Water Resources Center, Desert Research Institute
Annual Technical Report
FY 2001

Introduction

Research Program

A Multi-Level Approach to Modeling Ground- and Surface Water Exchange in Agriculturally-Dominated Settings

Basic Information

Title:	A Multi-Level Approach to Modeling Ground- and Surface Water Exchange in Agriculturally-Dominated Settings
Project Number:	2000NV2G
Start Date:	9/1/1998
End Date:	8/31/2001
Funding Source:	104G
Congressional District:	Nevada 02
Research Category:	Water Quality
Focus Category:	Nitrate Contamination, Geomorphological Processes, Groundwater
Descriptors:	surface-groundwater relationships, subsurface drainage, water quality modeling, irrigation, algae
Principal Investigators:	Wallace Alan McKay

Publication

1. Cook, Casey Wynton, 2001, A Discrete State Compartment Model of the Fernley-Wadsworth Groundwater System, University of New Mexico, Master's Thesis.
2. Kish, Suzanne, 2002, A Surface Water Quality Model for Agriculturally Dominated Areas in the Lower Truckee River Basin, University of Florida, Master's Thesis.
3. Peterson, Sarah, 2003, Impact of Agricultural Activities on Ground and Surface Water Quality and Related Instream Biological Communities in the Lower Truckee River Basin, Nevada, University of Nevada, Reno, Master's Thesis.
4. Gheberemicael, Senait, Dec 2002, Sources of and Controls on Arsenic in the Groundwater of Fernley Area, Nevada, unpublished MS thesis, University of New Mexico.
5. Pohll, G., D. McGraw, J. Ralson, B. Bohm, J. Thomas, A. McKay, M. Widmer, T. Minor, G. Lamorey, O. Dahan, R. Carroll, K. Cupp, E. Jacobson, E. McDonald, E. Stevick and J. Huntington, 2001. Evaluation of Groundwater and Solute Transport in the Fernley-Wadsworth Area. Desert Research Institute, Division of Hydrologic Sciences Report. No. 41173.

Problem and Research Objectives:

Water quality changes in the lower Truckee River have been linked to non-point source groundwater discharge by several investigators. Increasing salinity (in the form of total dissolved solids, or TDS) in the lower river has broad implications in the Basin, particularly within the context of terminal Pyramid Lake and two listed fish species. The objectives of the research were threefold:

1. Through intense field monitoring and associated numerical modeling efforts, quantify the flux of groundwater nutrients to the lower Truckee River;
2. Using bench- and reach-scale experimental methods and monitoring, assess the relationship between groundwater nutrient flux and benthic algal production; and,
3. Integrate findings from No's 1 and 2 into a numerical surface water quality model.

Methodology:

Objective 1: Two sites were chosen within the lower Truckee River Basin based on physical setting and land use. Both sites had active flood irrigation of field crops (alfalfa), were adjacent to the River and were in settings believed to be areas of active groundwater discharge. At each site approximately 20 shallow (<20 meters) wells were installed which were monitored over a two year period for water quality (major cations, anions and nutrients) and water levels. Concurrently, water quality and stage were monitored in adjacent river reaches.

The USGS public domain code MODFLOW (McDonald and Harbaugh) was used to develop a model of ground- and surface water interaction at the two study sites, and the transport code MT3D (Zheng) was used to help simulate nutrient transport between the ground and surface water domains.

Objective 2: Two different methods were used (one of which is ongoing) to address this objective. First, a parallel effort supported by Washoe County and the Cities of Reno and Sparks focused on monitoring benthic algal production in the lower river over an 18 month period. Monitoring sites for this effort included locations that were spatially coincidental with the aforementioned groundwater/surface water study sites. Also referred to as biomass monitoring, this program used USGS NAQWA protocol for sampling and analysis.

An ongoing effort is focusing on the use of metabolism chambers to simulate the impact of groundwater nutrients on algal production. We are using two-stage chambers to simulate groundwater flux into an upper water column comprised of Truckee River water. "Groundwater" is discharged through fused silica diffusers which function as the growth medium for the periphyton. Different "groundwater" solutions are used to help us assess the response of periphyton to different nutrient concentrations diffusing across the ground-surface water interface.

Objective 3: The US EPA public domain code WASP4 was used to integrate data obtained from Objectives 1 and 2 and to simulate the impacts of point and non-point nutrient inputs on instream water quality. While one version of the model is complete, other external support is helping the investigators to make further improvements on the model, particularly as it relates to benthic algal response to groundwater nutrients.

Principal Findings and Significance:

To-date, the principal findings of the NIWR-sponsored research are:

1. In areas of flood-irrigated agriculture, groundwater discharge to the lower Truckee River appears to be enhanced relative to non-irrigated areas;
2. In these same areas, nutrient loadings (both N and P) from groundwater comprise a significant portion of the total loads, particularly during periods of low river discharge. It is noteworthy that during low river flows, water quality standards are most difficult to achieve.
3. An 18-month biomass monitoring program has revealed a strong link between areas of high non-point source groundwater discharge and increased periphyton production.

A Method to Determine the Effects of Fire, Restoration, and Invasive Species on Local and Regional Hydrology in the Great Basin by the Use of Environmental Tracers

Basic Information

Title:	A Method to Determine the Effects of Fire, Restoration, and Invasive Species on Local and Regional Hydrology in the Great Basin by the Use of Environmental Tracers
Project Number:	2001NV4182B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	
Congressional District:	Nevada 02
Research Category:	
Focus Category:	Hydrology, Geomorpological and Geochemical Processes, Methods
Descriptors:	fire, hydrology, geochemistry, isotopes, recharge
Principal Investigators:	william.henry.albright.1

Publication

Problem and Research Objectives:

A combination of periodic fire and the introduction of aggressive, non-native plant species has significantly altered the landscape of the Great Basin and may have affected significant changes in the soil moisture dynamics and hydrology of the region. Shallow-rooted annual grasses (cheatgrass) and deeper-rooted perennial grasses (crested wheatgrass) have replaced native plant communities dominated by deep-rooted perennial shrub and tree species. While the changes in plant community composition have received considerable attention, the accompanying alterations in hydrology in the Great Basin have not been thoroughly investigated. The demands placed on soil moisture and the timing of those demands by the introduced species may change (increase) the quantity of water available for recharge.

The clear delineation between burned and unburned areas at the edges of a fire offer excellent opportunity to evaluate the hydrologic effects of fire and plant succession. At fire lines, treatment (burned) and control (unburned) are in close proximity and can be clearly identified. We proposed a field effort that will use environmental tracer methods to evaluate changes in hydrology resulting from fire and subsequent (re-) establishment of a plant community. Environmental tracer analysis of soil samples from soil coring activities at burn areas of various ages will provide a longer-term view of changes in soil moisture status, especially recharge, associated with burned areas.

Methodology:

Characterization of historic burns will seek to identify differences in recharge between control sites with native vegetation and burned sites with introduced vegetation using soil moisture measurements and a variety of environmental tracers. Measurements will be made at adjacent locations on either side of fire lines at burns of various ages. Soil cores will be taken to depths below the root zone. Soil samples at various depths will be analyzed for chloride, stable isotopes of hydrogen and oxygen of water (deuterium and oxygen-18) tritium, and chlorine-36. The tracers will be used to quantify the long-term hydrologic differences between areas with native vegetation and burn areas with introduced vegetation. The primary intent of this field exercise will be to identify differences in recharge rates in control areas with native vegetation and burn areas with introduced vegetation.

Principal Findings and Significance:

Continuous cores were taken at two field sites in May of 2002. Analysis of soil moisture and bulk chemistry has begun.

Evaluation of Ecosystem Metabolism at Selected Sites in the Lower Truckee River Basin

Basic Information

Title:	Evaluation of Ecosystem Metabolism at Selected Sites in the Lower Truckee River Basin
Project Number:	2001NV4281B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	Nevada 02
Research Category:	Biological Sciences
Focus Category:	Ecology, Surface Water, Nutrients
Descriptors:	metabolism, ecosystem, TMDL's,dissolved oxygen
Principal Investigators:	, Wallace Alan McKay

Publication

Problem and Research Objectives:

The lower Truckee River of Nevada is a lotic ecosystem influenced by our societies uses of the Truckee River Watershed's water and land resources. The use of these resources often create point source and non-point source loadings of the lower Truckee River with materials (nutrients, water, pollutants etc.) that influence the biota and water quality (WQ) which are integral components of the lower Truckee river's ecosystem that has a specific targeted set of beneficial uses.

In order to monitor the lower Truckee River's water quality the Truckee Meadows Water Reclamation Facility and the Desert Research Institute has deployed water quality sensors throughout the lower Truckee River (LTR). These monitors are primarily utilized to determine if oxygen levels in the LTRiver reach threshold levels that may compromise the LTR's beneficial uses. This information also has been used to tune and validate WQ models of the LTR that are being developed and refined as tools for helping guide regulations and operations that will maintain the WQ of the LTR.

Recently, as part of the efforts to validate WQ models for the LTR, the stocks and dynamics of algal and macrophytes biomass has been assessed. The rational e for such monitoring is based on the premise that algae and Macrophytes are primary agents of oxygen consumption and production as well as nutrient transformations.

The monitoring and assessment of algal and macrophytes biomass in the LTR is an operation that requires hundreds of hours in the field as well as laboratory assessments of biological constituents. In addition, the deployment of personnel into the field presents risks to institutional resources and health. Therefore, we are seeking alternative measures as proxy's for monitoring plant biomass or biomass dynamics in the LTR. Models being constructed for the LTR are indirectly providing means for accomplishing this general objective through mechanistic nutrient accounting and hydrodynamics simulations. Another approach worth exploring is the relationship between oxygen dynamics that are a function of community metabolism and the measured biomass in the river during the same time periods. By determining if there are site specific relationships between algal or macrophytes biomass or biomass dynamics and community metabolism we will be able to evaluate if there is a means to provide a more direct and perhaps more synoptic method for monitoring biomass in the LTR that influences WQ, beneficial uses and ecosystem function during the future.

Methodology:

YSI sondes nominally consisting of probes for the determination of dissolved oxygen, temperature, pH and conductivity have been deployed from the bridges located at Mogul, East McCarren, Lockwood, Tracy/Clark, Painted Rock, Wadsworth, Dead Ox and Little Nixon along the LTR. TMWRF personnel have maintained these sondes since their deployment starting in 1985. The data collected from these sondes are available on the

web at www.tmwrf.com or by contacting TMWRF at 8500 Cleanwater Way, Reno, NV 89503.

DRI personnel also have deployed additional sondes deployed at five additional locations during the summer to autumn of 2001. Such deployments were made to make additional assessments of DO dynamics at sites not traditionally monitored by TMWRF- yet are integral to providing synoptic information for the LTR. These additional sites also have coincided with periphyton biomass monitoring projects for the Lower Truckee River that was accomplished by DRI, TMWRF and Washoe County personnel.

Streamflow data, necessary for community metabolism calculations, were used to determine the discharge, velocity, and depth of the lower Truckee River. The United States Geological Survey (USGS) monitor real-time streamflow with current meters for several sites along the Truckee River including at the North Truckee Drain at Spanish Springs Road near Sparks, Vista, near Tracy/Clark, below Derby Dam, at Wadsworth, and near Nixon. Streamflow data collected by USGS are available on the web at www.usgs.gov. Sites nearest to the areas where DO sensors were deployed are initially being used as proxies for discharge at these sites. Cross sections for discharge at the sites of the DO sensor deployments are being used to evaluate the USGS gauges as measure of discharge at the DO sensor sites.

Principle Findings and Significance:

To date the accomplishments for the project include the deployment and recovery of the DRI dissolved oxygen sensors during the summer of 2001. Additional deployments also occurred in the spring and early summer of 2002. TMWRF DO sensor data has been collected and all the data has been time stamped and collated with the respective USGS discharge data for the stream gages nearest to the areas where the DO sensors have deployed. Calculations of community respiration have been completed and additional computations for community photosynthesis are being undertaken.

Once the respiration and photosynthesis calculations are complete we will be comparing these with the periphyton biomass data to determine the number of sites that have comparable data on biomass and DO fluctuations. We anticipate that these data queries and calculations will be complete in the next month. This time frame will allow sufficient time to write a synthesis report and present our findings at upcoming water quality meetings regarding the Truckee River and the Arid West.

Assessment of Ground Water Recharge in Mine-Altered Regions of Nevada

Basic Information

Title:	Assessment of Ground Water Recharge in Mine-Altered Regions of Nevada
Project Number:	2001NV6B
Start Date:	3/1/2001
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	Nevada 02
Research Category:	Water Quality
Focus Category:	Groundwater, Water Quality, Hydrogeochemistry
Descriptors:	arsenic, groundwater recharge mining impacts
Principal Investigators:	Scott Woodman Tyler

Publication

1. Kampf, S. M. Salazar and S. W. Tyler. Preliminary Investigations of Effluent Drainage from Mining Heap Leach Facilities, Vadose Zone Journal, Vol. 1(1): 186-196. 2002
2. Turrentine, J. A., T. Halihan and T. Fenstemaker, Vadose Zone Fluid Migration in a Heap-Leach Site using Transient Electrical Resistivity Surveys. Paper No. 7-21. Geological Society of America Annual Meeting, Abstracts with Program. October 26-31, 2002, Denver, CO.

Research Objectives:

This research will utilize the unique geometry and construction practices of heap leach gold mining presently used in Nevada to estimate ground water recharge contributions through mining waste material. It is well known that it is extremely difficult to accurately measure ground water recharge in arid and semi arid environments. However, heap leach mining structures allow for the collection of all recharge passing through these large (100-500 acre) structures. Following cessation of the mining operation, long term drainage from the heap leach structures can be used to directly estimate the recharge rates (and percentage of recharge to precipitation). This research will develop tools and quantitative measures for the prediction of long-term drainage and drainage behavior through highly heterogeneous mining waste using field-measured data from closed heap leach piles. Data collected through this research are critical to understand the impacts of these structures on ground water quality in Nevada. Additionally, the data gathered from this study can be used to assess various waste containment methods for closure of mines as well as rural sanitary landfills. Thirdly, data from this study will provide estimates of the potential changes in recharge on lands that have been disturbed in other ways, such as wildfires where vegetation has been significantly altered.

This project proposes to determine the rate of ground water recharge beneath disturbed mine lands in Nevada, with particular attention to heap leach piles, waste rock dumps and the associated issues of water quality with these areas. In the first year of the project, we have focused on sampling known closed mine sites and designing a field monitoring laboratory to investigate the flow and transport processes in these complex materials. We have and continue to analyze heap leach pile drainage data to determine rates of recharge from these structures. As heap leach piles are lined and drainage can easily be measured, these structures act as very large lysimeters, intercepting ground water recharge before reaching the water table. The integrated fluxes through these structures, long after active leaching and rinsing has stopped represent deep infiltration. Data gathered to date from field investigations shows a complex relationship between surface morphology, precipitation and long-term drainage rate. At several sites, changes in surface cover or management practices have been reflected in declines in drainage rates below that expected for native vegetation at these sites. Water quality from the studies sites shows a wide variation in dissolved constituents, primarily reflecting the mineralogy of the primary ore and waste rock, as well as the rinsing and closure strategies employed. Open pit precious metal mining in Nevada places large volumes of rock, some of which is reactive, at the land surface, both as heap leach piles and waste rock dumps. While the climate of Nevada is generally arid to semi-arid, rainfall and snowmelt can infiltrate following mine closure and become ground water recharge. Given the reactive nature of some of these mining wastes and the almost complete lack of quantitative data on long-term infiltration, it is critical that the rates of water and solute flux through these structures be quantified to determine if a significant potential for ground water degradation may occur and to develop effective management strategies.

As a result of efforts during the first year, we have developed a unique opportunity with Placer Dome Inc., to densely instrument a heap leach pad nearing completion. Currently, there does not exist any detailed, in-place monitoring and sampling facility to study the transport of water and contaminants through gold mining waste at the field scale. The constructed facility represents a partnership between industry and the university of significant benefit to both. At this time, no similar facility exists in the world and will provide tremendous opportunities for future research into contaminant transport from mining waste.

Placer Dome has provided the cost of instrumentation and monitoring as in-kind services, with UNR's activities focused on laboratory analysis, data analysis and experimental design. The focus of this second year effort will be to quantitatively understand the water and geochemical evolution under heap leaching, rinsing and long-term closure using this field site. This site offers a unique opportunity, unavailable to us when the first year proposal was completed, to study in situ, 1) the evolution of wetting and drainage in an active heap leach pile, 2) the geochemical evolution of waters produced during leaching operations, 3) the short term drainage effluent quality following leaching 4) the efficacy of rinsing in reducing toxic species in the effluent waters and 5) to test various cover/closure options to reduce both water flow and toxic element release. During this second year of the project, #1-3 are expected to be completed, with rinsing studies to be initiated but may not be completed. Final cover analysis (#5) will not be completed in this second year, but funding from others sources will be developed to continue testing of rinsing and closure.

Information on anticipated long-term infiltration through heap leach piles and waste rock dumps at precious metal mines in Nevada is critical for assessing the potential impacts of these structures on ground water quality. Research completed in the first year of this grant have focused on extending the database of existing mine drainage rates (Objective 1) field investigations of previously documented sites (Objective 2) and the design, in collaboration with Placer Dome Mining, of a comprehensive field site for investigation of flow and transport through heap leach piles and waste rock.

Methodology:

During the first year, the following tasks associated with the project have been completed:

Results from Objective 1: *To complete a database on existing post-rinsing heap leach pile drainage behavior in Nevada and other western states.*

During 2001, the Co-PI (Van Zyl) compiled and reported data from NDEP, U.S. Forest Service and Bureau of Land Management files on mine drainage, mine drainage water quality, closure plans and mine impacts on ground water from mines in Nevada (26) and So. Dakota (1). These data are now directly accessible on World Wide Web (http://www.unr.edu/mines/mine-eng/mlc/workshops.html) as part of UNRs Mine Life Cycle (MLC) Heap Leach Closure Workshop series. Most of these mine sites were not contained in the preliminary work of Kampf et al (2002) and represent new data available for the assessment of drainage rates and water quality from mining lands.

The drainage data added above to the data base developed by Kampf et al (2002) generally support the original conclusions, i.e. that long term drainage in the most arid sites is generally higher than would be predicted from simple water balance calculations while drainage at mine sites in higher precipitation zones is similar to that predicted by water balance and modeling.

Results from Objective 2: *To conduct field investigations at arid (<200 mm/yr) and other anomalous recharge rate heap leach piles to determine critical surficial features leading to either a) higher than anticipate rates of recharge or b) significant seasonal variation in recharge flux.*

Beginning in October 2001, field visits to the mine sites with preliminary data were initiated. Originally, we had proposed to visit only those showing anomalous drainage rate, however it there is only a marginal increase in time/driving to visit all eleven sites. . To date, 6 sites have been field visited, sampled and analysis of samples has begun. These mine sites are: Yerrington (I

and II), Wind Mt (I and II), Aurora and Boss. In addition, the Cortez Gold Acres site has been visited three times, to review monitoring design and to sample surface material. At each site visited, the following information has been obtained:

Current status of mine closure
General surface slope and geometry including height
Evidence of overland flow on the heap top
Evidence of overland flow from top surfaces to side slopes
Evidence of erosion of side slopes
Extent of vegetation (percent cover) on the heap surface and side slopes
Type of vegetation (shallow or deep rooted) present
Evidence of integrity of leachate collection system
Five samples of surface (0-30 cm deep) materials and/or cover soil for grain size analysis.
Storm frequency and type (data developed from climatic information at UNR)
Potential Evapotranspiration (data developed from climatic information at UNR)

In addition, GPS coordinates of heap boundaries and digital photography have been made at all sites visited to date.

Results to date indicate that some of the mines originally reported in the NDEP files to be closed are, in fact still in some form of closure activities. For example, recycling of drainage water continues at the Yerrington Mine Site resulting in elevated drainage rates. Other sites, originally reported to have significant revegetation completed show very limited vegetation, in response to the well below average precipitation during 2001. Analysis of surface materials shows a generally coarser texture than was reported in NDEP files for several of the mine sites showing anomalous drainage rates, suggesting that deep infiltration of precipitation may be more likely than originally estimated from the filed reports.

It is planned that the five remaining sites will be visited by December 30, 2001. Data from the field visits/sampling will then be used to update the database (Objective 1) prior to its electronic publication in February 2002.

Results from Objective 3: *To develop a predictive, field data based, water balance model for heap leach piles accounting for precipitation, climate, surficial properties (vegetation, percent coarse fragments at surface, etc.) and ore hydraulic properties*

The predictive modeling of heap and waste rock drainage is predicated upon the site visits, sample analysis and review of field data. Based upon results to date, the variability of closure designs and vegetation variability suggests that long term drainage prediction using simple static models can, at best, lead to drainage estimates accurate within 10-50%. Field visits to date have shown that vegetation density varies dramatically over time in response to the recent draught cycle and that cover maintenance may be critical towards reducing long term drainage. Cover design is also a critical factor. For example, Little Bald Mt., while in a very high precipitation zone, shows little long-term drainage. During our recent investigations, it was found that a 3-4' soil cover was added to this site that was not described in the NDEP files. The cover is very effective at minimizing deep infiltration at this site. However, this information was not available to us at the beginning of the project.

At this point in the project, we are now focusing our efforts at predictive modeling to those sites where only minimal closure/cover efforts have been expended. For those sites where comprehensive engineering covers have or are planning to be installed, simple numerical

simulations will prove to be more efficient at predicting long-term drainage and impacts to the water table. The codes used in this project as well as those currently commercially available make such calculations relatively straightforward. It is anticipated that a simple drainage model for uncovered sites, focusing primarily upon precipitation and monthly average temperature (to account for snow melt) will be completed by the end of February 2002 using field data collected from the nine sites.

Results from Objective 4: *To monitor and analyze at least one heap leach pile directly following rinsing to obtain hydraulic and geochemical parameters during drainage.*

The original proposal had focused on quarterly monitoring of draindown and geochemistry from a bankrupt site in eastern Nevada. With strong industry support, we have revised our original concepts and designed and planned much more detailed instrumentation at Placer Dome's Cortez Gold Acres facility in Crescent Valley, NV. The objectives of this facility are to measure, in space and in time, the fluid flow and contaminant transport processes within a large heap leach structure. The Gold Acres facility was deemed to provide much greater opportunity to study fluid flow in heap facilities, by integrating the sampler design into the construction of the heap leach pile, rather than relying upon a single outflow measurement as we had originally planned in Year 1. In late spring, 2001, UNR was contacted by Placer Dome Mining to develop an in-situ monitoring and research facility at the Cortez Gold Acres heap leach pad in Crescent Valley, Nevada. This facility, rather than simply monitoring the drainage effluent from the bottom of one heap leach pile, will be constructed such that water quality and flow properties can be monitored at various depths and locations of the heap as well as at the bottom. A large array of samplers has been designed and has been installed in the Cortez Gold Acres heap in January 2002.

The Cortez Gold Acres Facility represents a unique collaboration between the mining industry (Placer Dome), engineering consultants (SRK, Inc.) and the university to develop a state of the art heap leach monitoring system and forms the central focus of the second year's effort. The monitoring system will allow testing of various heap leach strategies, rinsing strategies and final closure strategies to reduce the impact of mining on the water resources of Nevada.

Beginning in the spring 2001, planning meetings were held with Placer Dome, Inc, UNR and SRK Consulting Engineers, Inc., to design field lysimeters to be placed within the Gold Acres Heap as it was completed. Mining plans were altered to allow for instrument construction and placement of ore in the summer of 2001. Currently, the heap is approximately 100 acres in size and ranges from 40-80' in height. The heap has been leached and rinsed and is awaiting placement of one final lift of ore. The instrumentation installed consists of large (50' by 20') pan lysimeters placed at four locations beneath the last 20-30' lift of ore stacked on the pad. The large pan lysimeters have been placed before the last lift of the heap is stacked. One lysimeter is also placed near the edge of the pad to investigate flow and transport along the side slopes. In addition, 15 smaller (6 ft^2) lysimeters are placed adjacent to the pan lysimeters and in a closely spaced array to investigate the spatial variability of fluid flow. Figure 1 shows the lysimeter design and the general layout of the lysimeters within the heap leach pile.

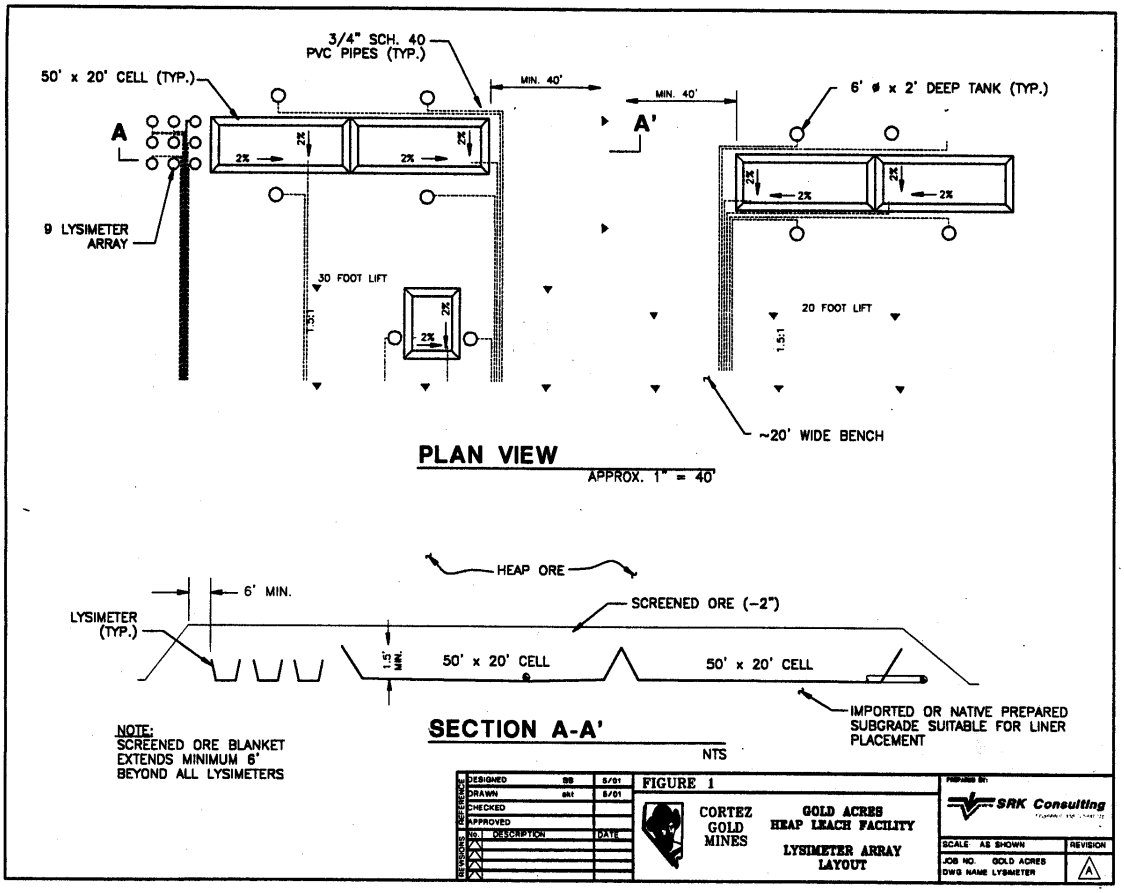

Figure 1. Schematic design of Cortez Gold Acres Facility (CGAF) lysimeter construction and location. Design drawings produced by SRK Consulting Engineers, Inc. for Placer Dome, Inc and the University of Nevada, Reno

Construction of the lysimeter facility was originally planned for late summer 2001. Changes in the mining plan have resulting in rescheduling construction and placement of the final ore lift for January 2002. Cyanide solution and gold recovery will proceed for 90 days, and was begun in late October and is to be followed by several rinsing strategies. Throughout the recovery and rinsing process, flow rates and fluid samples will be collected from each of the lysimeters to assess the fluid transport mechanisms, travel times and geochemical evolution of fluids both during active leaching and during draindown and rinsing. Samples will be collected weekly for fluid chemistry from each of the lysimeters and each lysimeter will have continuously recording flow meters to measure fluid flow.

Samples of ore to be placed above the lysimeters have been collected throughout the construction phase. Both particle size analysis and whole rock geochemical analysis are being conducted on ore samples as well as core samples from the heap prior to addition of the last lift. Samples of the leached ore beneath the lysimeter depths have also already been sampled and archived.

Results from Objective 5: *Modeling of arsenic transport at the field site.*
This objective was planned for starting in the second year of the project and is now listed as an objective for 2002/2003.

Watershed Modeling Work for the Truckee River WaRSMP

Basic Information

Title:	Watershed Modeling Work for the Truckee River WaRSMP
Project Number:	2001NV7B
Start Date:	6/1/2001
End Date:	5/31/2002
Funding Source:	Supplemental
Congressional District:	Nevada 02
Research Category:	Climate and Hydrologic Processes
Focus Category:	Management and Planning, Surface Water, Models
Descriptors:	modeling, surface water
Principal Investigators:	Douglas Boyle

Publication

1. Boyle, D.P., A.E. Jeton, and J.R. McConnell, "Application of a Distributed, Physically Based, Hydrologic Model to Improve Streamflow Forecasts in the Upper Part of the Truckee River Basin, California and Nevada." Presented at the NWRA Symposium of the Truckee & Carson Rivers, Reno, NV, November 14, 2001.
2. Boyle, D.P., A.E. Jeton, and S. Markstrom "Overview of WaRSMP MMS-PRMS modeling activities in the Upper Part of the Truckee River Basin, California and Nevada." Presented at Interagency Water Supply and Demand Forecasting Meeting, Sacramento, CA, June 5, 2002.
3. Boyle, D.P., A.E. Jeton, S. Markstrom, and J.R. McConnell, "Application of a Distributed, Physically Based, Hydrologic Model to Improve Streamflow Forecasts in the Upper Part of the Truckee River Basin, California and Nevada." Presented at the Truckee River Watershed Council, Northstar Resort, CA, June 12, 2002.

Problems and Research Objectives:

As part of the Truckee-Carson Program (TCP) of the U.S. Geological Survey (USGS), a modeling system to support water-resource planning and management was developed by the Nevada District USGS office. The USGSs Precipitation-Runoff Modeling System (PRMS) within the Modular Modeling System (MMS) model building framework, was used to simulate streamflow from seven gaged sub-basins, six reservoir catchments, and three ungaged areas in the upper Truckee River Basin. A detailed description of this effort is available in the USGS Water-Resources Investigations Report 99-4282, by A. E. Jeton, 2000.

As part of the Watershed and River System Management Program (WaRSMP)Recently, the U.S. Bureau of Reclamation (USBOR) decided to include the MMS-PRMS model of the upper Truckee River Basin as part of their real-time decision support system for real-time water resources operations on the Truckee River Basin. This prompted the need to revise the existing MMS-PRMS model as follows: 1) Re-delineate the subbasins and associated Hydrologic Response Units (HRU's) using the USGS Geographic Information System (GIS) Weasel software, and 2) apply the version of PRMS known as XYZ-PRMS, developed by Lauren Hay at the USGS, over the TCP study area. The motivation for the first model revision was primarily to provide more uniformity among the WaRSMP study basins. The work associated with the first model revision was performed by staff at the Nevada District USGS office. The second model revision was required to address climate data issues related to missing data, future changes in climate monitoring network, and developing linkages to telemetered databases. The work associated with the second model revision was performed by Douglas Boyle at the Desert Research Institute (DRI) in Reno in cooperation with USGS staff in the Lakewood Colorado and Nevada District USGS offices.

Methodology:

To date, the following tasks associated with the second model revision have been completed:

1. Identify real-time climate stations for use in this study.
The USGS, DRI, WRCC, Washoe County, NWS, and the Federal Water Master were contacted in an effort to identify all existing real-time climate stations within the study area. Ten real-time climate stations (NWS COOP and NRCS SNOT stations) were identified within or near the study area. Several other stations were identified that may have real-time values of precipitation and/or temperature in the near future.

2. Identify and evaluate different sources of data for each real-time climate station.
The climate data for each real-time station identified in Task 1 was available from more than one source (e.g. WRCC, NRCS, NWS, NCDC, etc.). To simplify real-time acquisition of the data and to provide consistent quality control on the information, the Western Regional Climate Center (WRCC) was selected as the data source for each real-time climate station. Steve Markstrom (USGS Lakewood) modified a data grabber to hit

the WRCC web pages (behind the DRI firewall) and download daily values of precipitation and minimum and maximum temperature. The data grabber also updates the MMS data file.

3. ***Apply the XYZ-PRMS model to the TCP study area.***
XYZ-PRMS models were built and run within MMS for the same subbasins modeled in the TCP with the exception of Hunter Creek (#16) and Dog Creek (#15), which are downstream from Farad. The Nevada District USGS office provided the XYZ-PRMS parameter file generated by the GIS Weasel for this modeling effort. These parameters were based on the final parameter file from the TCP and considered the "default" values for this study. The XYZ lapse rates were determined and multiple linear regression (MLR) relationships between climate variables and HRU's were developed based on the XYZ-PRMS methodology developed by L. Hay. A considerable amount of effort was required to successfully port the source code from the USGS computers in Lakewood Colorado to computers at DRI. The results of this effort were presented at the WaRSMP meeting at DRI in April 2002.

4. Evaluate the performance of the model.
Based on preliminary evaluation of the model by A. Jeton and D. Boyle after the completion of Task 3, it was decided that some aspects of the XYZ approach may not be suitable for this study. Specifically, the lack of a good (long) historical record of daily minimum and maximum temperatures at high elevations appears to be introducing a significant amount of bias in the temperature MLRs. As a result, A. Jeton and D. Boyle plan to test the model performance without the temperature MLRs using several measures of fit to the observed hydrographs. The results of this analysis are expected to be completed in the middle of July 2002. Based on these results, the final modifications to the MMS models will be made and the project will be completed.

Improving Streamflow Forecasts on the Upper Rio Grande

Basic Information

Title:	Improving Streamflow Forecasts on the Upper Rio Grande
Project Number:	2001NV8B
Start Date:	8/20/2001
End Date:	8/19/2002
Funding Source:	Supplemental
Congressional District:	Nevada 02
Research Category:	Climate and Hydrologic Processes
Focus Category:	Surface Water, Management and Planning, Models
Descriptors:	modeling, surface water
Principal Investigators:	Douglas Boyle

Publication

1. Boyle, D.P., R. Viger, S. Markstrom, L.E. Hay, J.R. McConnell, G. Leavesley, and T. Bardsley "Application of a distributed, physically based, hydrologic model to improve streamflow forecasts in the headwaters of the Rio Grande", Presented at 2001 Spring Meeting of the American Geophysical Union, Boston, MA, 29 May - 2 June, 2001
2. Gorham, T.A., D.P. Boyle, J. R. McConnell, S. Markstrom, R. Viger, and G. Leavesley, "Application of a distributed, physically based, hydrologic model to improve streamflow forecasts in the Upper Rio Grande Basin." Presented at the 2001 Fall Meeting of the American Geophysical Union, San Francisco, CA, 10-14 December, 2001.

Problems and Research Objectives:

Six federal agencies - the U.S. Bureau of Reclamation (USBR), U.S. Fish and Wildlife Service, U.S. Geological Survey (USGS), Bureau of Indian Affairs, the International Boundary and Water Commission (U.S. Section), and the U.S. Army Corps of Engineers - the cities of Albuquerque and Santa Fe, Rio Grande Restoration, Sandia and Los Alamos National Laboratories have recognized the need for a unified water operations model for the entire Upper Rio Grande Basin and, in 1996, entered into a Memorandum of Understanding (MOU) to develop such a tool to assist water managers. The interest of this cooperative effort is to develop a numerical computer model capable of simulating water storage and delivery operations in the Rio Grande from its headwaters in Colorado to below Caballo Dam in New Mexico and for flood control modeling from Caballo Dam to Fort Quitman, Texas. The Upper Rio Grande model (URGWOM) will be used in flood control operations, water accounting, and evaluating water operations alternatives.
In the Watershed and River Systems Management Program (WaRSMP) technical meeting in Denver CO (February 21-22, 2001), members of the USGS and the USBR expressed the need for both short and long term streamflow forecasts at 11 points (nodes) of the URGWOM model of the Rio Grande and its tributaries above Albuquerque, New Mexico. In this work, DRI proposed to develop real-time forecasting ability at the following 7 of the 11 nodes of the Rio Grande using the USGS MMS-PRMS model. In January 2002, the USGS requested that DRI include the remaining 4 nodes of the original 11 and an additional 11 nodes (total of 22 nodes).

Methodology:

To date, the following tasks associated with the project have been completed:

Delineation, characterization, and parameterization of study watersheds.
The USGS provided DRI with an ArcInfo data bin containing 100 m elevation grid and standard ancillary data set (forest, land cover, and soils ArcInfo work spaces) for each study watershed. The information within the data bin was used to delineate and characterize surfaces (e.g., flow direction, flow accumulation, slope aspect, etc.) and spatial features (e.g., basins, streams, flow planes, modeling response units (MRUs)) for each study watershed using the USGS GIS Weasel software. Initially, each study watershed was subdivided into MRU's ranging in size from 100 km^2 to 150 km^2 using the GIS Weasel software.

Develop hydro-climatic database of real-time climate stations for use in each study watershed.
This task require the identification of all real-time climate stations within or near each study watershed. The climate data for each real-time station, however, was available from more than one source (e.g. WRCC, NRCS, NWS, NCDC, CDSS, etc.). As a result, for each real-time climate station, each data source was evaluated in terms of issues relevant to forecasting such as quality control procedures, reporting frequency, and accessibility. The URGWOM group developed the hydro-climatic database to store

historic climate variables (e.g., precipitation, min and max temperature, etc.) for each climate station. The database was used in the applications of the XYZ-PRMS model to each of the study area watersheds as described in task 3 below.

Apply the XYZ-PRMS model to each study watershed

XYZ-PRMS models were built and run within MMS for each of the 22 study watersheds. Note that the effects of reservoirs less than 5,000 acre-feet were not included in the simulation of the watershed behavior and the determination of naturalized flows for any of the study watersheds. The XYZ-PRMS parameter files were generated by the GIS Weasel and used for this modeling effort. The initial parameters were based on the final parameter files from previous studies on the watershed above the Rio Grande at the Del Norte discharge station. The XYZ lapse rates were determined and multiple linear regression (MLR) relationships between climate variables and HRU's were developed based on the XYZ-PRMS methodology developed by Dr. Lauren Hay. It should be noted that the XYZ-PRMS methodology is primarily available as a research tool and is not well documented. As a result, frequent written and oral communication between DRI staff (Douglas Boyle) and USGS staff (Lauren Hay, Steve Markstrom, and Roland Viger) were required to apply the method as originally intended by Dr. Hay.

Evaluate the performance of the model

After completion of Task 3, the performance of the model was assessed in terms of several measures (objective and subjective) of its ability to simulate streamflow, precipitation, and evaporation as compared with observed hydro-climate information within or near each of the study watersheds. Based on these measures, the values of selected model parameters were modified to optimize the performance of the model on each of the study watersheds.

Extended Streamflow Prediction (ESP)

Upon completion of tasks 1-4 above, the modified version of the U.S. Weather Service's Extended Streamflow Prediction (ESP) program was activated within the MMS framework for each study watershed. This work was done by Steve Markstrom within the OUI framework.

Information Transfer Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	1	0	0	0	1
Masters	4	3	0	1	8
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	0	0	0	0	0

Notable Awards and Achievements

Publications from Prior Projects

None