Division of Hydrologic Sciences
Annual Technical Report
FY 2008

Introduction

Research Program Introduction

None.

Award No. 05HQAG0069 Water Resources of the Basin and Range Carbonate Aquifer System in White Pine County, Nevada, and Adjacent Areas in Nevada and Utah

Basic Information

Title:	Award No. 05HQAG0069 Water Resources of the Basin and Range Carbonate Aquifer System in White Pine County, Nevada, and Adjacent Areas in Nevada and Utah
Project Number:	2005NV125S
Start Date:	6/1/2005
End Date:	5/31/2008
Funding Source:	Supplemental
Congressional District:	Nevada 2
Research Category:	Not Applicable
Focus Category:	Water Quantity, Groundwater, Hydrogeochemistry
Descriptors:	
Principal Investigators:	James Thomas

Publication

2. Cablk, Mary E., Kratt, Christopher, A Methodology for Mapping Shrub Canopy Cover in the Great Basin Desert using High Spatial Resolution Satellite Imagery. Desert Research Institute Publication No. 41236, 28 p.

Water Resources of the Basin and Range Carbonate Aquifer System in White Pine County, Nevada, and Adjacent Areas in Nevada and Utah

The U.S. Geological Survey is conducting a cooperative study with the Desert Research Institute to evaluate geohydrologic characteristics of ground-water flow systems in selected basins in White Pine County, Nevada, and adjacent basins in Lincoln County, Nevada, and Utah. The main objectives of the proposed study are to evaluate the following geohydrologic characteristics within the study area:

(1) the extent, thickness, and hydrologic properties of aquifers,
(2) the volume and quality of water stored in aquifers,
(3) the delineation of subsurface geologic structures controlling ground-water flow,
(4) determining ground-water flow direction and gradients,
(5) the distribution of recharge and discharge areas, and
(6) determining representative rates of recharge and discharge.

Geologic, hydrologic, and supplemental geochemical information will be integrated to determine basin and, if possible, regional ground-water budgets. All geohydrologic data will by synthesized and evaluated to develop a three-dimensional conceptual model of the ground-water flow system in the proposed study area.

Information Transfer Activities: The research team has traveled to several communities, within the study area, to deliver progress reports to local residents. Topics of discussion include status of the various projects, identification and discussion of relevant findings, and question and answer sessions with the audience.

The complete report is posted on http://nevada.usgs.gov/barcass/pubs.htm

Modeling Biotic Uptake of Mercury in the Lahontan Resevoir System

Basic Information

Title:	Modeling Biotic Uptake of Mercury in the Lahontan Resevoir System
Project Number:	2006NV101B
Start Date:	3/1/2006
End Date:	12/31/2009
Funding Source:	104B
Congressional District:	Nevada 02
Research Category:	Water Quality
Focus Category:	Models, Toxic Substances, Ecology
Descriptors:	
Principal Investigators:	Rosemary Woods-Hart Carroll, Rosemary Woods-Hart Carroll

Publication

1. Warwick, J.J., and Carroll, R.W.H. 2007. Evaluating the impacts of uncertainty in geomorphic channel changes on predicting mercury transport and fate in the Carson River system, Nevada. 23rd Annual International Conference on Soil, Sediment and Water. Oct 15-18, 2007. University of Massachusetts, Amherst. Published in conference proceedings, Contaminated Soils, Sediment and Water, vol 13.
2. Warwick, J.J. and Carroll, R.W.H. (2008). Evaluating the impacts of uncertainty in geomorphic channel changes on predicting mercury transport and fate in the Carson River system, Nevada. International Journal of Soil, Sediment and Water.

Modeling Biotic Uptake of Mercury in the Lahontan Reservoir System

Synopsis

Year Two Progress Report – Not Final Report Due to No-Cost Extension

Problem and research objectives

The timing of maximum growth of phytoplankton relative to that of mercury loading could matter greatly if the loading signal varies strongly over time. Therefore, accurate prediction of mercury bioaccumulation may depend upon understanding mercury loading mechanisms and associated uncertainty to the system as well as the interaction between this loading and phytoplankton growth at sub-annual time scales (i.e. days to weeks). Also, using a well defined and strongly varying mercury signal may help to elucidate important bioaccumulation features (e.g., bioavailable forms of mercury and the rate of mercury transfer through different trophic levels).

The geologic and geochemical controls on THg and methylmerncy (MeHg) transport through the Carson River have been successfully modeled with a linked and modified version of RIVMOD (Hosseinipour and Martin, 1990) and WASP5/MERC4 (Ambrose et al., 1991) by Carroll et al. (2004), Carroll and Warwick (2001), Carroll et al. (2000) and Heim and Warwick, (1997). Proposed research will better quantify physical parameters impacting mercury transport into/through Lahontan Reservoir as well as quantify uncertainty associated with geomorphologic and biogeochemical controls influencing mercury loading into the Carson River and subsequently into Lahontan Reservoir. Results will be evaluated in their relationship to a varying mercury signal within the lower trophic levels occupying Lahontan Reservoir.

Methodology

Proposed research has been divided into two distinct phases based on site location. First, a detailed uncertainty analysis looks at geomorphic controls, bank moisture history, as well as methylation-demethylation on mercury loading into the Carson River and subsequently into Lahontan Reservoir. Hypothetical best management practices will address mitigation of fluvial loads into the reservoir and results will be incorporated into proposed bioaccumulation modeling. Second, Lahontan Reservoir will be investigated in greater detail. Detailed cross sections and stage modeling will ensure a correctly moving delta region which dictates sediment and mercury deposition at the mouth of the Carson River. With proper hydrodynamic modeling of the reservoir established, it is proposed to observe and model a temporally varying mercury signal in the lower food web, specifically within the phytoplankton communities. Collected data will

parameterize/drive a bioaccumulation model (e.g. Bioaccumulation and Aquatic System Simulator – BASS by the US EPA (Barber, 2004)) to simulate mercury pulse loading on bioaccumulation of MeHg in generalized/hypothetical trophic levels in Lahontan Reservoir. A verified model will allow model prediction of bioaccumulation based on hypothetical flow and mercury loading scenarios. Finally, a coupled uncertainty analysis of fluvial inputs and BASS model parameters will provide a quantitative assessment of the expected accuracy of model predictions. This will allow a determination of significant differences between simulated scenarios

Principal findings and significance

This project was granted a no-cost extension through December 2009 and therefore the listed findings will not meet all objectives listed above. Outcomes from the geomorphic uncertainty analysis were presented in the progress report from 2008 and are not presented here.

Observed phytoplankton mercury concentrations as related to mercury loading were discussed in the progress report from year 1, however reworking of data during March 2009 produced new insight with additional findings provided below.

- The amount of Hg and MeHg per unit mass Chl*a* increased throughout the summer months for smaller phytoplankton and showed a direct correlation to phytoplankton biomass.
- Accumulation of Hg in larger phytoplankton were directly correlated with high loading events from the river and indirectly related to biomass.
- Hg accumulation in larger phytoplankton was low during periods of substantial growth (growth dilution) and this might minimize the impact of larger phytoplankton in terms of benthic re-cycling of mercury back into Lahontan Reservoir's food web. Future work will need to better quantify impacts of sediment on C_b calculations during spring runoff and identify palatability of the larger phytoplankton during the spring months to substantiate the claim that large phytoplankton's role in trophic transfer, both directly into the pelagic food web and indirectly via the benthic sediments, is minimal.
- Smaller, more palatable phytoplankton appear the more viable mechanism of Hg and MeHg transfer into upper trophic levels with increased accumulation directly related to biomass (at least for peak biomass less than 10 □g/L). Mercury accumulation in small phytoplankton were highest during the late summer when internal cycling of mercury from benthic sediments is potentially high as opposed to periods of large loading from the Carson River.

Significant effort is ongoing with respect to the CRLR mercury transport model with special attention given to dissolved species. Dissolved species are bioavailable and impact bioaccumulation in the reservoir. Understanding dynamic

loading mechanisms of dissolved species is important and has never been done for this system (or any system). During the past fiscal year, the CRLR mercury transport model has been modified to include the following.

- Code errors (i.e. incorrect arrays) were detected during simulated best management practices. Code modifications were completed to correct these errors.
- Massive amounts of modeled THg entering the river during overbank flows necessitated a new approach to dealing with mercury associated with washload and the relative amount of DHg in relationship to these contaminated particles. Stokes settling velocities are now augmented with the assumption that mercury laden particles are slightly heavier than uncontaminated washload and settle at a faster rate. The fraction of DHg is computed as the ratio of Hg contaminated fine particles loads to the total Hg load modeled in a given river segment. This ratio is updated every timestep.
- Flow regimes are now divided into four categories to reflect different mercury loading mechanisms. Extremely low flows are dominated by diffusion. Low flows incorporate an advective flux term from the river bottom sediments. Medium to high flows are dependent on bank erosion inputs while overbank events experience massive bank erosion coupled with overbank deposition.
- Calibration now includes the 2006 water year that experiences all four flow regimes. Water year 2006 also represents the period of data collection in Lahontan Reservoir which will be used to calibrate BASS.
- Verification of the CRLR mercury transport model runs from 1994 to the end of 2008 using USGS data collected at Fort Churchill. This 14 year simulation runs for a total of 4 four days on DHS 3 Sunfire x4600's computer.

<u>Information Transfer Activities (ongoing)</u>

Papers (in development):

- Carroll, R.W.H., Memmott, J., Warwick, J., Fritsen, F.H., Bonzongo, J.C., and Acharya, K. draft. Seasonal variation of mercury associated with phytoplankton in Lahontan Reservoir, Nevada. *Co-Authors reviewing. Intended Journal – WaterSoil and Air Pollution. Estimated submittal May 2009*
- Carroll, R.W.H., and Warwick, J.J. draft. Mercury transport model of the Carson River and Lahontan Reservoir System, Nevada: An Investigation of Total and Dissolved Species and associated uncertainty. *Intended Journal. Ecological Modeling. Estimated submittal – September, 2009*

Intended Conference:

American Geophysical Union, December 2009. San Francisco. Work presented will be the CRLR transport model.

Student Support

This grant funds doctoral research for Rosemary Carroll who attends the University of Nevada, Reno graduate program of Hydrologic Sciences. Anticipated graduation is May 2010. Work from this project will serve as the entirety of her dissertation. The four chapters will be the four papers she has/will publish. These papers include:

Chapter 1: Evaluating the impacts of uncertainty in geomorphic channel changes on predicting mercury transport and fate in the Carson River system, Nevada (published 2008).

Chapter 2: Seasonal variation of mercury associated with phytoplankton in Lahontan Reservoir, Nevada. Intended journal – Water, Air and Soil Pollution , anticipated submittal - May 2009.

Chapter 3: Mercury transport model of the Carson River and Lahontan Reservoir System, Nevada: An Investigation of Total and Dissolved Species and associated uncertainty. Intended journal - Ecological Modeling, anticipated submittal - September 2009.

Chapter 4: Modeling mercury bioaccumulation in Lahontan Reservoir: the importance of loading dynamics. – work will be completed by close of this project. Anticipated paper submittal - spring 2010.

References Cited

Ambrose, R.B., T.A. Wool, J.L. Martin, J.P. Connolly, and R.W. Schanz (1991). WASP5.X: A Hydrodynamic and Water Quality Model: Model Theory, Users Manual and Programmer's Guide. U.S. Environmental Protection Agency, Athens, Georgia.

Barber, M.C. 2004. Bioaccumulation and Aquatic System Simulator (BASS). User's manual version 2.2. Ecosystem Research Division, U.S. Environmental Protection Agency. EPA Report No. 600/R-04.

Carroll, R.W.H., J.J. Warwick, K.J. Heim, J.C. Bonzongo, J.R. Miller, and W.B. Lyons (2000). Simulation of Mercury Transport and Fate in the Carson River, Nevada. Ecological Modelling, 125, 255-278.

Carroll, R.W.H. and J.J. Warwick (2001). Uncertainty analysis of the Carson River mercury transport model. Ecological Modelling, 137, 211-224.

Carroll, R., James, A., Warwick, J. and J. Miller. (2004). Modeling Erosion and Overbank Deposition During Extreme Flood Conditions on the Carson River, Nevada. Journal of Hydrology. 297(1-4): 1-21.

Heim, K.J. and J.J. Warwick (1997). Simulating Sediment Transport in the Carson River and Lahontan Reservoir, Nevada, USA. Journal of the American Water Resources Association, 33(1), 177-191.

Hosseinipour, E.Z. and J.L. Martin (1990). RIVMOD, A One-dimensional Hydrodynamic and Sediment Transport Model: Model Theory and User's Guide, U.S. Environmental Protection Agency, Athens, Georgia.

Flood Warning System for the Clark County Wetlands Park

Basic Information

Title:	Flood Warning System for the Clark County Wetlands Park
Project Number:	2006NV102B
Start Date:	3/1/2006
End Date:	8/31/2009
Funding Source:	104B
Congressional District:	Nevada 01
Research Category:	Not Applicable
Focus Category:	Floods, Hydrology, Models
Descriptors:	
Principal Investigators:	Thomas Piechota, Thomas Piechota

Publication

1.

Annual Report for “Flood Warning System for the Clark County Wetlands Park”

The FY2008 report for Project 2006NV102B is filed with Project 2008NV135B

Microbial and Phytoplankton Impacts on Endocrine Disrupting Contaminants: Las Vegas Wash and Lake Mead, NV

Basic Information

Title:	Microbial and Phytoplankton Impacts on Endocrine Disrupting Contaminants: Las Vegas Wash and Lake Mead, NV
Project Number:	2006NV104B
Start Date:	3/1/2006
End Date:	12/31/2009
Funding Source:	104B
Congressional District:	Nevada 01
Research Category:	Biological Sciences
Focus Category:	Toxic Substances, Water Quality, Acid Deposition
Descriptors:	
Principal Investigators:	Duane Moser

Publication

Annual Report for “Microbial and Phytoplankton Impacts on Endocrine Disrupting Contaminants: Las Vegas Wash and Lake Mead, NV”

The FY2008 report for Project 2006NV104B is filed with Project 2008NV136B

Soil Heterogeneity and Moisture Distribution Due to Rainfall Events in Vegetated Desert Areas: Potential Impact on Soil Recharge and Ecosystems

Basic Information

Title:	Soil Heterogeneity and Moisture Distribution Due to Rainfall Events in Vegetated Desert Areas: Potential Impact on Soil Recharge and Ecosystems
Project Number:	2008NV134B
Start Date:	3/1/2008
End Date:	5/31/2009
Funding Source:	104B
Congressional District:	Nevada 01
Research Category:	Not Applicable
Focus Category:	Hydrology, Geomorphological Processes, Drought
Descriptors:	
Principal Investigators:	Michael Young, Li Chen

Publication

1. Yin, J. 2008 Spatio-temporal variation in soil moisture and hydraulic properties and their impacts on rainfall-runoff and infiltration processes. Ph.D. Dissertation. University of Nevada Las Vegas, Department of Geosciences.
2. Yin, J., M. H. Young, L. Chen and Z. Yu, (2008) Modeling surface runoff on a semi-arid watershed using a physically based model. World Environmental and Water Resources Congress. Honolulu, Hawaii.
3. Chen, L. (2009) The Role of Clast Layer in Desert pavement in Rainfall-Runoff Process. World Environmental and Water Resources Congress, Kansas City, Kansas.

Soil Heterogeneity and Moisture Distribution Due to Rainfall Events in Vegetated Desert Areas: Potential Impact on Soil Recharge and Ecosystems

Annual Report
2009

Michael Young and Li Chen
Division of Hydrologic Sciences
Desert Research Institute, Las Vegas, NV

Problem and research objectives

Strong interactions exist between desert soils and plants, and these interactions will potentially control the overall movement and distribution of water, which are critical for water resources and desert ecosystems. The high level of spatial and temporal heterogeneities of near-surface soil and plant environments creates significant difficulty for quantifying, understanding and simulating how climate, soil properties and ecological resources interact with one another. Heterogeneities are attributed to physical, geomorphological, and biological variations across the landscape and soil surface; many of these attributes directly influence soil hydraulic properties and thus hydrological processes. The overriding objective of this research is to observe and simulate the contribution of surface feature heterogeneity to the landscape response from precipitation events, particularly as they relate to recharge and surface runoff in desert environments.

Methodology

Field Measurements

The proposed methodology for this study is to apply both field experimental and numerical approaches to examine the impact of the heterogeneity of soil surface introduced by microtopography, plant canopies, and soil hydraulic properties on rainfall-infiltration-runoff processes. In the experimental portion of the study, we set up three experimental plots (20 m by 30 m) on 3 geomorphic surfaces with ages that range from 500 to 100,000 years old (McDonald et al, 2003; Young et al 2004) at the Mojave National Preserve, CA, and then conducted high-resolution elevation and plant surveys within each plot. On each plot, a surface elevation survey was conducted using a Laser Total Station. Surface elevations were first measured on 5 m X 5 m control grid to represent overall topographic trends. Significant topographic structures such as channels, ridges and mounds were measured in more detail. A vegetation survey was also conducted in each plot. The quantity of plant in each category was counted and characteristic scales (long and short axes and hight) of selected individual plants were

measured, generating the spatial distribution of the plants. Topographic mounds under plants were also measured to investigate the micro topographic features.

Hydraulic properties (i.e., hydraulic conductivity function) were measured using a tension infiltrometer (TI) in every experimental plot for both interspace and under canopy soils. The soil hydraulic properties obtained from the TI data similar to the method described by Young et al. (2004). Soil samples were collected from each TI location and analyzed for soil texture (i.e., gravel, sand, silt and clay contents) and bulk density. Spatial distribution and correlation of the texture and hydraulic property parameters were analyzed. Experimental results were imported to a numerical model (described below) to simulate surface runoff on the experimental plots under a variety of different precipitation events.

Leveraging an internally-funded DRI project, rainfall simulation experiments were conducted at the plot located on the oldest (Qf3) surface. This study aims to investigate the impact of the clast (upper rock) layer found on many desert pavement surfaces on runoff and infiltration rates. We used a portable rainfall simulator on adjacent plots on surfaces with and without the clasts. In the case where clasts were removed, the underlying Av material was kept intact to the extent possible; thus, the difference between the two plots is the presence of the clast layer. Seven pairs of experiments (14 plots total) were conducted. In each experiment, characteristic times for runoff generation were recorded (i.e., time to ponding, initial runoff, runoff observed in all quadrant, full runoff connection and runoff to the trough) and the runoff volume was measured by collecting water in a downstream trough at specific time intervals. Changes in soil water content were also monitored continuously during the experiment using a Water Content Reflectometer (WCR, model 616, Campbell Scientific Inc., Logan UT). The soil cumulative infiltration curves obtained from the WCR measurements were used in a parameter estimation scheme to obtain the Green-Ampt infiltration parameters.

Numerical Modeling

The numerical model used for this research is known as CeRIRM (Cell-Based Rainfall Infiltration Runoff Model), a physically-based distributed model for rainfall-runoff modeling (Chen and Young, 2008). The model is capable of simulating surface runoff and infiltration using a very high-resolution distributed modeling approach. CeRIRM was originally developed by the co-PI for his dissertation and was further modified through funding from the U.S. Army Corp of Engineers. The model applies a two-dimensional surface runoff routing approach to account explicitly for topographic impact on overland flow movement, and it incorporates the Green-Ampt model to simulate infiltration. This comprehensive modeling technique addresses the interaction between the infiltration and surface runoff routing that is greatly complicated by heterogeneity of soil hydraulic properties and topography. The model has been modified to accommodate the plot scale rainfall-runoff simulation for this project. Parameter fields of topography and corresponding soil hydraulic properties have been

generated on regular numerical grid for the whole plots using interpolation methods based on the observed topography and soil hydraulic properties. Using this model, we have simulated cases with and without microtopography, with and without vegetation, and for different rainfall conditions.

A primary issue in rainfall-runoff modeling is how to efficiently represent the spatial variability of parameters in hydrologic models. Thus, the numerical modeling work for the past year was focused on the fundamental impact of spatial variability of soil hydraulic properties on runoff and infiltration, given specific storm distributions. The model was applied to the Walnut Gulch Experimental Watershed, near Tombstone, AZ, to investigate how different spatial patterns of watershed characteristics (e.g., vegetation coverage) and soil hydraulic properties (e.g., hydraulic conductivity and saturated water content) could impact runoff and infiltration in a semi-arid environment (Yin, 2008; Yin et al., 2008). In these studies, the model was used to examine how parameter generation – uniform versus random versus co-kriged– could affect the accuracy of runoff predictions at a small (approximately 44,000 m^2) watershed known as Lucky Hills 104. Parameter fields for this modeling study were generated using a pedotransfer function, using soil textural data obtained from samples collected at 33 locations across the watershed. Samples were collected at both interspace and undercanopy microsites (66 samples total) using a stratified sampling technique. Saturated hydraulic conductivity (K_s), saturated water content (θ_s), and wetting front capillary pressure for the Green-Ampt model (S) were then derived from the estimated hydraulic properties. Three different methods were used to generate the parameter field: geometric mean for K_s and arithmetic mean for θ_s and S; Latin Hypercube Sampling (LHS); and, cokriging using all three parameters. For each method, the parameter fields were generated using only interspace samples, only undercanopy samples, and the entire population (nine combinations of averaging and sample origin). The numerical model was then run for eight recorded rainfall events during the last 50 years that produced measurable runoff at LH104, using each parameter field respectively (72 simulations total). The runoff generation results were compared to find the best approach for representing soil heterogeneity.

Soil hydraulic parameter estimation is a key issue in hydrological modeling. Green-Ampt model parameters are wildly used in modeling practices. However, the most common parameter estimation method for Green-Ampt model is based on soil texture and pedo-transfer functions. Those functions are not solidly based on field observation, but mainly from conversion of other soil hydraulic parameters. A numerical optimization approach has been developed to inversely determine the parameters from the measured soil moisture curves. The new method can be useful for directly estimating G-A parameters for practical applications. However, further studies are needed to solve the possible multi-solution issue in this method.

Principal findings and significance

Results from the field studies and numerical modeling studies have shown:

- Soil surfaces are features with various scales of topographic elements, which mainly include channels, topographic mounds, under canopy soil mounds. These features can dominate the runoff routing dynamics and significantly affect the lateral water distribution and nutrient movement toward or away from ecological niches.
- Even small magnitude of microtopography can impact the surface runoff significantly. Because the function of concentrating flow, microtopography not only can affect the routing time of the water, but may also break the lateral continuity and reduce the connectivity of the flow. Such a flow pattern will alter the distribution of water resource on the surface. It may have more profound impact on the nutrient /contaminant transport process and habitat stability in the ecosystem.
- Present hydrological modeling approach can not effectively treat the microtopography in subgrid scale, even with detailed topographic data. Based on our current modeling results, it is possible to develop a new simple approach to better represent the microtopography and simulate the surface runoff more accurately. This new treatment will be more important for simulating solute transport in surface runoff because the partial connectivity of flow will lead to much higher dispersion rate compared to fully connected sheet flows.
- Soil hydraulic properties have significant variability across the surface, as seen by a qualitative review of the TI experimental results. Quantitative analyses of the results are undergoing and will show more details of the heterogeneity and spatial correlation.
- In the rainfall simulation experiment, results of both runoff and soil moisture did not show significant difference between plots with and without clasts, which implies that the rock surface does not impact runoff generation by itself. The result implies that remove the surface clast layer for infiltration experiments such as Tension Infiltrometer tests may be an suitable treatment that does not affect the results of measurement.
- Numerical simulation results showed that impacts of spatial variability depend on flood characteristics such as runoff coefficients. In general, the diffusion wave model captured the runoff characteristics for most storm events. Simulation results also showed that the best performance occurred for parameters fields generated using cokriging. Also the results showed that effects of vegetation on interception loss and increased roughness coefficient cannot be neglected. Results also indicated that small-scale spatial variability dominates the runoff generation mechanism when storm events are small.

Information Transfer Activities

Papers:

Yin, J., M. H. Young, L. Chen and Z. Yu (2008) Modeling the effect of spatial variability of soil hydraulic properties on the rainfall-runoff process in a rangeland watershed using a diffusion wave model. (In revision).

Chen, L. and M. H. Young (2008) Two-dimensional Diffusion Wave Equations for Surface Runoff on Hillslopes. *Water Resour. Res.* (under review).

Chen, L., L. Xiang, M. H. Young (2009) Impact of Microtopography on the Rainfall-Runoff Process. (In preparation)

Chen, L. (2009) The Role of Clast Layer in Desert pavement in Rainfall-Runoff Process. World Environmental and Water Resources Congress, Kansas City, Kansas.

Yin, J., M. H. Young, L. Chen and Z. Yu, (2008) Modeling surface runoff on a semi-arid watershed using a physically based model. World Environmental and Water Resources Congress. Honolulu, Hawaii.

Yin, J. 2008 Spatio-temporal variation in soil moisture and hydraulic properties and their impacts on rainfall-runoff and infiltration processes. Ph.D. Dissertation. University of Nevada Las Vegas, Department of Geosciences.

Presentations:

Chen, L., J. Yin, J. Miller and M. H. Young. Hydrologic impact of the clast layer in desert pavements, Brownbag Seminar, DHS, DRI, June, 2008.

Student Support:

This grant funded the research endeavors (time, instruments and travel) during Jun Yin's Ph.D. degree study. The grant has also supported the training of Long Xiang, a visiting Ph.D student to Desert Research Institute.

Reference

McDonald, E.V., L.D. McFadden, and S.G. Wells. (2003) Regional response of alluvial fans to the Pleistocene-Holocene climatic transition, Mojave Desert, California. p. 189–206. *In* N. Lancaster et al. (ed.) Paleoenvironments and paleohydrology of the Mojave and Southern Great Basin Deserts. GSA Spec. Pap. 368. GSA, Boulder, CO.

Young, M. H., McDonald, E. V., Caldwell, T. G., Benner, S. G., Meadows, D. G. (2004) Hydraulic Properties of a Desert Soil Chronosequence in the Mojave Desert, USA. *Vadose Zone J.* 3: 956-963

Flood Warning System for the Clark County Wetlands Park

Basic Information

Title:	Flood Warning System for the Clark County Wetlands Park
Project Number:	2008NV135B
Start Date:	3/1/2008
End Date:	8/31/2009
Funding Source:	104B
Congressional District:	Nevada 01
Research Category:	Not Applicable
Focus Category:	Floods, Hydrology, Models
Descriptors:	
Principal Investigators:	Thomas Piechota

Publication

Synopsis

Progress Report (Year 3)

Title: Analysis of past storm events and their contribution to flooding for the Clark County Wetlands Park

Investigators: Thomas C. Piechota and Jim Pollard

Problem and research objectives:

This research project will analyze the historical rainfall pattern and its impact on the generation of runoff from the major watersheds that are contributing to flood in the Clark County Wetlands Park located in the Las Vegas Valley. The Clark County has already experienced more than 11 floods since 1993. The most damaging storms mainly occur in between July and September (CCRFCD, 2008). The average rainfall in the Las Vegas Valley is 4.49 inches with half of the total rainfall generated mainly by summer thunderstorms. Although the rainfalls with magnitude greater than a tenth of an inch occur less than 10 days a year on average in Las Vegas ([1]Caraco, 2000), the flash floods have become a major concern that is causing devastating damage. The 9 major watersheds that are contributing to Las Vegas Wash are shown in **Figure1.** The Clark County Wetlands Park is located adjacent to the Las Vegas Wash and is an invaluable environmental resource. The facility is open to the public with various walking trails; however, there is potential for the facility to be inundated with flood waters during significant rainfall events. The proposed research project will online sources of data from the Regional Flood Control District (RFCD) website to
(1) Evaluate the seasonal variation in the rainfall pattern based on past storm events;
(2) Identify the threshold values of water depth for significant occurrence of flooding;
(3) Analyze the regional variation in the rainfall and water depth for historical events and for major watersheds.

Data and Methodology:

Among the 9 watersheds contributing to Las Vegas Wash, the major watersheds considered for study are Duck Creek (DC), Pittman Wash (PW) and C1 Channel. The runoff from these watersheds is assumed to significantly affect the Clark County's Wetlands Park. Therefore, the analysis of past storm events have been carried out for these watersheds. Each watershed possesses different number of stations throughout the area; most of which are installed by CCRFCD and some by USGS. Altogether 28 weather stations (DC-9, PM-11, C1-8) are actively working in these 3 watersheds with only one streamflow measuring station installed by USGS. The position of the weather stations along with their station ID in 3 different watersheds is clearly shown in **Figure 2.** The rain gauge network possesses both rainfall and water depth measurement at almost all stations. The triangular stations as represented in Figure 2 are considered for water depth analysis. The specific objectives will be met by a data driven analysis using the source of historical data available online. The major tasks include;
Task 1: Identification of major watersheds and download of required data for all stations.
Task 2: Build a program to extract only the significant storm events from the available historical real time data.
Task 3: Carry out the trend analysis for rainfall and water level data.
Task 4: Expand the similar analysis to other watersheds and summarize the concluding remarks.
The study tries to observe the major changes occurred in precipitation over time, flow over time and flow with respect to precipitation for the watersheds. This research project will focus only on

the watersheds mentioned above. However, if it seems suitable, the analysis could be extended to other watersheds as a future work. The measured instrumental data is taken into account to observe the trend change in precipitation and runoff that would serve as a basis to conclude the results.

The stations established earlier possess data for longer periods starting from 1990; while the stations installed later include data only after 2000 in most of the cases. The total rainfall considered in the study is greater than 0.04 inches for each storm event. The number of rainfall events and the historical records of rainfall data available for each station are presented in Error! Reference source not found.. In total, there are 990 rainfall events for C1 channel, 937 events for DC and 1267 events for PM Wash that exceeds the total rainfall of 0.04 inches.Due to lack of stations measuring stream flow, the increase in water level is used to fulfill the objective. The water level station considered is stationed on the downstream side of all the rain gauge stations on each watershed and near to the confluence of the Las Vegas Wash. The water level stations chosen at far d/s do not posses sufficient data for DC and PW watersheds. Thus one more water level station was selected in between with larger no. of data to compare the behavioral change. The stations taken into consideration and the data present for each station are incorporated in **Table 2.**

Principal findings:

This part of research could be considered a preliminary part of graduate study to understand the nature of rainfall and flow patterns in the watersheds. Some of the principal findings from the analysis are presented in this report.

Rainfall Analysis

The rainfall analysis is performed by categorizing the total events in terms of 2 seasons as Dec-May and June-Nov representing the events mainly in winter and summer. As shown in **Figure 3**, almost 90% of the total events are concentrated in the range of 1.0 inches of rainfall followed by approx. 1% events more than 2.0 inches. The number of events is higher for the C1 channel for rainfall below 0.2 inches for both seasons, Dec-May and June-Nov. DC possesses comparatively higher percentage of occurrence of rainfall events above 0.2 inches. The rainfall events are slightly higher for Dec-May within 1.5 inches of rainfall and almost equal above that range.

Based on cumulative occurrence frequency, more than 90 percent of the rainfall events are occurring within the depth range of 1 inch. The rainfall depth considering 90% cumulative probability of occurrence is considered the design storm for management of stormwater quality BMPs.In all 3 watersheds, for both the seasons, the normalized distribution of total rainfall events as in **Figure 4** shows about 0.7 inches of rainfall that possesses 90% of total cumulative events. In terms of intensity, it ranges from 0.4 -0.5 in/hr with higher value for PM wash and lower for DC watershed.

Based on rainfall duration, almost 10 -15 % of events are occurring above 12 hours in wet season and 4-8% in dry season. C1 and DC posses almost equal number of events in the range of 2 to 8 hours for both periods whereas it is comparatively higher for DC for more than 8 hours of duration. Most of the events concentrated on larger duration can be considered the major storm events in case of higher intensity of rainfall. Thus C1 and DC can be assumed to have significant effect (DC with higher dominating effect than C1) on the major rainfall events in comparison to PM wash. The median rainfall duration is higher in case of DC within a range of 2 inches of rainfall whereas the interquartile range in **Figure 5** shows the increasing trend with larger variation in the data. The

events above 1 inches of rainfall show almost similar median duration for DC and C1 channel. The higher intensity of rainfall occurring for longer duration implies the higher generation of runoff. This implies that the runoff produced is higher in case of DC and C1 channel than PM wash. The higher duration observed in the range of 1.5-2 inches of rainfall for PM wash might be due to occurrence of some of the concentrated major storm events in the watershed. The lower duration in case of PM wash for more than 2 inches of rainfall is due to the presence of few observations. The median duration in winter period is almost same for C1 and DC; both contributing equally for higher runoff generation. Very few events above 1.5 inches of rainfall are observed in PM wash. The contribution of smaller events is higher in both seasons with comparatively higher variation in the range of duration in summer than in winter.

Water Level Analysis

The observed precipitation data in the range of 0.2 to more than 2 inches are categorized into 5 classes (0.2-0.5, 0.5-1.0, 1.0-1.5, 1.5-2.0, >2.0 inches). As shown in **Figure 6**, the water depth increasing in a linear pattern up to a range of 1-1.5 inches shows a drastic increase for more than 1.5 inches of rainfall. It represents the higher storm events that occurred in the past in DC watershed. Very few events occur above 2 inches of rainfall and higher runoff can be expected for rainfall in excess of 1.5 inches in DC watershed. The water depth in PM is low in comparison to water depth in DC channel for the same range of ppt. This implies that the runoff is comparatively lower in case of PM wash than DC channel if the median increase in water depth is considered. For C1 channel, the median values for water depth is lower in comparison to DC and almost similar to PM Wash up to a range of 1.5 inches of rainfall. For higher precipitation, the water depths are similar to DC, comparatively more than PM Wash. This depicts the storm runoff in C1 Channel as similar to PM Wash (smaller than DC) incase of lower range (up to 1.5 inches) whereas some storm events show higher runoff (as incase of DC Wash) for more than 1.5 inches of rainfall.

The rainfall corresponding to 90 percent occurrence of rainfall events is 0.7 inches for all watersheds. The median water depth indicated by the box plots corresponds to a value of approximately 1.6, 0.8 and 0.8 ft. respectively for DC, PM and C1 channel respectively. The depth can be considered as the runoff depth that needs to be taken care of during the design of drainage channels. The rainfall events occurring above the indicated depths correspond to higher storm events that may cause devastating damages.The runoff depth and the duration of storm events are highly variable in between the storm events. Thus the median depth can be considered significant from design point of view.

Knowledge of the threshold value of runoff for low flows is also important during dry seasons with very low rainfall. The threshold values for low flows can be observed at a point with sudden change in water depth or higher water depth than previous rainfall events. This point indicates the starting point for the generation of runoff in the watershed. From the step change analysis, the threshold values of low rainfalls for DC, PM and C1 channel are 0.16, 0.04 and 0.08 inches of rainfall respectively as shown in **Figure 7.** The corresponding water depth with respect to low rainfall after which the runoff starts is 0.2, 0.25 and 0.15 ft. respectively for C1, DC and PM respectively. From the contour plot in **Figure 8**, the maximum water depth observed in case of PM wash is very low in comparison to DC and C1 channel. There is no fixed pattern of significant increase in water depth in case of DC. In case of C1 and PM, the maximum water depth is observed for maximum rainfall and duration. The higher depth observed in DC also signifies the occurrence of some major storm events. The higher depth with low rainfall and duration in all watersheds signifies the variation in rainfall pattern within the watershed.

Conclusions

- Large variation in the plot signifies the general nature of rainfall in Las Vegas; heavy rainfall occurring within shorter intervals in summer that lasts for longer duration during winter periods.
- Higher percentages of storm events were observed in lower water depth region that can hardly produce any significant water depth.
- DC comparatively possesses higher percentage of occurrences of events (> 0.2inches) that lasts for more than 12 hours in duration compared to C1 and PM.
- Runoff produced is higher in case of DC and C1 than PM wash; DC with the dominating effect.
- The total rainfall corresponding to 90% of the total cumulative events is found about 0.7 inches that is important in terms of stormwater quality BMPs.The median water depth with respect to rainfall are 1.6, 0.8 and 0.8 ft. for DC, PM and C1 channel respectively.
- During low flows, the generation of runoff for C1, DC and PM occurs at depths of 0.2, 0.25 and 0.15 ft. respectively for 0.08, 0.16 and 0.04 inches of rainfall.

[1]Caraco,D.(2000). Stormwater Strategies for Arid and Semi-Arid Watersheds. *The Practice of Watershed Protection.*Feature article from *Watershed Protection Techniques.*3(3)*:* 695-706.

Information Transfer Activities

a) Meeting with Stakeholders

- March 28, 2008: Clark County Parks and Recreation (Elise Sellars) and Jim Pollard.
- Regular group meetings at UNLV.

b) Conference Presentations:

- A report/ conference paper will be presented at the end of the project work.

c) Publications

- Still under revision. Not presented anywhere yet.

Student Support: No students supported in Year 2. Anil Acharya (grad. student) was working on the project and was funded on a state-supported assistantship in Fall 2008 and Spring 2009.

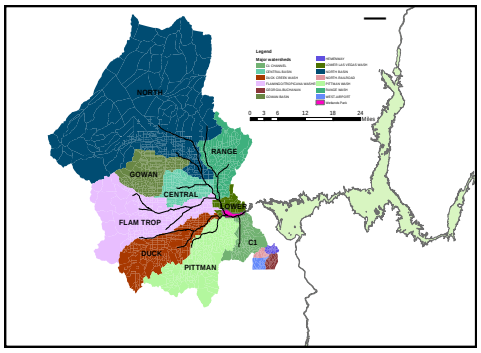


Figure1 Nine major watersheds contributing to Las Vegas Wash

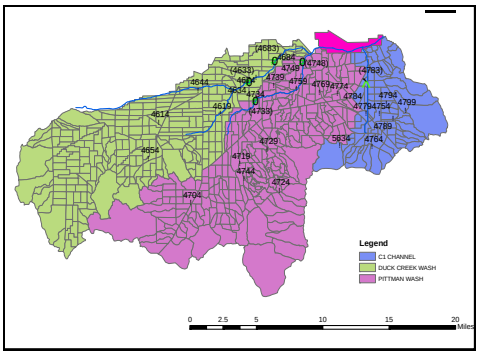


Figure 2 Location of weather stations

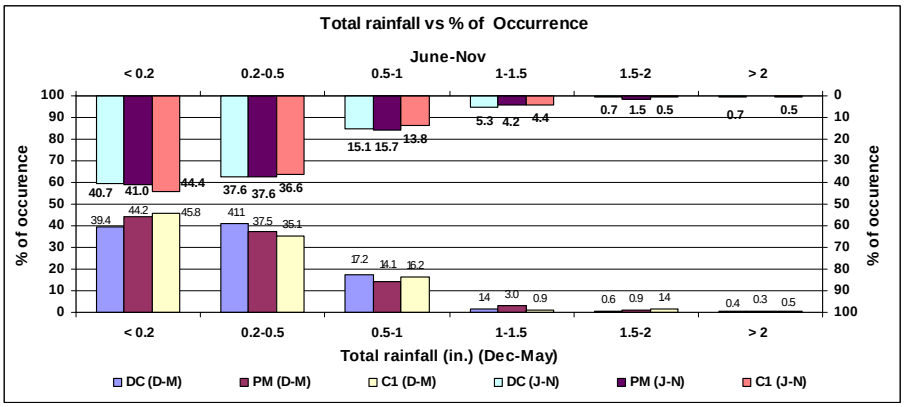


Figure 3 Total rainfall vs % of Occurrence

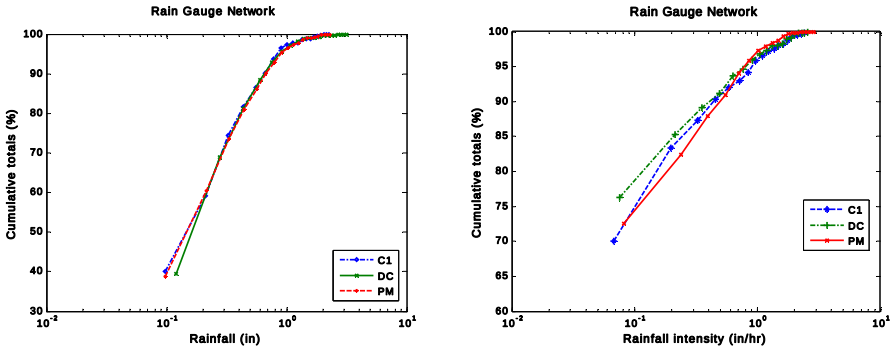


Figure 4 Normalized distribution of cumulative rainfall versus rainfall and rainfall intensity

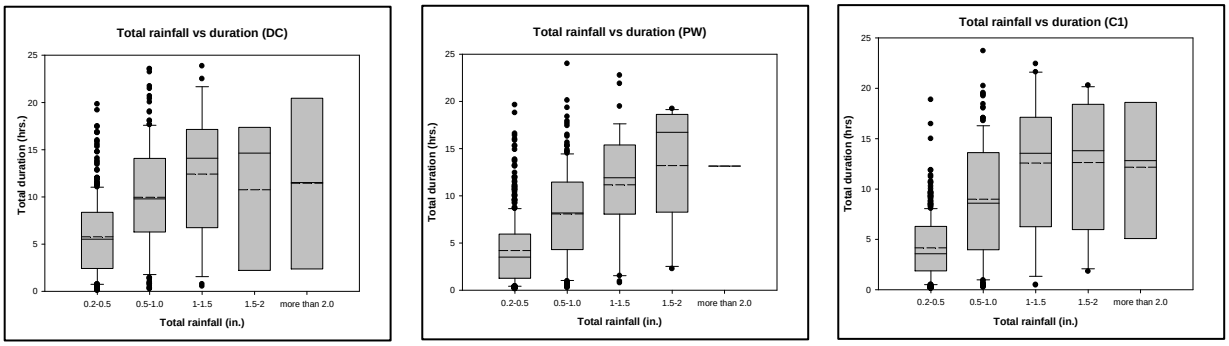


Figure 5 Total rainfall vs total duration; for a) DC channel (b) PM Wash (c) C1 Channel

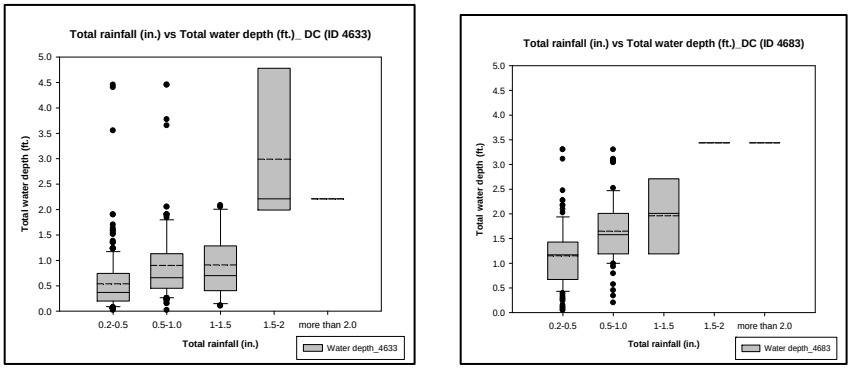


Figure 6 Total rainfall vs total water depth (DC); for water level stations a) 4633 & b) 4683

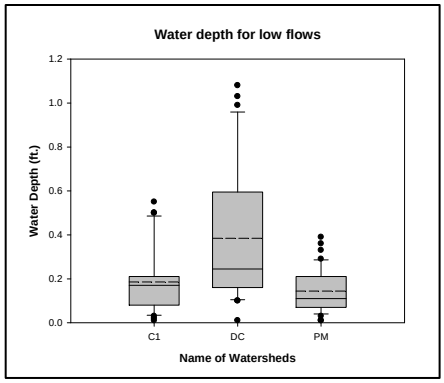


Figure 7 Water depth for low rainfall events that are significant at different depths i) C1 at 0.08" of rainfall ii) DC at 0.16" of rainfall iii)PM at 0.04" of rainfall.

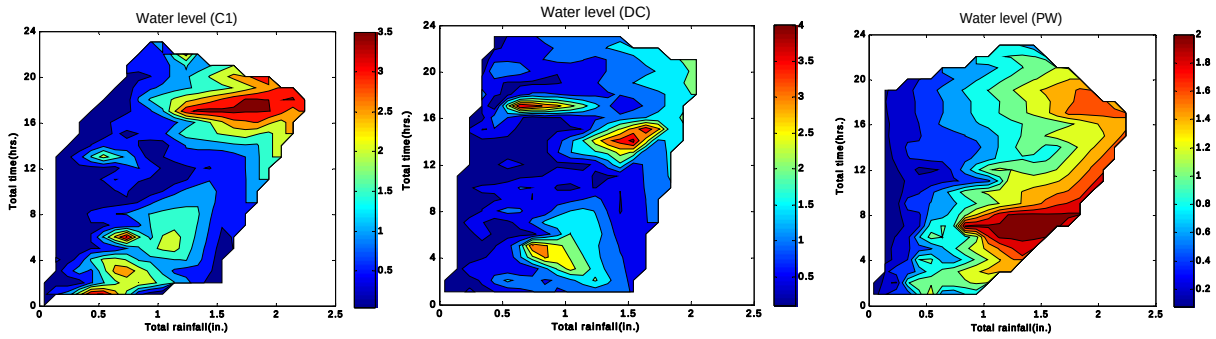


Figure 8 Contour plots of water level w.r.t. total rainfall and duration

Table 1 Rainfall data and total rainfall events considered for analysis

C1 channel								
St. Id	**4754**	**4764**	**4779**	**4784**	**4789**	**4794**	**4799**	**5634**
From	03/97	08/94	09/02	09/89	06/93	01/93	06/00	04/00
To	05/08	05/08	05/08	05/08	05/08	05/08	05/08	05/08
Events (> 0.2")	66	73	42	108	89	82	35	48
Total Events	141	173	65	185	157	133	58	78

DC channel									
St. Id	**4614**	**4619**	**4624**	**4634**	**4644**	**4654**	**4674**	**4684**	**4694**
From	06/89	09/01	06/91	08/89	03/97	07/97	01/02	07/01	11/05
To	05/08	05/08	05/08	05/08	05/08	05/08	05/08	05/08	05/08
Events (> 0.2")	103	35	113	98	54	67	45	39	5
Total Events	169	46	178	170	99	116	70	71	12

PM Wash											
St. Id	**4704**	**4719**	**4724**	**4729**	**4734**	**4739**	**4744**	**4749**	**4759**	**4769**	**4774**
From	08/89	01/03	06/01	08/02	10/88	08/95	02/93	03/00	09/99	05/02	04/92
To	05/08	05/08	05/08	05/08	05/08	05/08	05/08	05/08	05/08	05/08	05/08
Events> 0.2"	121	33	44	36	140	68	74	38	50	37	85
Total Events	205	55	70	66	199	127	139	83	85	66	172

Table 2 Water Level Data present for selected stations

Nameof Watersheds	**C1 Channel**	**Duck Creek**		**Pittman Wash**	
Stn Id	**4783**	**4633**	**4683**	**4748**	**4733**
From	02/1993	07/1991	07/2001	01/2004	05/1991
To	05/2008	05/2008	05/2008	05/2008	05/2008

Microbial and Phytoplankton Impacts on Endocrine Disrupting Contaminants:

Basic Information

Title:	Microbial and Phytoplankton Impacts on Endocrine Disrupting Contaminants:
Project Number:	2008NV136B
Start Date:	3/1/2008
End Date:	2/28/2009
Funding Source:	104B
Congressional District:	Nevada 01
Research Category:	Water Quality
Focus Category:	Toxic Substances, Water Quality, Wastewater
Descriptors:	None
Principal Investigators:	Duane Moser

Publication

Annual Report for "Microbial and Phytoplankton Impacts on Endocrine Disrupting Contaminants: Las Vegas Wash and Lake Mead, NV"

Funding Agency: National Institutes of Water Resources

Project Number: 2006NV104B

PI: Duane P. Moser, Desert Research Institute, Las Vegas, NV

Supported Student: Susanna Blunt, UNLV School of Life Sciences and Desert Research Institute

Major Collaborators: Michael Rosen, USGS; Shane Snyder, SNWA; Mark Benotti, SNWA

Reporting Period: March 1, 2008 through February 28, 2009

Problem and Research Objectives

Emerging contaminants represent an area of increasing concern as studies reveal their persistence in the environment and adverse effects they can trigger in wildlife. Among these are endocrine disrupting chemicals (EDCs), which are defined as exogenous chemical substances or mixtures that alter the structure or function(s) of the endocrine system and cause adverse effects at the level of the organism, its progeny, populations, or subpopulations (15). Many synthetic chemicals such as PCBs, flame retardants (PDBEs), dioxins, and phenols are known to be EDCs, however steroid hormones are considered the most bioactive. It has been suggested that natural and synthetic estrogens such as ethinylestradiol (EE2), 17β-estradiol (E2) and estrone (E1) are the primary compounds responsible for endocrine disruption in wildlife (3, 4). Steroid hormones including estrogens are excreted through human waste (e.g. resulting from oral contraceptive use) and although 90% or more may be removed through activated sludge treatment (5), many EDCs still make their way into streams and waterways through wastewater effluent causing potential problems for wildlife downstream (11).

Las Vegas Wash, a tributary of the Colorado River which enters the Boulder Basin of Lake Mead, Nevada, is fed primarily by tertiary treated wastewater. Various EDCs have been found in Las Vegas Wash and Las Vegas Bay and the estrogen E2 has been detected at concentrations as high as 2.7 ng/L (13). To put this in perspective, concentrations of estrogens as low as 5 ng/L have been shown to cause total collapse of fish populations due to adverse effects on reproductive health (6). Additionally, carp collected from Las Vegas Wash and Las Vegas Bay have been found to contain high concentrations of synthetic organic chemicals and in males, significantly raised levels of

endocrine biomarkers such as vitellogenin, an egg yolk precursor (2). Microorganisms are ubiquitous in the environment and are largely responsible for the alteration and fate of many organic chemicals (12). Certain microorganisms, for example, through the activity of 17β-hydroxysteroid dehydrogenase (7) have the ability to deconjugate EE2 to its bioactive intermediate E2 (16), although very little is known concerning the abundance and diversity of EDC-degraders. Thus, microbial communities may play a role in determining the environmental fate and persistence of these compounds and research into microbial mechanisms underlying EDC-degradation is timely. We propose that the fortuitous experiment embodied by Las Vegas Wash represents a unique resource for the elucidation of mechanisms underpinning the environmental processing of EDCs. The work described here details initial method development towards this end and provides some of the first information concerning the abundance, activity, and diversity of EDC-degrading microorganisms from the Southwest U.S.

Methodology

During this reporting period, much of our efforts focused on a comprehensive microcosm experiment, performed in close collaboration with Southern Nevada Water Authority (SNWA). Water column samples were collected at four SNWA long-term monitoring sites throughout the Lake Mead System: Las Vegas Bay, (LVB 6.7), Las Vegas Wash (at Pabco Weir), the SNWA Saddle Island drinking water intake (IPS2), and the Colorado River as it enters Lake Mead at the northern end of the Greg Basin. Five liters of water from each location was amended with pharmaceuticals and the steroid hormones progesterone, testosterone, and the estrogens E1, E2, and EE2 for a final starting concentration of 500 ng/L or less. Two additional samples from Las Vegas Bay served as controls, one with 1% sodium azide added as a “sterile” control, and a non-amended sample. Water was kept in glass carboys and incubated at room temperature on stir plates in the dark for 120 days at the River Mountain Water Treatment Facility laboratory. Subsamples were collected at days 0, 1, 2, 4, 7, 14, 29, 56, and 120, concentrated and extracted using solid phase extraction (SPE), and analyzed for steroid hormone concentrations using LC/MS/MS (Applied Biosystems 4000 Q Trap) as previously reported (1).

Microbial abundance was measured via serial dilution cultivation and flow cytometry. Aliquots were taken from each sample at prescribed time points and grown on four different microbiological growth media: R2A broth (10), a commonly used broad spectrum medium, M1 (9) defined medium plus formate, lactate, acetate and casamino acids at 2.5 mM each, M1 plus E1, E2, and EE2, and M1 with no carbon source added for a control. This was done in order to estimate the numbers of total culturable organisms as well as the number able to grow on estrogen as a sole carbon source. Additionally, to obtain more precise estimates of the total biomass throughout the experiment, microbial cell counts were measured directly using flow cytometry (MicroPro Advanced Analytical, Ames, IA). At each time point, microbial cells from 100 mL subsamples were collected by filtration onto 0.2 micron membrane filters (25 mm, Suport Polysulfone, Pall) and stored at -80 °C. DNA was extracted from archived filters using MoBio Ultraclean® soil kits (MoBio, Solano Beach, CA), and microbial community interrogation initiated using terminal restriction fragment length polymorphism (T-RFLP)

analysis (8), a DNA fingerprinting method which enables the broad comparison of collective microbial diversity between samples and assesses the relative abundance of specific organisms. Also, throughout the experiment, microorganisms from water samples were grown in culture and isolated on solid (purified agar) defined media with estrogen (EE2 and E2) provided at 1 ppm as a sole carbon source. These isolates were identified to the species level using 16S rRNA gene sequencing methods as previously described (14).

Principle Findings and Significance

Objective 1: Founding of a joint DRI/USGS/USFWS relationship focused on Lake Mead. This project was designed to complement SNPLMA-funded water quality research being performed by the USGS and USFWS. In this regard, prior to this reporting period, we were able to use this award to leverage a roughly 1:1 match in support of the USGS SNPLMA project. This supplementary award was used in combination with NIWR funding to support graduate student, Susanna Blunt (in the UNLV School of Life Sciences, Dr. Brian Hedlund, co-major advisor). Ms. Blunt has focused exclusively on this research. Within the contracting period, we have used our combined NIWR/USGS-funded project to leverage additional half-time support for Ms. Blunt in the form of an internship through SNWA. More importantly, the new relationship between DRI and SNWA has enabled a very productive collaboration to ensue. In particular, we have benefited from the state of the art analytical chemistry capabilities of SNWA and conversely have provided microbiological advice in support of project development. Thus, NIWR funds have fostered a number of very promising professional relationships between DRI and both Federal and Local agencies.

Objective 2: Identification of major EDC-degrading microorganisms and algae. Serial dilution experiments revealed that out of the total of about 10^5 culturable cells/mL present in these habitats, only 10^1 were capable of growth on estrogen as sole carbon source. This result contradicts our earlier results which suggested that the numbers of estrogen-utilizing microorganisms in the Las Vegas Wash were much higher (e.g. ca. 10^3 – 10^4 per mL, FY 2007 annual report, unpublished). Ultimately, this discrepancy was traced to our use of methanol (a potential carbon and energy source for microorganisms) as a solvent to enable the dissolution of otherwise insoluble estrogens to aqueous media. We have since developed alternatives to circumvent this experimental artifact (e.g. allowing the methanol to evaporate prior to the addition of other solid media components).

Whereas, our analyses are in progress, initial T-RFLP profiles reveal significant differences in the microbial communities between each sample site at the beginning time point of the experiment (Fig. 1). These results suggest that microbial diversity, rather than abundance, defines EDC biodegradation capacity in the environment. T-RFLP analysis for the remaining time points is currently underway as are steroid degradation confirmations involving individual bacterial isolates. Identification of twenty six estrogen-degrading microbial isolates using 16S rRNA gene sequencing revealed only six distinct species: *Ralstonia pickettii*, *Sphingomonas subterraneum, Hyphomicrobium vulgare, Novosphiongobium resinovorum*, and *Methylobacterium*

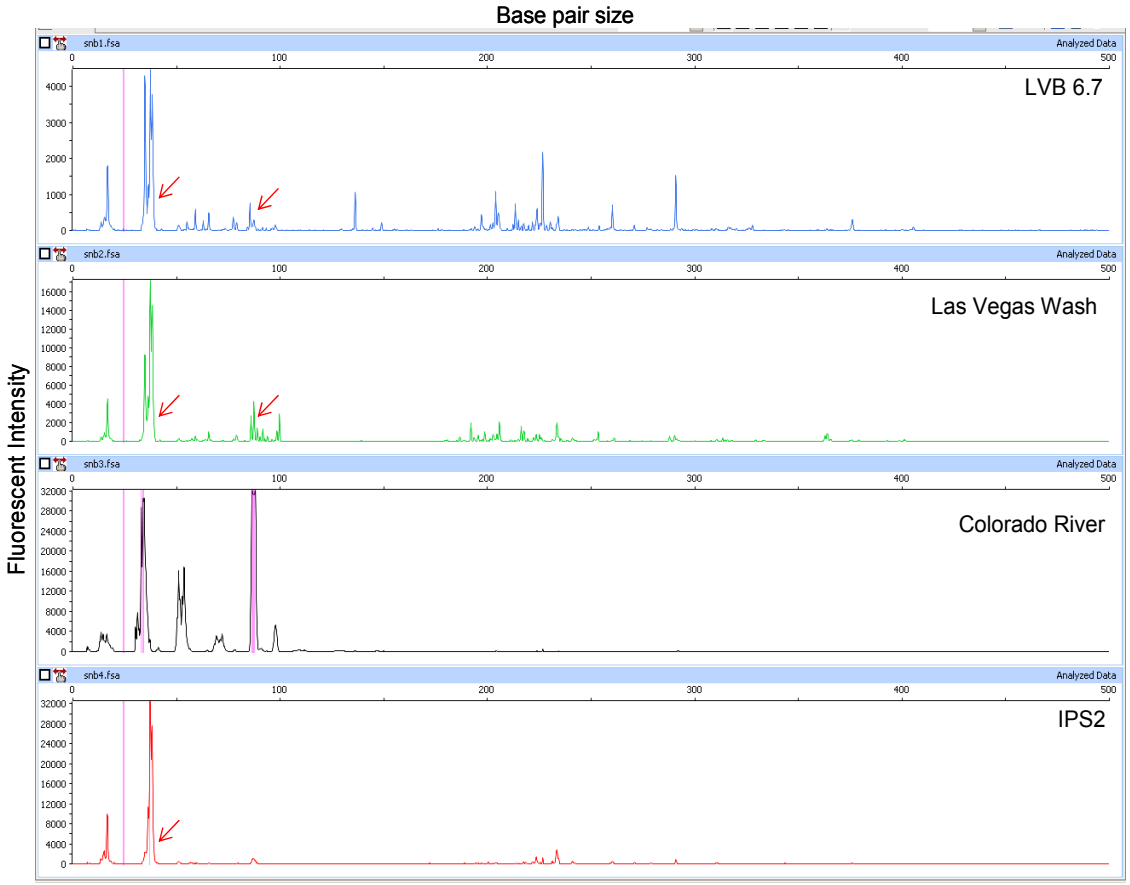


Fig. 1. Differences in bacterial community structure between samples at time point 0. Red arrows indicate similar T-RF peaks. Note that this work is in progress as of this writing and will be used to compare microbial community changes at subsequent time points as the data continues to come in.

extorquens. This result, coupled with the low numbers of estrogen-utilizing microorganisms from our earlier tests suggests that estrogen degradation is a relatively uncommon ability in wild microorganisms. To better constrain the environmental relevance of the detected strains, statistical analysis will be conducted on T-RFLP results in an attempt to correlate representatives from our culture collection with EDC-degradation performance in the microcosm experiments.

Microbial counts using flow cytometry revealed that despite the addition of sodium azide to the “sterile” control sample, cell density rebounded after approximately 7 days, and maintained populations above 2.5 x 10^5 during the remainder of the experiment (Fig. 2). Despite this, degradation rates remained considerably lower in this treatment than in the other samples (Fig. 3), further indicating that microbial population diversity, rather than simple biomass, defines biodegradation rates. It should be noted that the failure of a very common sterilizer (azide) in our experiments suggests that this approach may commonly fail in ecological studies; as in most cases, workers would not detect bacterial growth as we did using flow cytometry.

Although stated as a project objective, algal impacts on environmental estrogens has not yet been addressed in this work. This was the result of a conscious decision at the beginning of the current reporting period to focus on heterotrophic microorganisms in the interest of completing a publishable story within a realistic time frame.

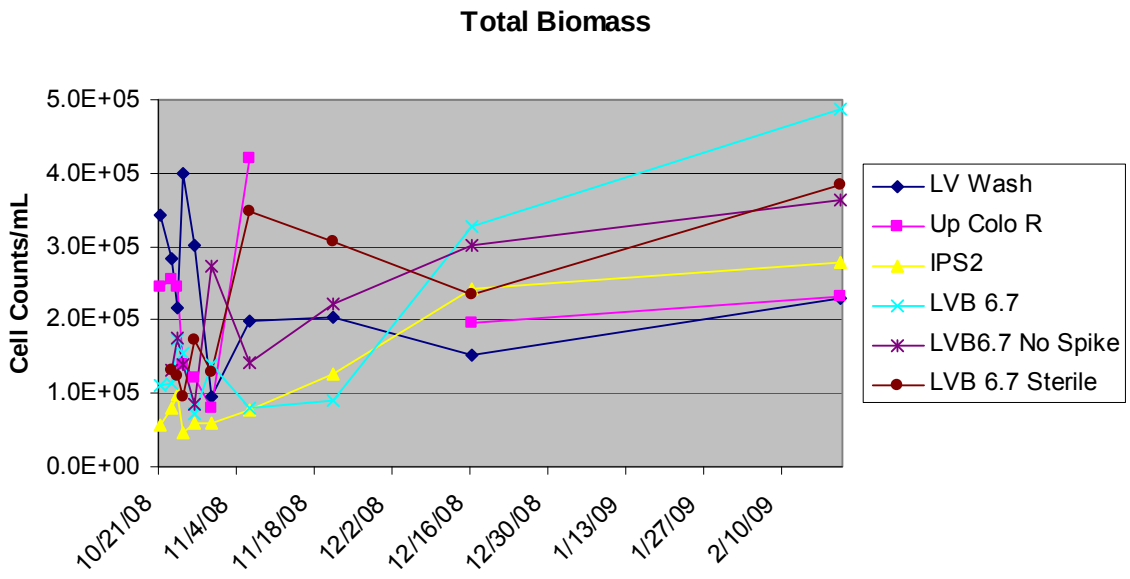


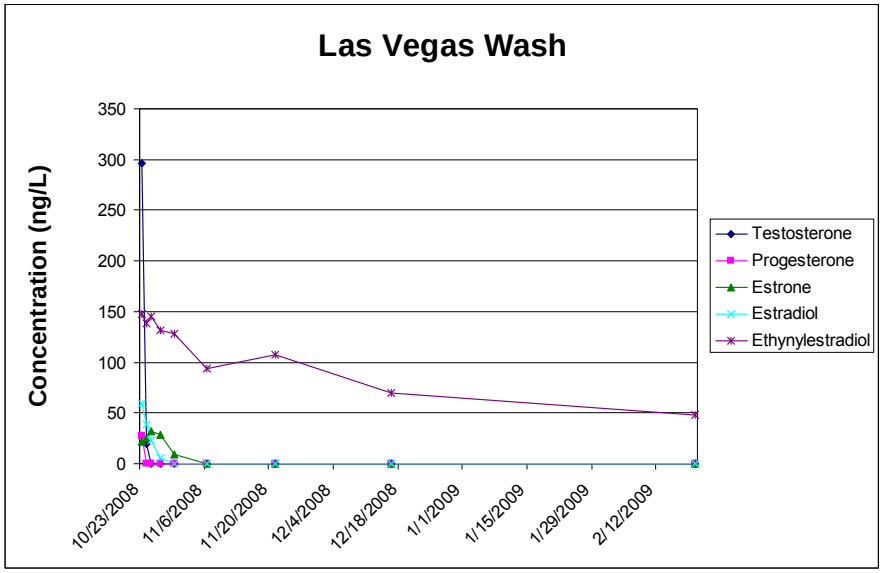
Fig. 2. Total cell counts ("biomass") using flow cytometry.

Objective 3: Measurement of potential EDC degradation and metabolite generation rates. Analysis of the steroid hormones indicates that estrone, estradiol, progesterone and testosterone were reduced to below detection limits (2 ng/L) in all samples with the exception of the sterile control (Fig. 3). Ethinylestradiol was reduced in concentration but persisted in all samples (except the non-amended control) throughout the duration of the experiment. The Las Vegas Wash and Colorado River samples showed the greatest rates of removal, whereas IPS2 (drinking water intake) and the Las Vegas Bay sterile control exhibited much lower potential degradation rates.

Objective 4: Determination of the possible impacts of proposed deep wastewater delivery to mid Boulder Basin. Not addressed at this time.

Information Transfer Activities

Research results were presented at the biweekly UNLV School of Life Sciences Microbiology Group Meeting in April, 2008 in a talk entitled *Microbial Degradation of Endocrine Disrupting Contaminants in Las Vegas Wash and Lake Mead.* This work was also presented at the Lake Mead Science Symposium in January, 2009. Our poster: *Diversity of Estrogen Degrading Microorganisms in Las Vegas Wash and Lake Mead, Nevada*, received the first place student poster award. In addition, this work received


Las Vegas Wash
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300
250
200
150
100
50
0
10/23/2008
11/6/2008
11/20/2008
12/4/2008
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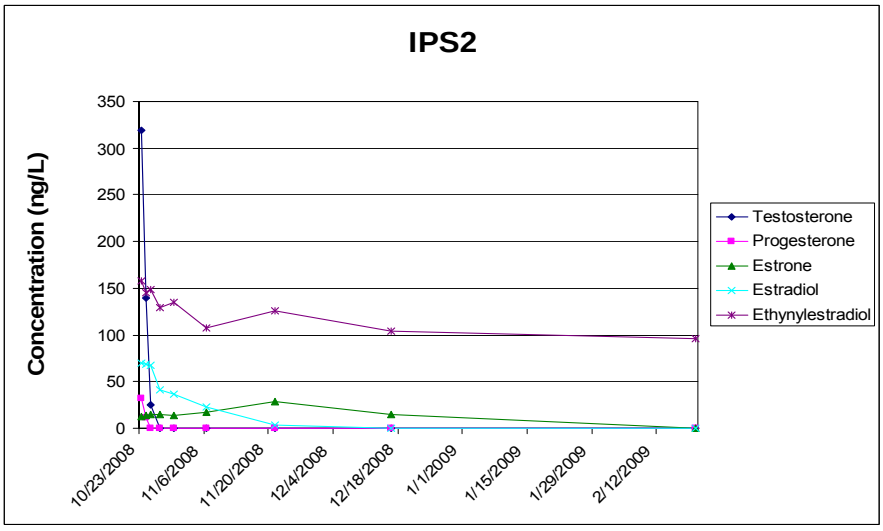
Progesterone
Estrone
Estradiol
Ethynylestradiol


IPS2
Concentration (ng/L)
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300
250
200
150
100
50
0
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11/6/2008
11/20/2008
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Testosterone
Progesterone
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Estradiol
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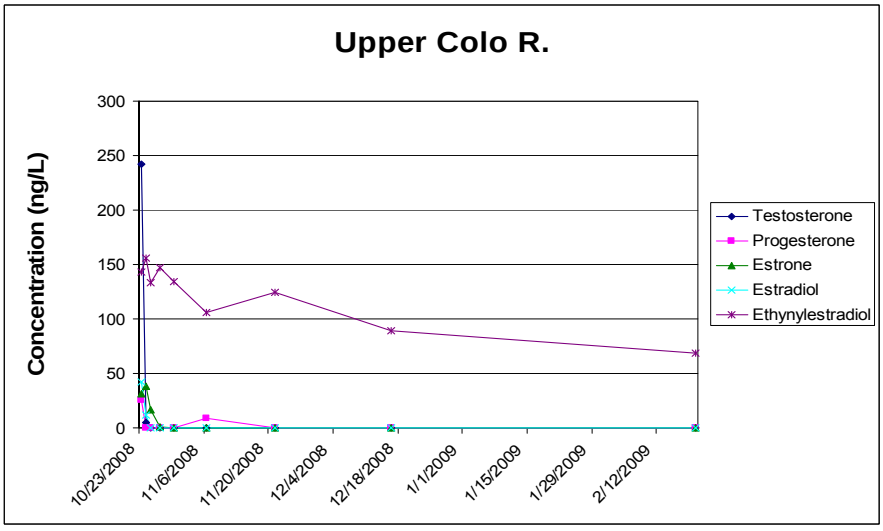
Upper Colo R.
Concentration (ng/L)
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250
200
150
100
50
0
10/23/2008
11/6/2008
11/20/2008
12/4/2008
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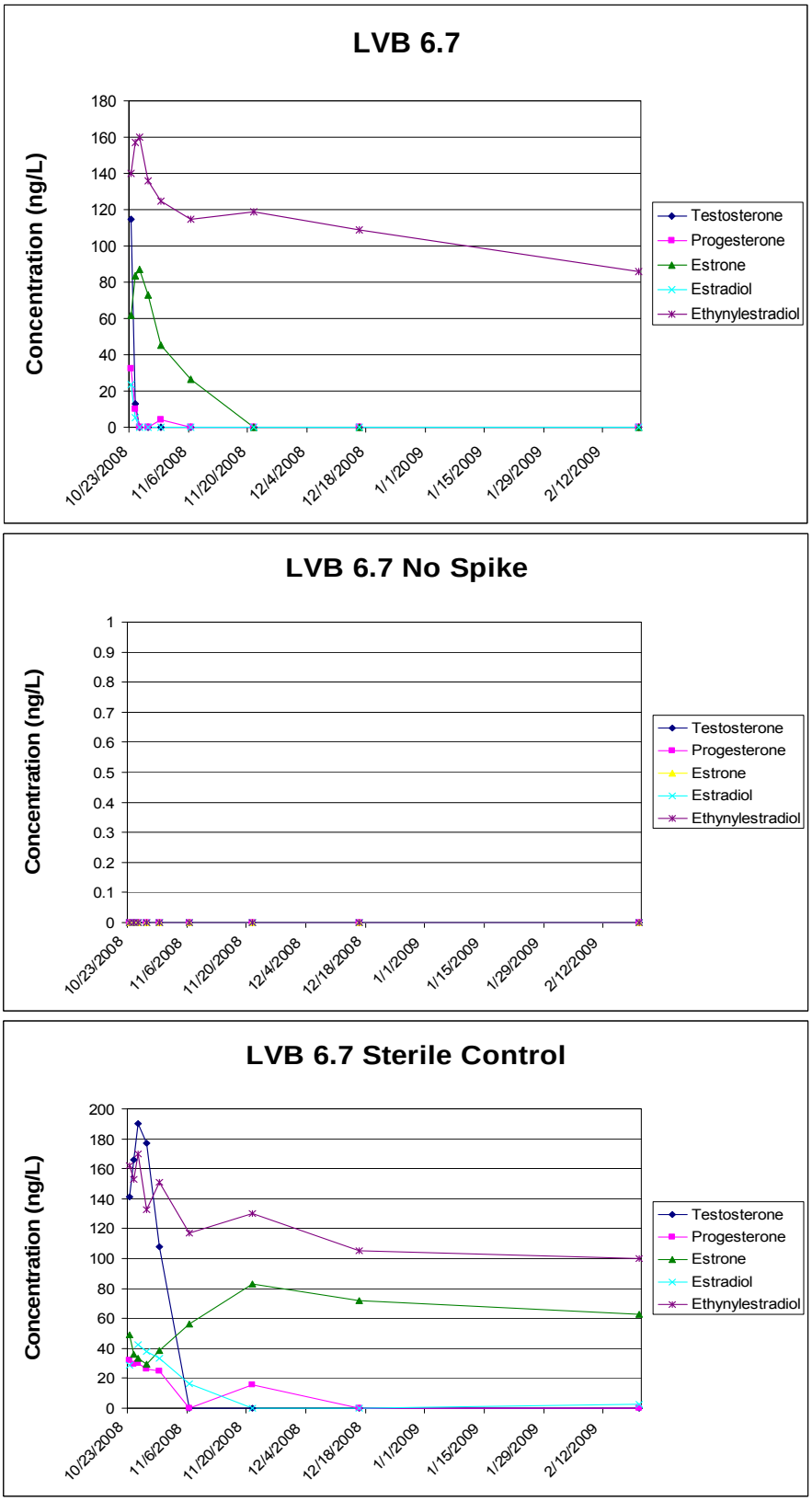

Fig. 3. Steroid hormone degradation curves from each sampling site. IPS2 = SNWA water intake at Saddle Island. LVB = Las Vegas Bay. Note that "sterile" control was actually not sterile as within a week (Fig. 2), microbial growth appeared in the test microcosm. In spite of this, EE2 and E2 degradation were substantially retarded, suggesting that the microorganisms capable of their degradation were inhibited by azide treatment.

considerable media attention including interviews by PI Moser with Martha Mendoza (AP) and Lee Moore of Reno Channel 4 television (03/10/08). The AP story went worldwide and appeared in such outlets as USA Today, the Boston Globe, the Denver Post and ABC News (television). Ultimately, the AP article prompted Senate hearings on this topic where Shane Snyder, our SNWA collaborator, was asked to testify.

http://www.denverpost.com/kreck/ci_8526203
http://www.usatoday.com/news/topstories/2008-03-10-2132121647_x.htm
http://www.usatoday.com/news/health/2008-03-09-water_N.htm?csp=34

This project was also mentioned by USGS collaborator, Dr. Steve Goodbred in a History Channel interview on 02/26/08.

Student Support

See Objective 1. Briefly, this award was used to support graduate student, Susanna Blunt (in the UNLV School of Life Sciences).

Publications

No publications for this time period. Submission to a peer-reviewed journal planned for fall of 2009.

Proposals

This project formed the partial basis for a preproposal to the American Water Works Research Foundation (AWWRF) Unsolicited Program. *Moser, D.P. Microbial transformation of polycyclic musks in Las Vegas Wash and Lake Mead, NV, (*02/01/08). $150K requested. This was not approved for full proposal (note, this activity falls slightly outside of this reporting period, but I neglected to report it in my previous annual summary). In addition, this work supported a preproposal to the Water Reuse Foundation: *Snyder, S., Gerrity, D., Benotti, M., Stanford, B., and Moser, D.P. Optimization of solids retention time in the activated sludge process for trace organic degradation and oxidant dosing.* (03/03/09). $235K. Although this was submitted just outside of this reporting period, most of the work was conducted within this reporting period, so it is included here. This preproposal is currently pending.

References

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Quagga Mussel Invasion in Lake Mead: Ecological Impact and Containment

Basic Information

Title:	Quagga Mussel Invasion in Lake Mead: Ecological Impact and Containment
Project Number:	2008NV137B
Start Date:	3/1/2008
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	Nevada 01
Research Category:	Biological Sciences
Focus Category:	Acid Deposition, Ecology, Water Quality
Descriptors:	
Principal Investigators:	Kumud Acharya, Charalambos Papelis, Mark Stone

Publication

1. Link, C., K. Acharya, L. Papelis, 2009. “Will Quagga Mussels Potentially Impact the Native Species’ Food Web in Lake Mead by Affecting Plankton and Nutrient Availability?” Lake Mead Science Symposium, Las Vegas, Nevada, January 13-14.

Annual Report

Title: **Quagga Mussel Invasion in Lake Mead: Ecological Impact and Containment**

PI: Acharya, Kumud (Desert Research Institute) and Papelis, Charalambos
Graduate Student: Link, Carolyn (UNLV, Water Resource Management)

Problem and Research Objectives

Lake Mead is the largest reservoir in the US and one of the most important water resources in the West. In January of 2007, Quagga mussels (*Dreissena bugensis*) were discovered in Lake Mead, for the first time west of the 100th meridian. This invasive species and the related Zebra mussel (*Dreissena polymorpha*) have disrupted ecosystems in a number of waterways elsewhere in the US and have cost billions of dollars in control efforts. Given the seriousness of the recent Quagga mussel invasion for the ecology and economy of the broader region, and for the overall management of the important water resources of the region, the primary goal of the proposed research is to study the ecology and biology of Quagga mussels and their impact on aquatic biodiversity and water quality in Lake Mead. Specifically, under the proposed research plan we will study the ecological impact of the invasion; the physiological ecology of the mussels; 4) the population structures; and the potential of Quagga mussels to bioaccumulate metalloids under local conditions. This study will use and contribute to the collection of data on Quagga mussels already under way by local, state, and federal agencies. The proposed study will also contribute to the development of local expertise, necessary to address this serious ecological and economic problem. Results will be published in peer reviewed journals and communicated to the public, in an effort to educate the public and to limit the negative impacts of the invasion. Finally, the experience and data collected from the proposed study will be used to support competitive proposals to national funding agencies to further contribute to our understanding of the problem and viable management strategies.

Methodology

Initial study has focused on the ecological impact and physiological ecology of the species. These studies include development of models for quantifying algae clearance and ammonia production of the species in controlled laboratory settings using spectrophotometry based regressions. Prefacing laboratory based studies, development of field sampling protocols for collecting mussels via SCUBA and shore collection were undertaken, as well as water collection for laboratory aquaria. Permitting applications for scientific collection were obtained through the Nevada Department of Wildlife. Establishment and

maintenance of in-lab aquaria capable of maintaining cultures of the species involved extensive background research along with trial experiments to arrive at appropriate water temperature, flow rate, light cycle, water chemistry, and maintenance schedule parameters. Clearance rate and ammonia production studies required development of lengthy experimental designs to ensure proper quantification and minimum variability between samples. Experiments required incubators to ensure proper light allowance or exclusion, and trials were completed during off-peak hours to minimize interference from other experiments and to ensure machine availability at exact required testing times.

Principle Findings and Significance

The data so far indicates Lake Mead quagga mussels are aggressive feeders of algae. Preliminary experiment suggests that clearance rates are extremely high, particularly among adults (See Figure 1.1). The preliminary results indicate lower clearance rates for juvenile mussels (See Figure 2.1), encouraging current and future studies that examine growth rate and biomass-to-clearance rate relationships. Observations of ammonia production studies have concluded similar results, with adults producing at higher rates than juveniles, with future studies concerning potential N/P ratio effects being inspired. The preliminary results of algae clearance and ammonia production studies have guided development of more exhaustive studies, as well as the development of growth rate studies, currently underway. Based on our preliminary data, quagga mussels' increasing population could have dramatic implications in the clarity and overall foodweb of the Lake Mead.

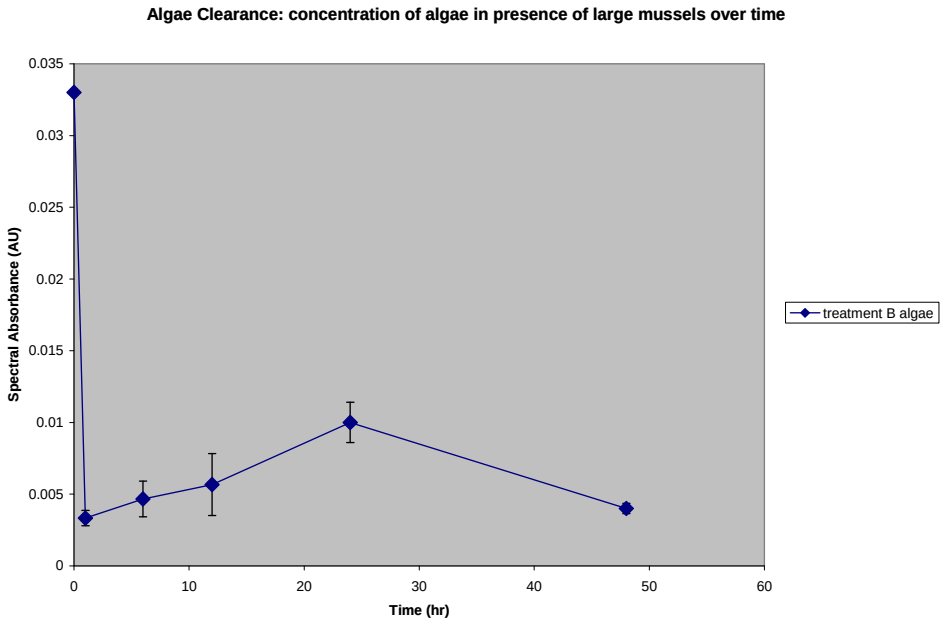

Figure 1.1

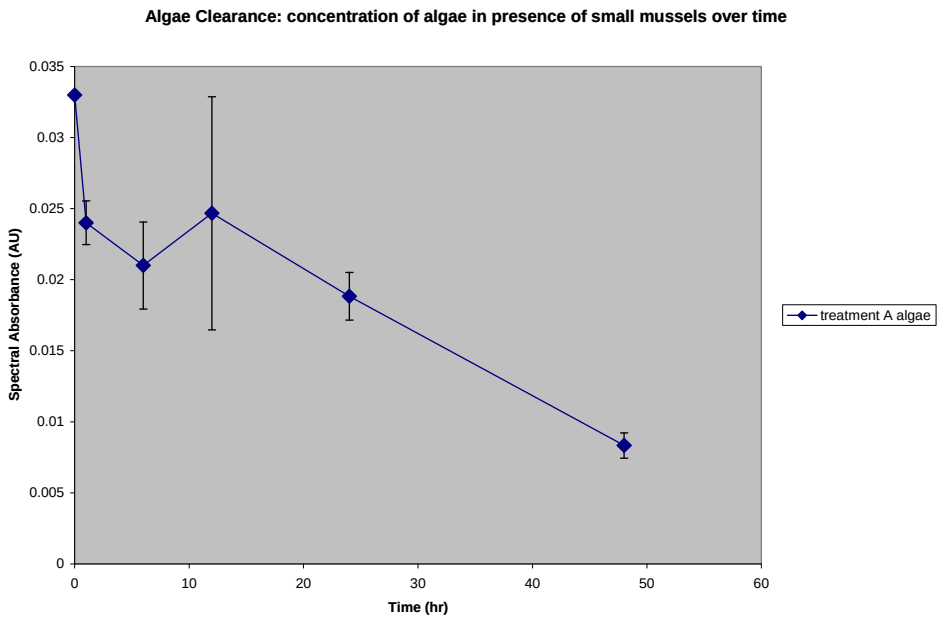

Figure 2.1

Information Transfer Activities

Results obtained so far were presented at the Lake Mead Science Symposium, in Las Vegas, NV, in January 2009 before stake holders and research communities. Similar efforts will continue as more data become available. The PIs and the graduate student (Carolyn Link) who are working on this project attend the quarterly meeting of Quagga mussels held at Southern Nevada Water Authority (SNWA) for information exchange.

Student Support

The project currently supports a graduate student, Carolyn Link for her research associate ship (RA). Carolyn is a graduate student in the Water Resource Management Program at the University of Nevada, Las Vegas.

Publications

Link, C., K. Acharya, L. Papelis, 2009. “Will Quagga Mussels Potentially Impact the Native Species’ Food Web in Lake Mead by Affecting Plankton and Nutrient Availability?” Lake Mead Science Symposium, Las Vegas, Nevada, January 13-14.

Estimation of Spatio-Temporal Statistics of Precipitation and Snow-Water Equivalent in the Truckee River Watershed

Basic Information

Title:	Estimation of Spatio-Temporal Statistics of Precipitation and Snow-Water Equivalent in the Truckee River Watershed
Project Number:	2008NV138B
Start Date:	3/1/2008
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	Nevada 02
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Surface Water, Water Supply
Descriptors:	
Principal Investigators:	Rina Schumer, Anna Knust

Publication

April 2009 Update
Estimation of spatio-temporal statistics of precipitation and snow-water equivalent in the Truckee River watershed

Rina Schumer and Anna Makowski, Division of Hydrologic Sciences,
Desert Research Institute, Reno, NV

Problem and Research Objectives

In this study, we will compile and analyze a previously undocumented dataset that includes up to 30 years of precipitation and SWE measurements recorded at 29 sites in the Truckee River watershed. The inclusion of this dataset with measurements from established monitoring stations in the watershed, will more than double the spatial sampling resolution, and the combined datasets can be used to 1) estimate temporal and spatial statistics of precipitation and SWE in the Truckee River watershed, 2) improve calibration of precipitation-runoff models in the watershed sub-basins, and 3) test independent models (e.g. SNODAS, PRISM) designed to estimate the distribution of precipitation and SWE.

Hal Klieforth, a former Desert Research Institute meteorologist, began measuring monthly precipitation and snow water equivalent at 29 sites between Spooner Summit and Henness Pass Junction (Figure 1; Table 1) in the early 1970's. The majority of these data only exist as hard copies located in Mr. Klieforth's personal office in Bishop, CA. The organization and digitization of this dataset will require a significant time commitment; however, it will facilitate the accomplishment of goals 2) and 3) above.

The goals of this project are to

1. Collect and organize a previously undocumented data set containing up to 30 years of precipitation and SWE measurements taken after storms events at 29 sites in the Tahoe Basin and Truckee River watershed,

2. Analyze the spatio-temporal statistics of precipitation and SWE from the newly compiled dataset combined with observations recorded by other sources (e.g. Snotel sites),

3. Assess the accuracy of models currently used to estimate the spatial distribution of precipitation and SWE in the Truckee River Watershed, and

4. Publish a database containing the new dataset.

Methodology

Multiple regression and data mining techniques, such as regression trees and k-nearest Land measurable factors such as temperature, elevation, aspect, slope, and vegetative cover. Time series analysis will be used to look for trends and changes in the point data over the period of record. We will use the newly acquired measurements as a validation dataset to assess the

PRISM model performance in distributing precipitation and DRI precipitation-runoff models and SNODAS data performance in assigning SWE at the Klieforth sampling locations.

Project update
During Year 1 of this project we

1. Recruited a graduate student for the project (Hal Voepel),

2. collected and digitized summaries of Hal Klieforth's original field logs provided by Jim Ashby, a former Klieforth field assistant,

3. located original Klieforth field logs, and

4. obtained and copied Klieforth's original field logs.

Graduate student Hal Voepel is currently organizing and cataloging the original field notes. He is currently developing a format for the database in preparation for digitization.

Information Transfer Activities
Following data analysis, we will publish a map of the Klieforth sampling locations with links to a database of all precipitation and SWE measurements.

Student Support
UNR Graduate Program of Hydrologic Sciences student Hal Voepel has received some funding under this grant to organize and develop the database format for this project.

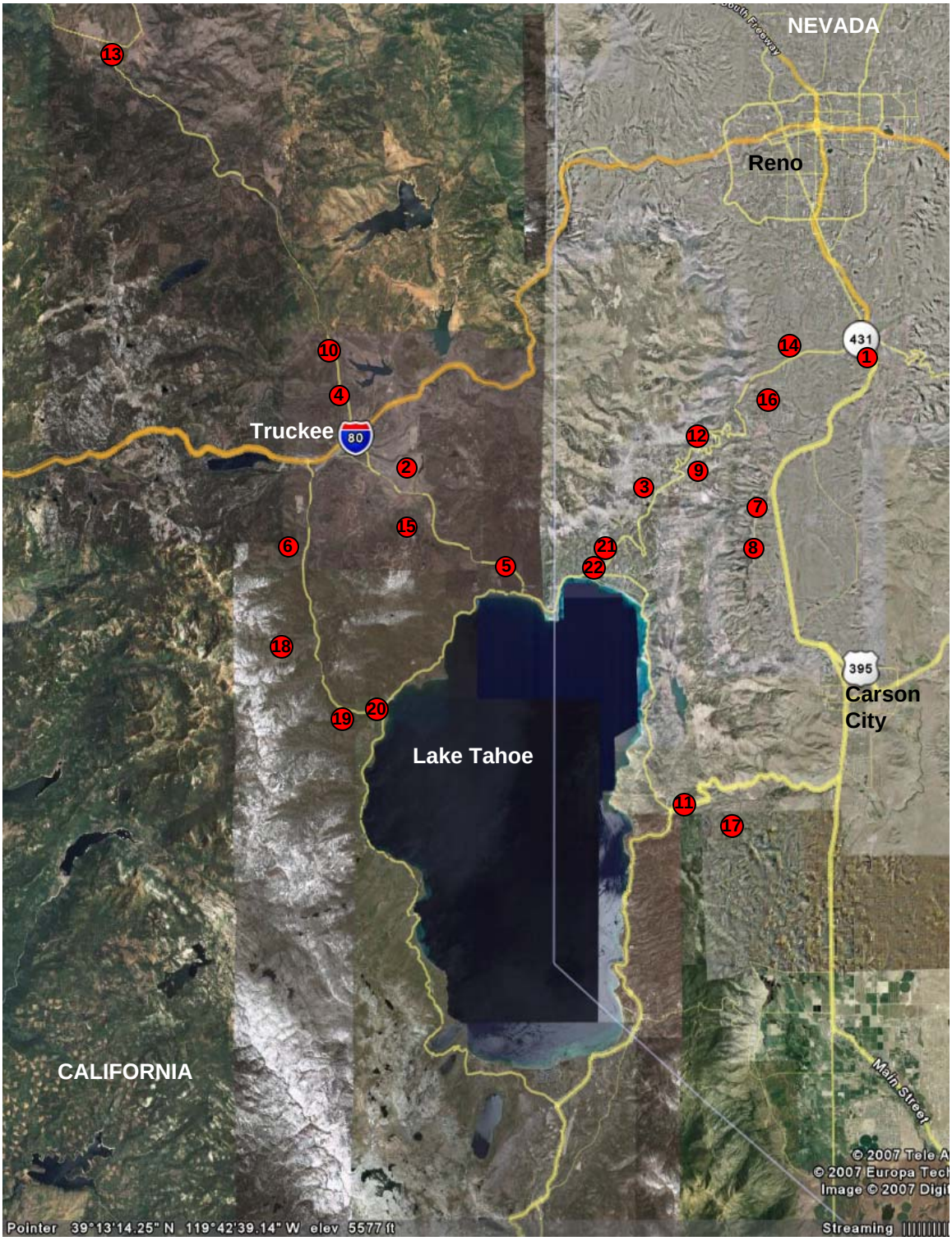

Figure 1. Approximate locations of SWE and precipitation measurement sites described in Table 1.

Klieforth Sampling Locations

Site Number	Code	Elevation	State	POR	Station Name and Location
1	8	4590	NV	1968-92	Mt. Rose Highway - Junction U.S. 395 and NV 431
2	4TA	5900	CA	1968-92	Truckee/Tahoe Airport
3	A	8500	NV	1968-92	Mt. Rose Highway - Tahoe Meadows
4	AC	6960	CA	1974-92	Alder Creek - Tahoe Donner
5	BS	7200	CA	1968-92	Brockway Summit
6	CK	6540	CA	1981-92	Cabin Creek - Off Highway 89 between Squaw Vly & Truckee
7	DC	5160	NV	1969-92	Davis Creek Park
8	FT	5250	NV	1969-92	Franktown - Cliff Ranch
9	G	8280	NV	1968-92	Mt. Rose Highway - Base of Mt. Rose Ski Area
10	HM	5850	CA	1970-92	Hobart Mills
11	JC	5800	NV	1971-92	Clear Creek - Off U.S 50 below Spooner Summit
12	K	7620	NV	1968-92	Mt. Rose Highway - Base of Sky Tavern Ski Area
13	LT	6410	CA	1973-92	Henness Pass Junction - U.S 89 north of Truckee
14	N	7060	NV	1968-92	Mt. Rose Highway - Across from Reindeer Lodge
15	NS	6320	CA	1978-92	Northstar Fire Station
16	R	5700	NV	1968-92	Off Mt. Rose Highway - Evergreen Hills Road
17	SS	7260	NV	1970-92	Spooner Summit - U.S. 50
18	SV	6240	CA	1979-92	Squaw Valley Fire Station
19	TC	6200	CA	1970-92	Thundercliff - On Highway 89 nr Alpine Meadows turnoff
20	TP	6240	CA	1973-92	Tahoe City
21	U	8000	NV	1968-92	Mt. Rose Highway - Upper Incline
22	Z	6235	NV	1968-92	Incline Village - Third and Incline Creek, 100 yds from Tahoe
23	2	6000	NV	1968-92	Mt. Rose Highway - Jones Creek
24	4	5670	NV	1968-92	Mt. Rose Hoghway - Whites Creek
25	6	5110	NV	1968-92	Mt. Rose Highway - Lancer
26	BF	6200	CA	1974-92	Bennett Flat - near Tahoe-Donner Clubhouse
27	LV	6540	NV	1969-92	Little Valley
28	O	6400	NV	1968-92	Mt. Rose Highway - RNR Test Site
29	V	7300	NV	1969-92	Mt. Rose Highway - Incline Village, Apollo Way

Table 1. Name, location, and period of record (POR) for Klieforth precipitation and SWE sampling sites.

Uncertainty and Sensitivity of Ground-Water Discharge Estimates for the Shrublands in the Great Basin Area

Basic Information

Title:	Uncertainty and Sensitivity of Ground-Water Discharge Estimates for the Shrublands in the Great Basin Area
Project Number:	2008NV139B
Start Date:	3/1/2008
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	Nevada 01
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Water Supply, Groundwater
Descriptors:	
Principal Investigators:	Jianting Julian Zhu

Publication

1. Zhu, J., and Young, M. H., Sensitivity and Uncertainty of Ground-Water Discharge Estimates for Semi-Arid Shrublands, Journal of the American Water Resources Association, in press, 2009.
2. Zhu J., and Young, M. H., Uncertainty and Sensitivity of Evapotranspiration Estimates for Semi-Arid Shrublands, Nevada Water Resources Association Annual Conference, Mesquite, Nevada, March 5 – 6, 2008.

UNCERTAINTY AND SENSITIVITY OF GROUD-WATER DISCHARGE ESTIMATES FOR THE SHRUBLANDS IN THE GREAT BASIN AREA

Progress Report (3/1/2008 – 2/28/2009)

Problem and Research Objectives

Recent years have seen a rapidly growing population coupled with a decreasing water supply in Nevada, and the American Southwest in general. Las Vegas and the surrounding metropolitan area, one of the fastest growing cities in the U.S., depends on an allotment of water from the Colorado River consisting of 300,000 acre-feet per year plus an additional amount of water equal to what it discharges into Lake Mead through the Las Vegas Wash. This limited water supply will not be enough to support its growth. With future needs of water resources in mind, local water authorities are looking northeast to the Great Basin. One plan – among many others – proposes to pump water from the Great Basin aquifers. Before such action can be taken, it is necessary to investigate the way in which the aquifers are influenced and the potential for long-term pumping to affect water availability to phreatophytic vegetation.

Federal legislation (Section 131 of the Lincoln County Conservation, Recreation, and Development Act of 2004) was enacted to conduct a water resources study of the alluvial and carbonate aquifers in Nevada and Utah. The study was known as the Basin and Range Carbonate Aquifer System Study, or BARCAS study. The study area includes 30 sub-basins in 12 valleys. Of particular focus in the BARCAS study was the amount of ground water lost through evapotranspiration (ET). ET is the primary mechanism that removes water from the soil and shallow ground water, especially in the presence of phreatophytic vegetation that survives, in part, on ground-water uptake. Estimates of mean annual ground-water discharge obtained from the original BARCAS study were based solely on estimates of mean annual ET, assuming that no other ground-water sinks existed in the study area. While ground-water ET as an overall water budget component has been estimated in other studies, including BARCAS, the estimates of sensitivity and uncertainty have not been analyzed systematically to the best of our knowledge.

Given the large size of the study area (a total of more than 4 billion m^2 in 12 valleys), and the dearth of previous studies of the valleys, ground-water discharge through ET was estimated using a rather sparse dataset. As a result, the ET rate and area uncertainty have significant influence on the ground-water discharge estimates. Because discharge estimates are expected to be used in water budget analysis for the study area, it is beneficial to quantify the uncertainty associated with these estimates in order to help maximize future data collection efforts. This project seeks to propose an integral approach to quantify the uncertainty and sensitivity of ground-water discharge estimates.

Methodology

A) General Steps to Quantify Contributions of Uncertainty from Individual Independent Variables

Here we present the general steps for quantifying fractional contributions of uncertainties in individual independent variables to the estimation uncertainty of ground-water discharge by ET, when large numbers of independent variables are involved:

1. Establish model(s) to estimate ground-water discharge that relate independent variables to the calculations of ground-water discharge.

2. Estimate uncertainty ranges and probability density functions for the independent variables based on field characterization, professional judgment, etc.

3. Randomly select realizations from the prescribed probability distributions of the independent variables, and calculate ground-water discharge values based on the selected model(s) in Step 1 for all realizations.

4. Select influential independent variables, based on the physical characteristics and model structure of the considered problems. The main goal of this step is to reduce the number of independent variables included in the subsequent sensitivity analysis.

5. Conduct sensitivity analysis to quantify the uncertainty contributions from individual independent variables.

B) Uncertainty Analysis of Ground-Water Discharge Estimates

To quantify how parameter-level uncertainty affects ground-water discharge estimates, we conduct Monte Carlo simulations that represent independent variables as statistical distributions rather than as single values. Each independent variable is assumed to be characterized by a normal distribution, with the mean ET rate estimated either through remote sensing analyses, values taken from the literature, or from existing data. The uncertainties are quantified by the coefficient of variation (CV). The CVs for ET rates are calculated based on the assumption that the estimated ranges from previous studies represent ±2 standard deviations of a normally distributed variable. Many factors can contribute significantly to the uncertainties of quantifying ET rates. If better methods of quantifying ET rates can be developed that account for these conditions, the CV of the ET rates can be reduced, likewise reducing the uncertainty of ground-water ET estimates accordingly. If different CV values for ET rates and other independent variables are used, the uncertainty of the ground-water ET estimate may differ; but the step-by-step approach proposed in this study still applies.

C) Computational Procedure to Conduct Monte Carlo Simulations

The general Monte Carlo procedure used in this study consists of five steps:

1. The mean and standard deviation of each variable is established for each sub-basin.

2. Values from the given distribution are selected for each independent variable. For each sub-basin, a total of 21 random, independent variables are used to calculate ground-water discharge.

3. Ground-water discharge from each ET unit is calculated and totaled for each sub-basin. This represents the ground-water discharge of the sub-basin for this realization.

4. The procedure is repeated for all 30 discharge sub-basins in the 12 valleys.

5. Ground-water discharges from all subs-basins are totaled for the study area, representing the total ground-water discharge for this Monte Carlo realization.

After repeating steps 1 to 5 for all realizations, we then compute the probability distribution and the basic statistics of the ground-water discharge for each sub-basin and the entire study area. The basic statistics include the mean ground-water discharge and the uncertainty in the estimate, as represented by the distribution and the corresponding CV.

D) Sensitivity Analysis of Ground-Water Discharge Estimates

To examine the sensitivity of the total ground-water discharge estimate to the three independent variable categories in general, we also systematically vary the standard deviations for the independent variables. The Monte Carlo simulations based on the original standard deviations described earlier are considered as the Base Case. By comparing the results relative to the Base Case, we can assess how uncertainty from each independent variable category contributes to the uncertainty of the total ground-water discharge estimate. For this purpose, we investigate two main themes: (1) varying the standard deviations of one individual independent variable category, while holding constant the standard deviations of the other two categories at the Base Case levels; and (2) varying the standard deviations of one individual independent variable category while using the mean of the other two independent variable categories (i.e., standard deviations equal zero). By investigating theme (2), we can explore how uncertainties in individual variable categories propagate to the uncertainty in the total ground-water discharge.

After the Monte Carlo simulations, we develop regression models that relate total ground-water discharge to individual independent variables, and we use these models to assess overall sensitivity of the total ground-water discharge estimate to the individual independent variables. The squared values of standardized regression coefficients simply represent the fractional contributions from the individual independent variables to the total variance of the ground-water discharge.

Principal Findings and Significance

The principal findings are:

1. Although the independent variables in this study typically have small CVs, the CV of ground-water discharge estimates in some sub-basins can be as high as 150%. Thus, decisions based on estimates of water budget components need to account for levels of uncertainty.

2. In general, the uncertainty of ET rates is the most significant contributor to the uncertainty of ground-water discharge estimates. We find that a total of 630 variables affect the estimates of total ground-water discharge, but that only seven variables account for almost all of the variability in the discharge estimates. We demonstrate that ground-water discharge estimates using the simplified regression relationship and the full relationship correlate very closely ($r = 0.982$).

3. Quantitatively, the variability in ET rates for the moderately dense desert shrubland contributes to about 75% of the variance in the total ground-water discharge, while some independent variables contribute less than 1%. The results indicate that field data collection to reduce overall uncertainty should focus primarily on this ET unit, and less on other units.

Information Transfer Activities

Zhu, J., and Young, M. H., Sensitivity and Uncertainty of Ground-Water Discharge Estimates for Semi-Arid Shrublands, Journal of the American Water Resources Association, in press, 2009.

Zhu J., and Young, M. H., Uncertainty and Sensitivity of Evapotranspiration Estimates for Semi-Arid Shrublands, Nevada Water Resources Association Annual Conference, Mesquite, Nevada, March 5 – 6, 2008.

Student Support

This grant was partly used to fund student training. Feng Pan (PhD student at University of Nevada Las Vegas (UNLV), Department of Geoscience) and Rushikesh Veni (summer student from UNLV, Department of Computer Science were funded partially from this grant during the project period.

Publications

Journal Paper:

Zhu, J., and Young, M. H., Sensitivity and Uncertainty of Ground-Water Discharge Estimates for Semi-Arid Shrublands, Journal of the American Water Resources Association, in press, 2009.

Abstract and Presentation:

Zhu J., and Young, M. H., Uncertainty and Sensitivity of Evapotranspiration Estimates for Semi-Arid Shrublands, Nevada Water Resources Association Annual Conference, Mesquite, Nevada, March 5 – 6, 2008.

Award No. G09AP00003 Depleted Uranium Transport by Water

Basic Information

Title:	Award No. G09AP00003 Depleted Uranium Transport by Water
Project Number:	2008NV158S
Start Date:	10/23/2008
End Date:	10/22/2009
Funding Source:	Supplemental
Congressional District:	Nevada 03
Research Category:	Climate and Hydrologic Processes
Focus Category:	Toxic Substances, Hydrology, Radioactive Substances
Descriptors:	
Principal Investigators:	David Shafer, Julianne Miller

Publication

Progress Report: "Depleted Uranium Transport by Water in the Mojave Desert"
USGS Water Resources Research Institute Program Award No. G09AP0003

Problem Statement and Research Objectives

Depleted uranium (DU)-armored munitions have seen increasing use in arid and semi-arid regions of the world, and have been used as part of training exercises and ballistic tests at U.S. Department of Defense (DOD) installations in the Mojave Desert of the southwest United States. DU is a by-product of the uranium enrichment process used to create fuel rods for commercial and military reactors where the most radioactive of the three uranium (U) radioisotopes, ^{235}U, is concentrated. Although it has less ^{235}U than naturally occurring U, DU and DU oxides remain a radiological hazard and are potential human health and environmental hazards because of their toxicological characteristics as well.

Because of its potential health and environmental effects, DOD is taking steps to limit the area impacted by DU and DU oxides by reducing its transport in the environment However, there remain uncertainties about properties of DU in areas such as the Mojave Desert that are being addressed in part by this research. In particular, this research focuses on the potential transport of DU by water (channel and overland flow, and as a dissolved phase) during "flow events" in the Mojave Desert. The focus of the research is mechanical transport of DU and DU oxides, although the potential for a dissolved phase of U to form is being evaluated as part of laboratory studies. Hydrous DU oxides form quickly on the surface of DU munitions after a precipitation event and form essentially a separate phase in the environment. At the primary study area, the runoff properties of different geomorphic surfaces/soils on which DU occurs are being determined for a 10-year, design event storm. These data are being used to populate a runoff and transport model to predict how far DU and DU oxides may migrate over time. Based on the results, recommendations will be made to DOD on steps it can take to reduce DU migration, as well as data that could be collected to validate predictive models of DU migration.

Methodology

Preliminary Mapping of Geomorphic Units: Aerial photos and other imagery were used to make a preliminary map of geomorphic surfaces/soils in the study area. Groundtruthing was done in areas of uncertainty. Locations where DU was found during sampling conducted in 2008 by DOD were plotted to understand its distribution as a function of the geomorphic/soil units. Bulk density measurements and soil particle size analysis of soil samples are being conducted to see if any of the geomorphic units can be statistically combined in terms of their runoff characteristics.

Hydrologic Testing of Soils on Geomorphic Units: Rainfall simulation (RFS) tests to develop runoff curve numbers and tension infiltrometer tests (TI) to develop pedo-transfer functions are being performed on the different geomorphic units. The two tests are being conducted at the same locations. For the major geomorphic units, at least four RFS and TI tests are being conducted to understand spatial variability of the soil properties. Although the tests provide complementary data (a soil with low infiltration capacity should show greater runoff), employing multiple methods improves confidence in the results for transport analysis.

Geochemistry of DU Oxides: Samples of soil containing DU oxide particles have been analyzed using x-ray diffraction (XRD) and indicate that all of the oxides are a single hydrated U oxide phase, the mineral schoepite ($UO_3 . 2H_2O$). XRD was also used to identify other minerals in the soil that could react with dissolved U phases to reduce U mobility. One sample contained 15 percent merlinoite, a zeolite, a mineral that may bind strongly with cationic forms of U and prevent or slow U transport. In addition to the XRD analysis, specific surface area analysis and scanning electron microscopy of different soils are also currently being conducted.

Water Runoff and DU and DU Oxide Transport Modeling: Modeling will be conducted to determine the amount of runoff in the watershed, and the distance that DU and DU oxides might be transported over time. A model grid using FLOW-2D has been developed for the watershed.

Principal Findings and Significance

Because site characterization and model development are still underway, there are no significant findings to date. Site characterization work was delayed in the early part of this year because of a series of storms that caused the water content of the soil to be too high to conduct TI and RFS tests. However, all elements of the project are underway now. The amount of additional hydrologic testing of soils is still being determined. Some geomorphic units are showing trends where the amount of runoff increases on their distal portions that may require more tests to be performed on some than others.

Information Transfer Activities

Because site characterization and model development are still underway, there have not been any publications to date. However, it is anticipated that at a minimum the methodology being used for the study will be used for presentations at professional meetings in 2009 including the Geological Society of America and the American Geophysical Union. It is anticipated that the results will be published in at least two peer-reviewed journals.

Student Support

William Meyer, a graduate student in Civil and Environmental Engineering at the University of Nevada, Las Vegas is conducting the flow modeling as part of his thesis. In addition, Karletta Chief, a Post-Doctoral Fellow at DRI, is the lead researcher on soil infiltration properties.

Information Transfer Program Introduction

None.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	3	0	0	1	4
Ph.D.	1	0	0	0	1
Post-Doc.	3	0	0	0	3
Total	9	0	0	1	10

Notable Awards and Achievements

Susanne Blunt, Masters student, received the best poster award at the Lake Mead Symposium at University of Nevada, Las Vegas in January, 2009 for her presentation of preliminary results on the Microbial and Phytoplankton Impacts on Endocrine Disrupting Contaminants: Las Vegas Wash and Lake Mead, NV.

Publications from Prior Years