organizations and scientific journals.

Likely Effects of Climate Change on Water Resources in Colorado

Dr. Ellen Wohl
Department of Geosciences, Colorado State University

Abstract:

Future changes in temperature and precipitation predicted from climate modeling are likely to alter water supply for human uses and aquatic and riparian ecology of rivers in Colorado. Water available for consumptive use in Colorado presently comes from ground water and surface water sources. Ground water sources in the eastern portion of the state are compromised by declining water tables and contamination. Continued availability of ground water requires continued recharge from precipitation and stream flow, but recharge is likely to decline as changing climate causes declines in precipitation east of the Rockies. Surface water sources are typically fully appropriated and in some cases contaminated. Rivers that head in the mountains discharge more than 70% of their annual flow during the 2-3 months of peak snowmelt, with discharge highly dependent on the snow pack and the rate of snowmelt. Climate change models indicate that snowmelt will occur as much as 30-40 days earlier in the year and that base flow will decline on these rivers. Rivers that head on the eastern plains of Colorado have intermittent flow. The greatest discharge and longitudinal connectivity of surface flow occur during spring and early summer, and the channels then dry back to isolated pools that provide refugia during dry periods for aquatic organisms. The combined effects of enhanced drought over the eastern plains, reduced snow pack, and earlier snowmelt and peak flows will challenge the ability of human communities to store water for consumptive uses during the remainder of the year. Changes in stream flow will also challenge aquatic and riparian organisms with lifecycles governed by the characteristics (magnitude, timing, duration) of peak flow, and with suitable range governed by stream flow. It is difficult to precisely quantify the likely effects of climate change on water resources because of the multiple interactions that govern suitability of habitat for aquatic organisms, for example, but ranges and abundance of many aquatic and riparian organisms are likely to decline. Western rivers are highly dynamic landscapes, with continual fluctuations in water and sediment supply, but the range of variability of river systems will likely increase as climate changes. Consequently, protection of remaining functional river ecosystems within the state will be critical for preservation of aquatic and riparian species.

Biographical Sketch:

Dr. Wohl earned a Doctor of Philosophy in Geosciences from the University of Arizona in 1988 and a Masters degree from Arizona State University in Geology in 1984. She has been a Professor of Fluvial Geomorphology in the Department of Geosciences in the Warner College of Natural Resources since 1989 but her research interests extend to hydraulics, sediment transport, controls on channel morphology and human impacts on bedrock and mountain channels. Dr. Wohl received the 2000 and 2003 G.K. Gilbert award for excellence in geomorphic research from the Association of American Geographers being the only person to have won it twice. Dr. Wohl's international experience has brought her to Israel through a Fulbright Fellowship and to Japan via a fellowship with the Japan Society for the Promotion of Science.

The Expectations for Changing Rainfall in a changing climate

Dr. Graeme Stephens
Professor, Department of Atmospheric Sciences,
Colorado State University

Abstract:

Much of the scientific discussion about long-term climate change has predominantly been framed around global warming. Predictions of warming have focused on global surface temperature change as the measure of global change and this focus is in part understandable given that 1) theories both simple and complex exist that directly connect perturbations of radiative forcing associated with changing concentrations of greenhouse gases to global-mean surface temperature and 2) that relatively long records of global surface temperature or proxies for it, can be constructed from diverse observations thus providing a way of testing such theories. Until recently, changes to global rainfall and its distribution have received much less scientific attention despite the more immediate importance of such changes to life on Earth. Understanding how the patterns and types of precipitation are likely to change in the face of increasing greenhouse gases as well as by other anthropogenic factors like pollution, are essential for understanding the scope of a looming planetary-scale water supply crisis.

This talk briefly reviews those factors that control precipitation change and why we expect global precipitation to increase generally as the Earth warms, what changes are thought to have already taken place already, what projected changes are presently expected, and some sense for the degree of confidence placed on such projections. Some of the revolutionary new insights on precipitation from new observing systems developed at CSU will also be presented to highlight our current understanding of the climatological patterns of precipitation.

Biographical Sketch:

Dr. Stephens is a Colorado State University Distinguished Professor. He completed his B.S. with honors from the University of Melbourne in 1973 and received his Ph.D. in 1977 from the same university. Dr. Stephens was appointed to the CSIRO Division of Atmospheric Research in 1977 as a research scientist and promoted to senior research scientist in 1982. From 1979 to 1980, Professor Stephens served as a post-doctoral research student at the CSU Department of Atmospheric Science. He joined the faculty as an associate professor in 1984 and was promoted to full professor in 1991. Professor Stephens' research activities focus on atmospheric radiation including the application of remote sensing in climate research to understand the role of hydrological processes in climate change. He also serves as the primary investigator (PI) of the NASA CloudSat Mission and associated research group which has launched a satellite to study the internals of clouds using equipment similar to radar.

Session IV

Topic: Where are the coming opportunities for the Land Grant University to Panel engage in global water issues?
Moderator: Melinda Laituri (Forest, Rangeland and Watershed Stewardship)
Participants: Eugene Stakhiv (IWR, Army Corps of Engineers), Brian Richter (TNC), Pierre Julien (Engineering), Ellen Wohl (Geosciences), Valerie Assetto (Political Science)

Panel discussion:

The Land Grant University has an explicit mission of outreach and engagement to the general public, rural communities, and stakeholders concerning issues resource management, public education, and agriculture. The 21st Century will present a host of new challenges with regard to global water issues within the international arena. How will the institution respond?

This panel will discuss the following questions:

1. What are the key global water challenges that the Land Grant University should engage in?
2. What mechanisms need to be developed to ensure that the Land Grant University can participate in working on global water challenges?
3. What needs to change within the Land Grant University to meet these challenges? What needs to change externally to assist the Land Grant University to be successful in meeting these challenges?
4. What role does research and technology play in meeting these challenges?
5. What outreach and education programs should be developed to meet the instructional needs of their clientele?
6. What are the key (specific) actions that CSU should undertake to address the pressing challenges and opportunities we discussed today?

Global Water Issues/Research Matrix

Key issues areas with regard to global water include the following:

- **Water supply and sanitation:** The failure to provide safe drinking water and adequate sanitation to the world's population is a fundamental failure of the 20th C. In 2007, the concentration of the world's population for the first time is in urban, sub-urban, exurban and peri-urban areas rather than the rural countryside. On of the Millennium Development Goals (MDG) adopted by the United Nations and the international water community is to reduce by half the proportion of people unable to afford safe drinking water by 2015. The development of water supply and sanitation facilities along with urban conservation efforts will be critical to meeting this goal. *What new technologies and strategies need to be developed to meet the MDG goals?*

- **Environmental water:** The world's freshwater is part of numerous ecosystems: rivers, lakes, marshes, wetlands, aquifers, that provide a multitude of environmental services. These services are difficult to measure and include flood pulses, fertile silt suspended in water, stream flows along an ecological gradient. *As the human population shifts to increasingly urban environments, what management strategies will need to be developed to balance ecosystem and human needs? How might human populations better understand the importance of ecosystem services in their role of providing a healthy and safe human environment?*

- **Disasters and hazards:** Global climate change, human use and abuse of natural resources, and population growth contribute to an environment where threat from disasters (both human-caused and natural) are increasing. Flood and drought represent the opposite ends of a spectrum of too much or too little water where the result if often devastation to local environments. A key arena to better understanding disasters and hazards is the role of adaptation and resilience. *How might we better understand the role of disturbance on both natural and human environments?*

- **Climate change:** Global climate change plays an important role in scientific and policy debates over effective water management. International and national levels of climatic impacts have been fairly well documented and researched. A critical area for examination is to better understand regional and local impacts. *What methodologies and models that project regional and local impacts of climatic change and variability need to be developed?*

- **Oceans:** One of the key global commons is the ocean. Oceans provide the heating and cooling mechanisms in conjunction with the atmosphere via the movement of currents and winds. Also, they provide a multitude of habitats that provide food and resources to the world's human populations. There are vast areas that remain unexplored. However, they have also become a contested area due to shipping routes, military activity, fishing regulation, and dumping activities. Global cooperation and innovative institutional responses are needed. *How will these be negotiated?*

- **Energy:** Water is critical to harnessing energy that fuels modern society. With increasing scarcity of global oil resources, hydroelectric and geothermal resources become more important. A key feature of hydropower is dams. Dams impound water and displace ecosystems and people providing energy for populations often far removed from the reservoir and dam. *What are the alternatives to energy development?*

Cross-cutting themes:

The cross-cutting themes include poverty, sustainability (including urbanization and population growth), public health, conflict (and security) and globalization (the economy). Each of these themes transcends any of the explicit issues described above; each of these themes is inextricably interlinked. At the beginning of the 21st C, we are uniquely situated to begin the difficult process of examining and explicating the linkages between these themes and develop innovative cross-cutting solutions where interdisciplinarity and integration are key elements.

What are the past contributions of CSU? What are current activities taking place at CSU?

How is CSU currently positioned, where are the research gaps, and what are the priority areas for CSU in the next 10-15 years?

Cross-cutting themes: Human Dimensions	***Poverty***	***Sustainability*** *Urbanization/population growth*	***Health***	***Conflict***	***Economy***
Issue Areas					
Water supply and sanitation					
Environmental needs/					
Disaster/hazards					
Climate change					
Health of Oceans					
Energy					

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Rapid Assessment of the Presence of FRNA bacteriophages in Water Allows for Detection of Fecal Contamination and Microbial Source Tracking

Travis Steiner and Lawrence D. Goodridge
Department of Animal Sciences, Colorado State University, Fort Collins, Co, 80523

Abstract:

Waterborne pathogens are considered to be major contributors of preventable morbidity and mortality. FRNA bacteriophages (phages) have emerged as a new class of microbial indicators of the presence of, and source, of fecal contamination in water. These phages can be separated into four distinct groups based on serology, and serogroups I and IV have been associated with animal wastewater, while groups II and III are typically found in wastewater from human sources. There is a need for rapid and simple methods to isolate, detect, and characterize FRNA phages in large volumes of water. The objective of this study was to demonstrate the ability of an anionic exchange resin to isolate FRNA phages from tap water, followed by real time polymerase chain reaction (RT-PCR) to detect and characterize the phages. FRNA phages MS2 (group I), GA (group II), SP (group III) and Qβ (group IV) were individually seeded into 50 mL volumes of tap water at a concentration of 10^4 PFU mL^{-1}. One gram of anionic exchange resin (Amberlite® IRA 900) was added to each water sample. The samples were continually agitated and aliquots were withdrawn at 15 min intervals for 2 h, and assayed for phage via the double layer plaque assay. Phages attached to the resin beads were directly detected by RT-PCR, carried out using a multiplex primer set specific for the two genera of the *Leviviridae* and *Allolevivirida*e. Capture efficiency utilizing the anionic exchange resin was found to be > 80%, 92%, and 97% for all phages after 15, 60 and 120 minutes. Detection limits of the multiplex RT-PCR performed directly off of the anionic exchange resin beads were found to be 10^0 PFU mL^{-1} for all phages. A lateral flow device (LFD) was designed to allow for field based detection of FRNA phages in water. The lateral flow device was capable of detecting group I FRNA phages (indicative of the presence of animal fecal material), and the LFD was able to detect the presence of group I FRNA phages in irrigation water runoff, as confirmed by RT-PCR. Taken collectively, these results show that anionic exchange resin based capture of FRNA phages followed by RT-PCR or LFD analysis is a simple and rapid way to concentrate, detect and characterize FRNA phages from water, and the method may also be applicable to rapid capture and detection of enteric viruses from large volumes of water.

Urban Landscape Irrigation with Recycled Wastewater

Sarah Wilhelm and Yaling Qian
Agricultural Sciences, Colorado State University

Abstract:

The population increase in Colorado has increased fresh water demand and consequently increased the volume of wastewater generated. The use of recycled wastewater for landscape irrigation is one way to maximize limited water resources. Based on data from the Department of Public Health and Environment, Water Quality Control Commission there are about 10 permitted recycled wastewater facilities in Colorado that can treat and deliver about 56 million gallons of effluent water every day for reuse purposes. During the past 5 years, we have conducted research to: 1) assess variability of chemical properties of recycled wastewater in the Front Range of Colorado, 2) evaluate landscape soils and plants that are currently under recycled wastewater irrigation, 3) determine the relative tolerance of commonly used conifers to irrigation with RWW for the purpose of selecting species that are best suited for landscapes irrigated with RWW. There were variations in water quality between wastewater treatment facilities. In all cases, the water samples met or exceeded the regulations in regard to of E. coli count as defined in the state Regulation 84, therefore the water is suitable for landscape irrigation. Nevertheless, RWW does contain varying quantities of soluble ions. Soil salinity and sodium content on clay soils increased after long-term application of RWW. Our results indicated that, among the conifers tested, Rocky mountain juniper and pinyon pine were the most tolerant, while ponderosa pine was the least tolerant to RWW irrigation in Colorado climates. Currently, research is in progress for on site and real time monitoring of soil salinity and development of best management practices for urban landscapes with RWW irrigation.

Occurrence and Fate of Steroid Hormones in the Environment

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Abstract:

The exposure of humans and wildlife to chemicals in the environment may disrupt their endocrine system functions, even at extremely low concentrations. Suspected endocrine-disrupting chemicals (EDCs) include steroid hormones such as 17β-estradiol, progesterone, and testosterone. The authors are investigating the possible occurrence of steroid hormones in the Cache la Poudre River (Poudre River), the potential for steroid hormone runoff from agricultural lands, and the potential for steroid hormone photodegradation and biodegradation under natural conditions. In November 2007 and January 2008, water samples were collected from six locations along the Poudre River. The sampling locations ranged in character from nearly pristine (Site 1) to urban (Site 4) to heavy agricultural (Sites 5 and 6) environments. In January 2008, 17β-estradiol was observed at Sites 4, 5 and 6. In both sampling periods, potential degradation products of 17β-estradiol and testosterone (e.g., estriol, estrone and androstenedione) were observed at several sites. These preliminary data suggest that steroid hormones and their degradation products are present in the Poudre River. Laboratory experiments were conducted to study the potential for photodegradation of steroid hormones in UVA light, because 99% of the sun's ultraviolet light that reaches the Earth's surface is in the UVA range. These experiments also examined the possibility of reactions with natural compounds such as nitrate (10 mg/L) and humic acid (5 mg/L) that might become reactive upon exposure to UVA light. The authors found that testosterone degraded under UVA light, and that the rate of degradation increased in the presence of humic acid. Progesterone degraded under UVA light, but the rate of degradation was unaffected by humic acid. Finally, 17-β estradiol did not degrade under UVA light directly, but degraded rapidly in the presence of humic acid. The effect of nitrate was insignificant. Photodegradation of testosterone was also observed in water samples taken from the Poudre River and the Suwannee River. These preliminary results suggest that natural sunlight can degrade steroid hormones in the Poudre River. The authors are currently working to identify the products and mechanisms of such photodegradation. In addition, the authors are conducting laboratory experiments to investigate the potential for biodegradation of steroid hormones by bacteria commonly found in manures and soils. The authors intend to identify the pathways and products of such biodegradation, and quantify the degradation rates

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Bridging the Gap between Agricultural and Municipal Water Needs In an Increasingly Scarce Water Environment

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Abstract:

Population growth is a significant driver of change in the western United States. Burgeoning populations are increasing municipal water demand in the West, a phenomena that is changing rural and urban economies. Agricultural water is a preferred source for meeting growing 4demands, but transfers often require formerly irrigated land to be fallowed removing a key base industry from rural regional economies. One alternative to 'buy and dry' strategies is gaining interest. The alternative allows farmers to lease a portion of their water portfolio to cities. Leased water is generated as farmers reduce the consumptive use of their cropping operations by limiting irrigation. Examples of limited irrigation strategies include timing irrigations during vegetative growth and adopting innovative crop rotations. Importantly, the limited irrigation cropland remains in production so that rural economies suffer reduced affects vis a vis buy and dry activity. The initial results of the poster illustrate the importance of irrigated agriculture to the local economic base; yet, the economic activity is quite different based on the location. A major reason for the differences is the prevailing cropping patterns and the amount of product exported from the region. The efficacy of a leasing program is gauged from a producer survey of South Platte River Basin farmers in Colorado, a basin experiencing significant population growth. Initial agronomic results of limited irrigation strategies are presented with particular attention to forage crops. Ultimately, the long-term objective of this integrated, multi-disciplinary, multi-agency research project is to assist farm operations and municipality to create economically sustainable strategies to use the limited water resource environment.

Afghanistan Water, Agriculture, and Technology Transfer Program (AWATT)

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Abstract:

Afghanistan faces a significant shortage of the physical and human capital needed to optimize use of its water resources and manage its irrigated farms. The project's objective is to bolster human capital and water resource management capabilities by surveying available resources, developing (with Afghani counterparts) water institutions that make best use of available resources, providing demonstration of irrigation and agriculture techniques/technologies, and delivering curricula to Afghani specialists who may then disseminate information in the field. Following nearly three decades of conflict and war related destruction, and a harsh environment characterized by extended drought, Afghanistan's agriculture and natural resource sector is facing serious challenges. Under the AWATT program, Colorado State University (CSU) will work closely with consortium partners; New Mexico State University, University of Illinois at Urbana Champaign, Southern Illinois University Carbondale (SIUC) and the four Afghanistan universities (Balkh, Nangarhar, Herat and Kabul), Afghanistan's Ministry of Agriculture, Irrigation and Livestock (MAIL) , Ministry of Water and Energy, and Afghanistan Ministry of Higher Education, international development organizations, Private sector and other local developmental organizations (NGO's, PRT's and ALP's) for effective delivery of curricula and integrated water resource management (IWRM) techniques. The CSU activities include:

- Natural Resource, Irrigation Water Resource Management (IWRM).
- Afghan University Capacity Building and Stakeholder Cooperation for agriculture, natural resources, and rural economic development research and application needs
- Technology Transfer through demonstration farms for increasing Afghanistan's agriculture productivity in areas of seasonal drought and high risk of land degradation.

This project was initiated in March 2008 with funds from USAID.

The Agricultural Water Conservation Clearinghouse:
A New Resource for Agricultural Producers and Water Managers

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Abstract:

Colorado and the Western United States (U.S.) are experiencing water conflicts as rapid urbanization and limited water resources shape how we farm, manage our water supplies, and create natural resource policies and laws. With production agriculture accounting for 86 percent of the consumptive use of water in Colorado, it is important to address the needs of producers and water managers living in areas where critical water resources are limited. Based on the issues and problems agriculture faces with regards to limited water supplies, the Colorado Water Resources Research Institute (http://cwrri.colostate.edu/) and the Northern Plains and Mountains Regional Water Program (http://region8water.org) are currently developing an online regional and national clearinghouse of information, concerning agricultural water conservation, which highlights state of the art research and technology by experts facing similar water constraints.

The Ag Water Conservation Clearinghouse (http://agwaterconservation.colostate.edu) will ultimately provide current, science-based information on a wide variety of agricultural water conservation issues. The centerpiece of this online clearinghouse is a comprehensive searchable database called the *Library*, which identifies current research and educational outreach publications regarding 8 major themes: cropping systems; delivery systems; irrigation management; irrigation technology; agricultural economics and policy; agricultural water recovery, reuse and recycling; phreatophyte control; and soil moisture and evapotranspiration measurement. This database will eventually house all of these agricultural water conservation topics in a variety of formats, including books, conference proceedings, fact sheets/bulletins, refereed journal publications, management plans, reports, and theses/dissertations.

The Agricultural Water Conservation Clearinghouse website will also provide current links to Agricultural Experiment Stations and Land Grant Universities, as well as up-to-date information on agricultural water related research centers, irrigation management curriculum / workshops, and irrigation tools. As development of the website expands, we will be featuring upcoming news and events related to agricultural water conservation for regional and national audiences. Additional features also include a comprehensive glossary and frequently asked questions (FAQs). With a built-in feedback option, this clearinghouse is designed to help build knowledge, information and open networks for agricultural producers and water resource managers from various local, state, regional, and national organizations – providing them access to agricultural water conservation research and expertise.

Do the Application of Magnesium Chloride Dust Suppressants Alter Stream Water Chemistry in Northern Colorado?

Ronda Koski, Betsy Goodrich, William Jacobi

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Abstract:

Magnesium chloride ($MgCl_2$) salt solutions are effective dust suppressants and help to stabilize non-paved roads. Although the use of these products are increasing in the arid west, there is limited information concerning if and how much $MgCl_2$ moves into surface waters near treated non-paved roads. Our study was initiated to measure concentrations of magnesium and chloride in sixteen streams in Grand and Larimer Counties, Colorado that are crossed by roads treated with $MgCl_2$. Water sampling occurred every two weeks from May through October 2004 on seven streams in Grand County and May to October in 2004 and 2005 on nine streams in Larimer County, Colorado. Water was sampled upstream and downstream from the roads. The average upstream "background" concentrations of both chloride and magnesium upstream were low and ranged 0.1 to 2.5 mg/L for chloride and 2.4 to 14.0 mg/L for magnesium. While mean concentrations of chloride and magnesium in downstream sites were also low, ranging from 0.7 to 36.8 mg/L for chloride and 2.0 to 14.0 mg/L for magnesium, the chloride component in $MgCl_2$ moved from treated roads into three out of seven streams in Grand County and seven out of nine streams in Larimer County. Mean chloride concentrations significantly correlated with road surface area draining into the stream, winter precipitation, as well as yearly average and cumulative rates of $MgCl_2$ applied. Magnesium concentrations correlated with surface area, yearly and winter precipitation, as well as average yearly amount of $MgCl_2$ applied. The chloride concentrations measured over the summers of 2004 and 2005 were well below the 250 mg/L levels reported to be deleterious to the health of aquatic life based on previous research and standards set by Environment Canada and the United States Environmental Protection Agency. Other compounds and ions such as sulfate, sodium and calcium were higher in downstream water samples but were not elevated to dramatic levels.

The Republican River Conservation Reserve Enhancement Program (CREP)

Dr. James Pritchett* and Jenny Thorvaldson**.

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Abstract:

The Republican River Basin lies within the Ogallala Aquifer, which has been identified as a national concern regarding water quantity and water quality. Declining water levels within the Ogallala have reduced both well productivity and crop yield. As a result of the Republican River Compact settlement, no further groundwater development is permitted in the Republican River Basin.

The State of Colorado seeks to obtain federal funds through the USDA for the purpose of encouraging some farmers in the Republican River Basin to enroll in a voluntary CREP. This program would offer financial incentives and technical assistance to participants who forego irrigation for 14 or 15 years and enter their land into eligible conservation practices, such as native vegetation establishment or wildlife conservation. In this way, CREP aims to help the basin sustain its water resource without disastrously impacting its local economy and social fabric.

Study Area

The area's agricultural output has both regional and national significance. Ninety percent of the total land area is in farm and ranch. Of the land in farm and ranch, 60 percent is cropland. Of the cropland, 25 percent is irrigated. The introduction of irrigation from has diversified crops, increased livestock production, and stabilized the population by reducing the effect of droughts and floods.

Communities throughout the region depend on the agricultural sector for their economic base and stability. There are few economic alternatives to agriculture in the area. Areas relying more exclusively on irrigated agriculture for economic activity, such as this one, are likely to suffer greater impacts from a loss of irrigated agriculture versus regions with a broader, more diverse economic base.

Problem Statement and Study Purpose

Even though individual farmers will be compensated for participation in CREP, a reduction in irrigated cropland has implications not only for the agricultural sector, but also for the larger economy of the region. The economic impact of a substantial decrease in irrigated crop production will ripple throughout the rest of the economy via inter-industry linkages.
This analysis uses IMPLAN to estimate the economic impact resulting from the conversion of 6,240 acres of alfalfa and 24,960 acres of corn grain to grassland in the portions of Kit Carson and Yuma counties that lie within 3 miles of the Republican River and its tributaries. The total impact is disaggregated into its component parts (direct, indirect, and induced) and by sector.

Managing Residential Water Demand During Drought in Aurora

Douglas Kenney*, Chris Goemans**, Bobbie Klein*, Jessica Lowrey*, Kevin Reidy***

Abstract:

Residential water demand is a function of several factors, some of which are within the control of water utilities (e.g., price, water restrictions, rebate programs) and some of which are not (e.g., climate and weather, demographic characteristics). In this study of Aurora, Colorado, factors influencing residential water demand are reviewed during a turbulent drought period (2000-2005). Findings expand the understanding of residential demand in at least three salient ways: first, by documenting that pricing and outdoor water restriction policies interact with each other ensuring that total water savings are not additive of each program operating independently; second, by showing that the effectiveness of pricing and restrictions policies varies among different classes of customers (i.e., low, middle, and high volume water users) and between predrought and drought periods; and third, in demonstrating that real-time information about consumptive use (via the Water Smart Reader) helps customers reach water-use targets.

***Western Water Assessment, NOAA/University of Colorado **Colorado State University ***Aurora Water**

Monitoring Perchlorate in Water Using Microchip Capillary Electrophoresis

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Abstract:

Perchlorate, ClO_4^-, is a small, persistent, highly water soluble anion arising from both natural and anthropogenic sources. Anthropogenic sources include solid rocket fuel, matches, dyes, paints, airbag inflators, pyrotechnics, flares, and fertilizers, with solid rocket fuel being the largest contributor. Perchlorate is able to travel long distances in groundwater and is therefore a pervasive problem once released into the environment. Widespread ClO_4^- contamination in the United States was discovered after the spring of 1997, when an analytical method with a reporting limit of 4 ppb was developed. Additional sampling and analysis techniques have since been developed that can detect perchlorate at concentrations of 1 ppb and lower. Perchlorate is a concern because without sufficient iodide the human thyroid cannot make enough thyroxine to allow for proper endocrine function. Perchlorate inhibits the uptake of iodide into the thyroid, thereby decreasing its function. A new microchip capillary electrophoresis method is reported here for the rapid, sensitive detection and quantification of perchlorate in water. The presented method is capable of resolving perchlorate from common interferences in less than two minutes, achieving detection limits of 0.5 ppb ± 0.03. Sample pretreatment is not required as only small, highly mobile anions are injected into the system, while particulates and other undesired contaminants are excluded from injection. Analysis of surface and groundwater samples is presented, illustrating the effectiveness of the overall approach.

Human exposure to perchlorate has become important problem in environmental research, as illustrated by the large number of mainstream media reports concerning its presence. Perchlorate inhibits uptake of iodide into the thyroid gland, leading to irregular production of thyroid hormone and giving rise to developmental problems,[1] neurological disorders,[2] reduced intelligence,[3] and cerebral palsy.[4] Perchlorate is wide spread as a result of both natural and anthropogenic[5] sources and has been detected in drinking water[6], food[6] and both human and cow milk.[7, 8] The extent of human exposure to perchlorate is largely unknown because of limited testing of drinking water and foods, however several examples of contamination exist and drinking water in these areas is affected.[9] Currently, the EPA draft estimate of a future regulatory limit of perchlorate in drinking water is 1 ppb, based on toxicity assessment.[10] This would make perchlorate one of the most regulated ions in water with the exception of bromate.[10-14] Sensitive and selective methods for in field monitoring would aid in mitigating exposure as well as tracing remediation efforts.

Insitu Leach Mining of Uranium: Centennial Project: Is it Environmentally Safe?

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Abstract:

Powertech Uranium Corporation (Powertech) has proposed an insitu leach (ISL) mining of uranium project occupying 9 square miles in Weld County, Colorado. The southern extent of the project is located near the town of Nunn and only about six miles from Fort Collins. This project has received a lot of public attention and Powertech's homepage indicates that the Centennial Project is one of their major holdings and is scheduled for near term production. ISL mining is not a new technology and was first tried in the 1960s and 70s primarily in Wyoming and south Texas. A pilot scale ISL mining operation was also conducted in the late seventies near Grover Colorado. In March 1979, three mile accident occurred and uranium prices dropped drastically with the result that very limited uranium mining has occurred in the United States for the past almost thirty years. Recently uranium prices have increased and future demand for uranium appears to be strong. Uranium located in roll front deposits in tertiary age sandstones (in our case Laramie Fox Hills Sandstone) that are amenable to ISL mining are located extensively over the western United States, Canada and in many other parts of the world. With ISL mining an array of wells are used to inject a lixiviant (leaching agent) into the aquifer to mobilize the previous immobile uranium. A host of other radioactive elements are mobilized along with the uranium. At the conclusion of mining the aquifer is contaminated with pregnant lixiviant and radioactive elements. Sandstone formations are considered as a major aquifer type and contain large quantities of groundwater that is commonly a primary source of drinking water. The proposed Centennial Project is just the tip of the ice-berg. The large number of potential ISL mining projects represent a major threat to our groundwater resources. In the case of the Centennial Project the nearby proximity to population centers (about 270,000 persons) and surface water bodies represents an even greater threat.

Major environmental concerns associated with ISL mining include horizontal and/or vertical excursion of pregnant lixiviants and fugitive radioactive elements during the mining process. At the conclusion of mining operations, the aquifer is contaminated with lixiviant and mobile radioactive uranium and other radioactive elements. The chemical equilibrium that existed prior to mining is now disrupted. Prior to mining the uranium ore was primarily uranium(IV) and afterwards is uranium(VI). Uranium(IV) is relatively immobile whereas uranium(VI) is highly mobile in the groundwater. In the 1970s, ISL mining represented one of the first attempts to restore a contaminated aquifer. Subsequently groundwater professionals have gained considerable experience working on superfund sites. The "final" National Priority List had 1,243 sites with groundwater and soil contamination as a major environmental threat at over 80 percent of these sites. Some, of the lessons learned are: 1) it only takes a small quantity of contaminants to pollute large quantities of groundwater; 2) groundwater does not magically clean itself; 3)groundwater moves very slowly and the impact of groundwater contamination on the surrounding environment (wells and or nearby surface water bodies) may not occur for many years or decades after the original contamination occurred; 4)once contaminated, groundwater is very difficult, time consuming and expensive to clean; and 5) pump and treat groundwater restoration systems (method used with ISL mining) have consistently under performed and require large pore volumes of water to be re-circulated to achieve cleanup. According to EPA at 224 of the Superfund sites, much less achieve aquifer restoration, contaminated groundwater migration is not under control. Permitting agencies have allowed closure at some former ISL sites. For the sites that I have reviewed, aquifer exemption and renegotiation of cleanup standards has been a key component to achieve closure.

Nanofiltration/Reverse Osmosis Membrane Fouling by Produced Water

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Abstract:

Produced water (PW) or co-produced water is a by-product of oil and gas production processes. Management of this produced water (PW) has become a major concern in the feasibility of oil and gas field development. Surface discharge of large volumes of PWs has already had many adverse environmental affects, such as stream bank erosion, change in natural vegetation, salt deposition etc. Further, given the scarcity of water in the western United States, PW which is a waste product from oil and gas drilling is in fact a very valuable natural resource. Treatment of produced water requires de-oiling and demineralizing the water. However, membrane fouling constitutes a major obstacle to the application of membrane-based processes for the treatment of PWs for beneficial uses. Membrane fouling during filtration of produced water can result in significant loss of performance and can have a serious impact on the efficiency and economics of the separation process. The aim of this investigation is to evaluate the filtration characteristics and membrane fouling of commercially available Dow Filmtec nanofiltration (NF 90 and NF 270) and reverse osmosis (BW 30) membranes. Membrane fouling was studied using attenuation total reflection - Fourier transform infrared analysis (ATR-FTIR), X-ray photoelectron spectroscopy (XPS) and field emission scanning electron microscopy (FESEM). The results obtained showed that due to their bigger pore size, water flux through the NF 270 membrane is high compared to NF 90 and BW 30. The water flux of PWs from oilfield is low as compared to coal bed methane (CBM) produced water regardless of the membrane selection. The presence of dissolved organic and inorganic matter leads to greater water flux decline for PWs from oilfield. X-ray photoelectron spectroscopy (XPS) studies reveled the fouling of membranes by inorganic matter exists in the produced water. FESEM images clearly showed the foulants deposited on the membrane surface.

Characterization of Streamflow Variability over the 20th Century in the Gunnison River Basin

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Abstract:

Increasing hydrologic variability is cited as a major cause of decreasing accuracy and lead time for water supply forecasts in the Colorado River Basin. This study strives to understand the underpinnings of the hydrologic variability attributable to climate cycles, climate change and modifications to land use, land cover and water use change in the Colorado River Basin. Quartile and linear regression analyses are applied to temperature, precipitation and streamflow data for Sept-Mar between 1910 and 2005 for the Gunnison River, one of the most variable systems in the Colorado River Basin. The results reveal streamflow responses to cyclic variations in temperature and precipitation patterns which correspond to prevailing climate cycles, as well as responses to temperature increases and shifts in precipitation over the twentieth century. Linear regression results show that streamflow responds in patterns consistent with the complementary patterns in temperature and precipitation which establish by fall and evolve between fall and early spring according to the prevailing climate cycles. But the complementary temperature/precipitation patterns and streamflow patterns are also affected by increases in temperature and shifts in precipitation that are likely due to climate and land use, land cover and water use changes over the 20th century. These results may be used to improve accuracy and lead time in water supply forecasting, and improve water resource management.

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Hydrology, Sediment, and Contaminant Modeling

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Abstract:

The hydrologic model CASC2D originally began with a two-dimensional overland flow routing algorithm developed and written in APL by P.Y. Julien at Colorado State University in 1988. Significant modifications by Saghafian, Ogden, and Velleux improved the hydrologic and hydraulic computations. A sediment transport algorithm was developed by Johnson and Rojas and the code was renamed CASC2D-SED. The most recent developments by Velleux and England led to the addition of a contaminant transport algorithm for the transport and fate of metals from mining areas. This code TREX has been used for the transport of Zn, Cu and Cd at Californa Gulch, Colorado, as well as the simulation of the PMP and PMF on the Upper Arkansas River Basin.

All versions of CASC2D and TREX present the results in two-dimensional color graphics. Some of the parameters displayed includes rainfall precipitation, infiltration rates, flow depth, snowpack depth and snowmelt rates, sediment transport and sediment concentration, metal concentration and fluxes and erosion and deposition of sediment and metals.

Currently, there have been significant graphical improvements of the results. A three dimensional representation of the results is possible for the input and result data. This three dimensional representation helps provide better visualization of several surface processes including: runoff from urban and forested hillslopes, flow convergence and divergence from surface runoff and detention storage. The flow interaction between the main channel and the floodplain is also well illustrated with this graphical representation. Present research efforts with TREX are aimed at validating the model with a number of newly available hydrologic data collected from a combination of remote sensing and point gage sources. In addition, research is being conducted to develop an improvement to the Modified Einstein Procedure for determining total sediment load. The improvements include clearer definition of the modes of transport.

Sustainable Applications for Advanced Decentralized Wastewater Treatment Technologies

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Abstract:

Decentralized (small-scale) wastewater treatment technologies have great potential to add to sustainability and low impact development (LID) potential for residential neighborhoods, commercial business parks, as well as industrial parks. Small-scale systems enable reuse of treated wastewater and graywater for beneficial uses locally through easy access to effluent. Beneficial uses include irrigation, toilet flushing, and industrial or commercial processes. Organics from treatment processes provide a clean source of nutrients for local farms and gardens. Small-scale systems can be built as population increases, preventing over-sizing of infrastructure based on future population projections, as is often a problem for large-scale treatment operations. Environmental damage from infrastructure development, such as disturbing sensitive ecosystems during the installation of wastewater lines, is also more effectively mitigated by reducing stream and wetland crossings.

Benefits of decentralized wastewater treatment systems research reach beyond applications in sustainable urban development. Decentralized treatment technologies have the potential to benefit rural areas and new growth in developing countries which tend to either rely heavily on septic systems for treatment or have no treatment at all. In 2000, estimates from the World Health Organization showed 2.4 billion people without access to improved sanitation, of which 81% were located within rural areas (World Health Organization 2004). Continued research in the area of decentralized wastewater treatment is imperative to make affordable and effective sanitation technologies available to developing countries and rural areas.

Research is commencing at Colorado State University (CSU) to study the application of decentralized treatment technologies for the expansion of the CSU Foothills Campus. Currently, design of a pilot study is underway for the implementation of small scale, decentralized wastewater treatment systems to serve the expansion development. Two goals of this study are to implement technologies which minimize the import and export of water from the site as well as provide a renewable source of green energy. Results of this study will provide greater understanding and knowledge regarding the benefits that decentralized treatment systems can offer to sustainable and low impact development in both developed and developing regions of the world.

Sources:

World Health Organization. (2004). "Facts and figures: Water, sanitation and hygiene links to health." Retrieved February 2008, from http://www.who.int/water_sanitation_health/publications/factsfigures04/en/.

Meteorologic, Topographic and Canopy Controls on the Scaling Characteristics of the Spatial Distribution of Snow Depth

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Abstract:

In this study, LIDAR snow depths, bare ground elevations (topography), and elevations filtered to the top of vegetation (topography + vegetation) in five 1-km^2 areas are used to determine whether the spatial distribution of snow depth exhibits scale invariance, and the control that vegetation, topography and winds exert on such behavior. The one-dimensional and mean two-dimensional power spectra of snow depth exhibit power law behavior in two frequency intervals separated by a scale break located between 7 m and 45 m. The spectral exponents for the low frequency range vary between 0.1 and 1.2 for the one-dimensional spectra, and between 1.3 and 2.2 for the mean two-dimensional power spectra. The spectral exponents for the high frequency range vary between 3.3 and 3.6 for the one-dimensional spectra, and between 4.0 and 4.5 for the mean two-dimensional spectra. Such spectral exponents indicate the existence of two distinct scaling regimes, with significantly larger variations occurring in the larger scales regime. Similar bilinear power law spectra were obtained for the fields of vegetation height, with crossover wavelengths between 7 m and 14 m. Further analysis of the snow depth and vegetation fields, together with wind data support the conclusion that the break in the scaling behavior of snow depth is controlled by the scaling characteristics of the spatial distribution of vegetation height when snow redistribution by wind is minimal and canopy interception is dominant, and by the interaction of winds with features such as surface concavities and vegetation when snow redistribution by wind is dominant.

Ecohydrologic controls on vegetation density and evapotranspiration across the climatic gradients of the central United States

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Abstract:

The soil-water balance and plant water use are investigated over a domain encompassing the central United States using the new Statistical-Dynamical Ecohydrology Model (SDEM). The seasonality in the model and its use of the two-component Shuttleworth-Wallace canopy model allow for application of an ecological optimality hypothesis in which vegetation density, in the form of peak green leaf area index (LAI), is maximized, within upper and lower bounds, such that, in a typical season, soil moisture in the latter half of the growing season just reaches the point at which water stress is experienced. Another key feature of the SDEM is that it partitions evapotranspiration into transpiration, evaporation from canopy interception, and evaporation from the soil surface. That partitioning is significant for the soil-water balance because the dynamics of the three processes are very different. The partitioning and the model-maximized LAI are validated based on observations in the literature, as well as through the calculation of water-use efficiencies with modeled transpiration and large-scale estimates of grassland productivity. Modeled-maximized LAI are seen to be at least as accurate as the unaltered satellite-based observations on which they are based. Surprising little dependence on climate and vegetation type is found for the percentage of total evapotranspiration that is soil evaporation, with most of the variation across the study region attributable to soil texture and the resultant differences in vegetation density. While empirical evidence suggests that soil evaporation in the forested regions of the most humid part of the study region is somewhat overestimated, model results are in excellent agreement with observations from croplands and grasslands. The implication of model results for water-limited vegetation is that the higher (lower) soil moisture content in wetter (drier) climates is more-or-less completely offset by the greater (lesser)amount of energy available at the soil surface. This contrasts with other modeling studies which show a strong dependence of evapotranspiration partitioning on climate.

Hydraulic Analysis of the Galisteo Reach located within the Middle Rio Grande

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Abstract:

In central New Mexico, the Rio Grande has been subjected to man-made alterations. Indirect changes to the river from mining, ranching and logging and direct changes from the construction of dams, irrigation canals and levees now threaten the natural state of the Rio Grande and riparian habitat. These human influences have resulted in problems associated with erosion and sedimentation along the Middle Rio Grande. The objective of this study is to analyze geomorphologic, hydraulic, hydrologic, and equilibrium trends along the Galisteo reach to determine the anthropogenic influences from 1918 to 2006 to help facilitate better management of restoration, irrigation, and flood protection efforts. The Galisteo reach spans 8.1 miles from along the middle Rio Grande from Galisteo Creek to Arroyo Tonque, north of Albuquerque.

Several methods were utilized in performing the geomorphic, hydraulic, hydrologic, and equilibrium analysis. Discharge and bed material data was collected from USGS database. Channel geometry was classified using HEC-RAS 4.0, Arc GIS and quantitative equations based on slope/discharge, channel morphology and stream power. Additionally, hydraulic trends in channel width, depth, and velocity were determined using HEC-RAS 4.0. Both spatial and temporal trends were explored. Equilibrium width and slope were predicted using regression and empirical equations.

The overall discharge in the Galisteo reach has decreased since 1970. Channel classification analyses through aerial photos and quantitative results have indicated that the channel has narrowed and is slightly more sinuous. This is due to the reduction in channel width, which had caused the velocity to increase. The channel is trying to achieve a dynamic equilibrium by changing the sinuosity, thus reducing the velocity within the reach. Moreover, the median bed particle size has increased from 0.38 mm to 28.45 mm since 1962, indicating the bed material changed from sand to gravel due to channel degradation. The most dramatic changes correlate with the closure of Cochiti Dam in 1973. As of yet, the Galisteo reach is far from a state of dynamic equilibrium. All initial equilibrium prediction suggests that the river will need to continue to narrow and steepened to reach equilibrium.

Normalized Difference Vegetation Index Versus Band Combinations in Assessment of Soil Salinity: Case Study in the Lower Arkansas Basin

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Abstract:

The objective of this study was to develop a methodology to generate high accuracy soil salinity maps. The technique used included the integration of field data, geographic information systems (GIS), remote sensing, and spatial modeling techniques. Ground data from four fields planted with corn in the year 2004 and four fields planted with alfalfa in the year 2001 in the lower Arkansas River Basin in Colorado are compared with data derived from different satellite images. Two datasets were checked, one representing corn fields where Aster, Landsat 7, and Ikonos images were used, and the other representing alfalfa fields where Landsat 5 and Ikonos images were used. Different types of satellite images were used to check the correlation between measured soil salinity and remote sensing data. Normalized Difference Vegetation Index (NDVI) was compared with the best band combinations from each satellite image. Two different strategies were applied to check which of the NDVI or combination bands correlates better with soil salinity data. First, NDVI was compared with the best band combination where NDVI was not included in the combination. Second, NDVI was compared with the best band combination where NDVI was included in the combination. Multiple regression analysis was used to explore the coarse-scale variability in soil salinity as a function of the different satellite image bands. A stepwise procedure was used to identify the best subset of independent variables (band combination) from the satellite images to include in the regression models. The spatial structure of the residuals from the multiple regression models were analyzed using the variogram. An Exponential, Gaussian and Spherical models were fit to the sample variograms using a weighted least squares method. The variogram model with the smallest Akakie Information Corrected Criteria (AICC) was selected to describe the spatial scales of the soil salinity data. The results show that in most of the cases, the combinations where NDVI is included perform better.

Efficient Irrigation Water Management in the Middle Rio Grande—the Use of Decision-Support Models

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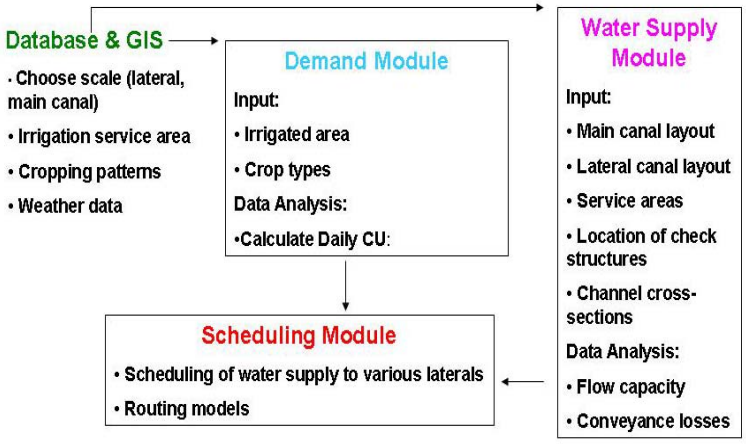
Abstract:

The New Mexico Interstate Stream Commission (Office of the State Engineer) and the Middle Rio Grande Conservancy District have sponsored a project with Colorado State University to develop a decision support system (DSS) for the Middle Rio Grande river basin (year 2004-present). The DSS model will assist implementation of more efficient water management and its use in the Middle Rio Grande river basin. Water is the lifeblood of the American West and the foundation of its economy, but it remains its scarcest resource. The case of the Middle Rio Grande (MRG) river basin illustrates the problem very well. The river is the ecological backbone of the Chihuahuan Desert region in the western United States, and supports its dynamic and diverse ecology, including the fish and wildlife habitat. The Rio Grande Silvery Minnow is federally listed as endangered species, and the irrigated agriculture in the Middle Rio Grande has come under increasing pressure to reduce its water consumption while maintaining the desired level of service to its water users.

The MRG DSS is fundamentally a logical arrangement of information including available water supplies and demands, mathematical model and GIS and graphical user interfaces, which is used by managers to make informed decisions. The DSS can organize information about water supplies and demands in the river basin and then provide recommendations for water delivery options to most efficiently fulfill the demands. The DSS consists of three elements; a water demand module, a supply network module, and a scheduling module. A Graphical User Interface (GUI) is the framework for linking the three elements of the DSS, and provides the user with the ability to access data and output for the system.



Designing a Phased Potable Water System for San Antonio Abad, El Salvador

Abstract:

Currently, a project is underway in the community of San Antonio Abad (SAA), located in northwestern El Salvador. SAA is a town of approximately 600 residents with projected population growth up to 2500 people. Previously, the community has relied upon the purchase of relatively expensive bottled water and hand dug wells for consumption and general use. Additionally, many of the hand dug wells in the community go dry during the dry season, and all are considerably contaminated due to the proximity of numerous latrines and disposal sites.

In January 2007 a team of students from CSU working with Engineers Without Borders (EWB-CSU) drilled and tested a deep well accessing a productive aquifer deep beneath the ground surface, and significantly deeper than any existing well in SAA. Through the remainder of 2007, a civil engineering senior design team compiled a preliminary design for a phased water distribution system, starting with multiple community distribution centers throughout the town. During this time, the town's water board has been organizing and raising funds to meet the expense of their final goal, a community-wide distribution network with running water to each house. After an August 2007 site visit, modifications were made to the design in an effort to create a plan that worked conjunctively with the desires of the community and the implementation procedures set forth in the original design.

With funding from Rotary International, SAA completed the structure for a pump house and in January 2008, EWB-CSU returned to install a well pump and the piping and treatment system for the pump house in order to create the first community distribution center. Work is continuing this semester on a formally submitted design for the proposed community-wide system. Additionally, a second civil engineering senior design team was formed in late 2007 to tackle the major problems of erosion and washwater disposal throughout the town. The combination of all of these efforts goes towards the implementation of a clean, sustainable water supply system for the future growth of the community, and the protection of the groundwater on which they depend.

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Reregulating the Flows of the Arkansas River: Comparing Forms of Common Pool Resource Organizations

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Abstract:

What sociological attributes characterize the form of an enduring social organization that empowers individually rational self-interested actors to provide themselves with a common property resource and collective good?

In order to address this research question, the analyst compared three common property resource and collective goods organizations for water management located in the Arkansas River basin of Colorado to an integrated ideal type model combining the work of David Freeman and Elinor Ostrom. It was the objective of this research to employ empirical observations while giving consideration to existing common property resource theories in an effort to formulate new theory. The three organizations being studied in this research were:

1. The Arkansas River Water Bank Pilot Program,
2. The Lower Arkansas Valley Water Conservancy District,
3. The Lower Arkansas Valley Water Management Association.

A brief overview of the findings were as follows:

1. The Arkansas River Water Bank Pilot Program failed to show the characteristics that the analyst's integrated ideal type model would suggest were important to the creation of a long-enduring organization. The pilot program also failed to generate local interest.
2. The Lower Arkansas Valley Water Conservancy District had some attributes of the integrated ideal type model, and is believed to have been partially successful for this reason. This organization will require further observation in the future to see just how successful it will be.
3. The Lower Arkansas Water Management Association had virtually all the characteristics of the integrated ideal type model. It was the only organization studied that should be considered a success story, success being defined by member support for the organization and the capacity of that organization to re-regulate flows on the Arkansas River.

Implications for policy and theory are also addressed in this dissertation. The conceptual "ideal type" models do identify variables and relationships that can be associated with success and failure of social organizational experiences in the Arkansas Valley. The empirical observations of the three valley organizations do support aspects of the conceptual models found in the literature. Additionally, new theoretical propositions will be advanced.

Squeezing the Margins: Unintended Consequences of Historical, Social Adaptation to Water Scarcity

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Department of Sociology, Colorado State University

Abstract:

This research evaluates the historical patterns of water appropriation, demographic growth, and environmental changes in Colorado's South Platte River Basin from 1905-2005. Findings show that changes in the socio-ecological system have led to a reliance on groundwater as the primary water supply in the region. The resulting over-appropriation of the South Platte supplies, coupled with institutional responses of demand management has led to a more vulnerable system where there is little room for error in times of shortage. The global implications of the research focus on the unintended consequences of policy in a complex and rapidly changing social and ecological system.

Predicting Effects of Flow Change from Ecological Theory

Thomas K. Wilding, N. LeRoy Poff
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Abstract:

The science of environmental flows aims to predict the ecological effects of flow alteration to guide the sustainable management of streams and rivers. How ecological processes and patterns vary along gradients of streamflow is well documented, but few studies have quantified the ecological responses of flow change per se. Thus, despite ample commentary about the potential effects of flow alteration, predictive models lack accuracy.

New research will seek answers to these problems. Ecological theory can direct us to where effects are most likely to be measurable. For example, large changes to the major environmental drivers of river ecosystems (disturbance, temperature, river morphology) are expected to produce pronounced effects. Taking this further, a heuristic model (e.g. Bayes Nets) will be constructed to predict the combinations of ecosystem-type and type of flow-change that are most likely to produce measurable effects. Flow interacts with other major drivers of stream ecosystems (geomorphology, temperature, food source), so it cannot be examined in isolation. By predicting which functional traits (populations or life stages) are more susceptible to proposed changes in flow (directly or indirectly), we can better target monitoring efforts. Even a model that serves only to identify those issues *less* likely to be critical would make an important contribution to management.

This approach represents a shift in research focus from increasing precision (e.g. PHABSIM -> 2D -> 3D habitat models) to greater accuracy (is habitat the limiting factor?). We hope this will improve our ability to predict ecosystem response, when used to guide more detailed investigations.

Snowcover Variability Due to Wind & Rangeland Shrub Interactions in North Park, Colorado

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Abstract:

Snowpacks in high-altitude plateaus, such as North Park, Colorado, are subject to dramatic changes in depth and area on large and small scales. The shallow depth of snow cover enhances the effects of albedo-induced melt. Over a winter the snowpack can completely disappear and re-accumulate several times. Low night temperatures can help prolong a persistent shallow snowpack late into the spring. Wind contributes greatly to the variability of snowcover in this environment where the terrain is relatively flat and vegetative cover is small. The variability of the ground cover density and profile height provided by shrubs creates numerous, random depressions and isolated voids that can capture blowing snow. Spatial variability in snowpack cover can be observed between areas with different densities of vegetative cover. Dramatic snow drifts can appear behind larger shrubs due to high wind velocities.
Differences in albedo among varying densities of ground cover become most apparent during the initial accumulation and during snowmelt. These differences are also associated with variability in snow present: early in the snow season snow depths can be greater around shrubs while late in the season these depths can be less than the surrounding open areas. Early season snow depths can be misleading due to void space under more dense branches that have become prone due to the overlying snow mass. To assess net accumulation and snowmelt patterns, albedo, snow depth, and snow density were measured within and between two rangeland shrubs species, in particular big mountain sage (*Artemisia tridentata*) and cinquefoil (*Potentilla fruticosa*).

Developing a Framework for Testing Distributed Hydrologic Models at the Hillslope Scale

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Abstract:

Numerous hydrologic models solve the Richards equation for the variably saturated subsurface domain. However, the scarcity of measured hydrologic states and variables and the scale discrepancies between observations and simulations pose a challenge in testing and evaluating such models. We develop a flexible framework for testing distributed hydrologic models at the hillslope scale. The proposed method consists of three major steps. First we generate "hypothetical realities" representing the hydrologic response of a synthetic watershed modeled after the 10.5 ha Tarrawarra catchment in Australia. The catchment was extensively monitored and has a relatively simple geometry with 0.5-1.5m deep soils overlaying bedrock and a fairly uniform grass cover. Eleven years of half-hourly time increment hydrological states and fluxes generically termed "hypothetical realities" have been generated at Stanford University using the complex Integrated Hydrology Model (I*n*HM) representing fully coupled 3D variably saturated subsurface and 2D surface flow with high resolution. In the second step, simpler distributed hydrologic models can be evaluated against the hypothetical realities, which represent an error-free data set of hydrologic variables. The simpler distributed models are run first without calibration and then with calibration against different combinations of the observed data from the hypothetical realities. In the third step, further tests of distributed models incorporate event based and continuous simulations, variable spatial and temporal scales and increasing amounts and types of model input data and observed data.

The Effects of an Estrogenic Endocrine Disruptor on the Reproductive Success of the Male Red Shiner (*Cyprinella lutrensis*)

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Abstract:

Endocrine disrupting compounds (EDCs) are found worldwide in both aquatic and terrestrial ecosystems and can lead to developmental and reproductive disruption in fishes. The estrogenic EDC 17β-estradiol (E2) is a natural hormone found in most wastewater effluent-treated waters. We exposed adult male red shiners (*Cyprinella lutrensis*) to E2 at a concentration of 120 ng/L. After 44 days of exposure, males were allowed to spawn with females, during which time male mating behavior, reproductive output, fertilization success, and hatching success was measured. After a three week spawning period, morphological and histopathological characteristics of the males were measured. We observed reduced male mating behaviors, fewer and less developed nuptial tubercles, reduced spawning coloration, and reduction in spermatogenesis with E2 exposure. In tanks containing exposed males, reproductive output, fertilization success, and hatching success was lower. Changes in behavior, secondary sexual traits, and male reproductive development may influence mating opportunities and success, while decreases in reproductive output, fertilization success, and hatching success may influence survival and recruitment. Our study suggests that exposure to E2 influences developmental and morphological processes as well as productivity, potentially having negative consequences for population growth.

Geomorphic Implications of Hydroclimatic Differences Among Steep Channels

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Abstract:

This research uses nine step-pool channel segments from six regions to examine the magnitude, frequency, and duration of flows hypothetically capable of mobilizing the D_{50} and D_{84} of streambed sediment. Each channel segment is located close to a gage with a record of discharge in 10- or 15-minute increments for the period 1994-2003. Channel geometry along approximately 50 m of channel was surveyed during base flow conditions, and streambed grain-size distribution was measured using a grid spaced at half the largest clast size. Field and gage data were used with the Manning equation to estimate shear stress as a function of discharge at a representative cross section. Critical shear stress was estimated using equations developed by Buffington (D_{50}) and Komar (D_{84}). Critical shear stress was equated to a threshold discharge for sediment mobilization, and stream data were filtered to determine the exceedance of the threshold discharge during the period analyzed. Magnitude was the ratio of maximum discharge each year to threshold discharge. Frequency was number of events per year during which threshold discharge was exceeded. Duration was number of minutes per event and total number of minutes per year during which threshold discharge was exceeded. A cumulative mobility variable was developed from the product of the sum of the discharges exceeding the threshold and the duration of those discharges for each year of record. The six regions examined represent different hydroclimatic regimes: Switzerland (snowmelt runoff and high-intensity rainfall during summer); Puerto Rico (runoff from high-intensity, short duration rainfall throughout the year); Colorado (snowmelt runoff); Oregon and northern California (low-intensity winter rainfall runoff); and Idaho (snowmelt and rain-on-snow). Puerto Rico ranked highest for the majority of variables related to magnitude, frequency, and duration, and cumulative mobility of D_{50} and D_{84}. These results suggest some of the geomorphic implications of the highly peaked runoff events characteristic of many tropical montane reigions.

The Colorado State University GetWET Observatory: A Fluid Learning Environment Promoting Deeper Understanding

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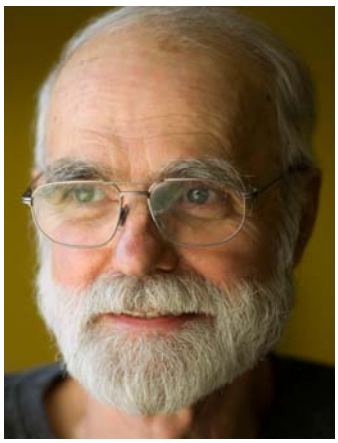
Abstract:

A groundwater well field installed on the Colorado State University campus in Spring 2006 provides undergraduate students with a learning experience focused on hands-on exposure to the linkages between surface water and groundwater. The GetWET Observatory consists of six monitoring wells adjacent to Spring Creek, a regulated perennial stream that experienced a high magnitude flood in 1997 and record drought in 2002. Three principal learning goals have been established for the site, including: 1) providing non-majors with quantitative, real-life hydrogeologic experiences that increase awareness of the importance of the groundwater portion of the water cycle, 2) field-based, interdisciplinary learning opportunities in surface and groundwater hydrology in five courses for geoscience majors, and 3) support for K-12 science teachers via professional development workshops, well access, inquiry-based classroom and field activities, and equipment loans. Laboratory-based exercises have been developed to include basic site characterization where CSU students collect data on water levels, hydraulic and tracer tests, and general water quality indicators. Students develop potentiometric surface maps as a basis for flow-net analysis, evaluate drawdown and recovery data to determine hydraulic conductivity of the unconfined aquifer, analyze and interpret tracer data to determine additional aquifer properties and the interaction with surface water, and interpret water quality results based on compliance with regulatory standards. Well-logs and cores completed and described by students during drilling are used for developing subsurface cross-sections and to further define aquifer properties. In the near future, there will be continuous logging of hydraulic head, temperature, and specific conductance in several wells. A web accessible data allows students to make annual and seasonal comparisons that enhance student understanding of surface and groundwater processes over time. To date, approximately 1000 undergraduates have completed laboratory exercises at the well field since its installation, three professional development institutes were held attracting 39 K-12 teachers to learn about key concepts in surface and groundwater, and over 390 students from local public schools have visited the GetWET for water education exercises. Generous donations by local industry partners provided state-of-the-art equipment for student use at the GetWET Observatory.

Art Posters

Phil Risbeck, Ph.D.



Phil Risbeck is professor of art and teaches junior and senior graphic design students. Especially active in poster art, he co-founded and co-directs the Colorado International Invitational Poster Exhibition. His students have won major regional and national student awards and found professional employment coast to coast. He exhibits his own work nationally and internationally.

Classes:

Spring semester: ART356 and ART456.

Participating students:

Babb, Jessica
Bartlett, Liz
Braden, Makayla
Cowhick, Tyler
Downey, Anna
Ferrell, Casey
Fowler, Shannon
Frank, Latonya
Genty, Susannah
Gonzalez, Sam
Heyse, Kevin
Hoffman, Ashley
Iron, Chris
Jackson, Lindsey
Johnson, Margee
Kelly, Brian
Miles, Shane
Nelson, Cameron
Olano, Erick
Oldemeyer, Sterling
Pintauro, Kristin
Romero, Alex
Ruoff, Courtney
Ryan, Tony
Schmidt, Elizabeth
Shrestha, Danielle
Slagle, Lisa
Sperry, Dan
Stanton, Brady
Steiner, Hannah
Stupinsky, Michele
Supino, Adriane
Taggart, Kyle
Tesar, Kim

Jason Frazier, MA

Jason Frazier received his Bachelor of Fine Arts in Design in 1993 from Missouri State University. He was a member of the Office of Publications at Missouri State University for eight years, working on design and marketing projects for the university including recruitment, performing arts, special events, homecoming, the president's office and legislative affairs, to name a few, and also began teaching in the Department of Art at Missouri State in 2000. In 2003, Jason came to Colorado State University to pursue a Masters of Fine Arts in Design, which he completed in 2007, and is now an adjunct faculty in the Art Department at CSU and the supervisor of the Art Department Computer Lab. He also continues to pursue commercial work in addition to teaching, working in publication design, identity design and interactive and time-based media. Jason has been exhibited for his poster, publication and media work in the United States and in Mexico, and is the recipient of over 25 regional and national awards for his graphic design.

Classes: Illustration, Advanced Illustration, Typography and Design Systems, Advanced Typography and Design Systems, Introduction to Graphic Design, Graphic Production

The below students entered art posters for the Global Water Colloquium

Beckman, Richie
Bowers, Tyler
Brown, Mallory
Carlson, Brandy
Carnes, Mattie
Ceron, Shannon
Chandler, Shannon
Christopherson, Kelly
Clewe, Sidney
Collier, Michael
Cook, Morgan
Copelin, Gentry
Criswell, Summer
Crowe, Amber
Dillon, Kymber
Dubinski, Erin
Elder, Jonathan
Fryberger, Raine
Gilmer, Robin
Giustino, Nick
Gosting, Emily
Guthman, Amethyst
Harper, Casey
Hlushak, Andy
Hoshide, Cody
Knoop, Kyle
Kobayashi, Lauren
Krohn, Jonathan
Kruk, Bryson
Kuenstler, Britni
Larson, Megan
Lee, Nina
Lindau, Michael
Marron, Brian
McGowan, Stephanie
Montoya, Aaron
Mulder, Nichole
Naumburg, Michael
Olsen, Kyle
Paine, Julie
Pottberg, Brian
Rogers, Melissa
Schler, Dan
Schnell, Jennifer
Schroeder, Leah
Sheffield, Rebecca
Slosky, Matthew
Smiley, Connor
Swartz, Steven
Thome, Alexandra
Vinson, Katrina
Watanabe, Nicole
Wichman, Nick
Workman, Jennifer
Wyne, Gordon

Acknowledgements

The Global Water Research Colloquium was made possible by funding from the Vice President for Research (VPR), International Programs and the CSU Water Center. We would like to extend a special thanks to Margaret Saldaña, Assistant to the Associate Vice President for Research and Faith Sternlieb, Research Associate at the CSU Water Center.

In addition, we would like to acknowledge the Faculty Advisory Committee (listed below by department). The Faculty Advisory Committee was led by 3 Chairs: Reagan Waskom, Director of the CSU Water Center, Melinda Laituri, Associate Dean of Academic Affairs for the Warner College of Natural Resources, and Luis Garcia, the Department Head of Civil and Environmental Engineering.

Global Water Research Colloquium (GWRC) Faculty Advisory Committee

Agricultural Sciences

- Chris Goemans - Ag Econ

Business

- Carl Hammerdorfer - Director, Master of Science in Business Administration in GSSE

Engineering

- Neil Grigg - Civil
- Jorge Ramirez - Civil

Liberal Arts

- Troy Lepper - Sociology
- Evan Vlachos - Sociology

Natural Sciences

- LeRoy Poff - Biology

Office for International Programs

- Jim Cooney

Veterinary Medicine & Biomedical Sciences

- John Nuckols - Director of Environmental Health Advanced Systems Laboratory

Vice President for Research

- Hank Gardner - Associate Vice President for Research

Colloquium Co-Chairs

Dr. Melinda Laituri
Biographical Sketch:

Dr. Laituri earned a Doctor of Philosophy from the University of Arizona in 1993 and is an associate professor, holding a joint appointment in Colorado State University's Department of Forest, Rangeland and Watershed Stewardship and Department of Earth Sciences. She is the Associate Dean of Academic Affairs for the Warner College of Natural Resources. Dr. Laituri researches vulnerability studies, emergency response and environmental equity issues. Dr. Laituri uses geographic information systems (GIS) to better understand spatial relationships of vulnerability and disaster. Her international experience includes a Fulbright in South Africa as well as research activities in New Zealand, Sweden, India, the South Pacific, and the US-Mexico border. She is involved with an NSF funded Biocomplexity Project focusing on river systems in Puerto Rico. Additionally, she is developing partnerships with the European Science Foundation to conduct environmental histories of river basins across the globe. Dr. Laituri is organizing GIS workshops for University students in Ethiopia.

Dr. Luis Garcia
Biographical Sketch:

Dr. Garcia is Director of IDS and Professor and Head of the Department of Civil and Environmental Engineering at Colorado State University. He received his Ph.D. in Civil Engineering from the University of Colorado at Boulder and his Masters in Civil Engineering from Texas A&M University. Dr. Garcia's research interests are in the area of computer modeling of water and natural resources. He is the founder of the Integrated Decision Support group, a multidisciplinary research group that is part of The Water Center at Colorado State. At the present time Dr. Garcia is involved in the development of a number of Decision Support Systems in the area of consumptive use estimation, wetland analysis, habitat management, and conjunctive irrigation and drainage design. Garcia joined Colorado State as an assistant professor in March 1991. Garcia has also served as associate director of the Colorado Agricultural Experiment Station at Colorado State and has worked as a consultant for numerous government organizations.

Dr. Reagan Waskom
Biographical Sketch:

Reagan Waskom currently serves as the Director of the Colorado Water Resources Research Institute and as Director of the Colorado State University Water Center. Dr. Waskom is a member of the Department of Soil & Crop Sciences faculty with a joint appointment to the Department of Civil and Environmental Engineering at CSU. In addition, Reagan currently serves as the National Chair and Regional Director of the USDA-CSREES Integrated Water Program. Dr. Waskom has worked on various water related research, education and outreach programs in Colorado for the past 22 years.

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