Water Resources Center, Desert Research Institute

Annual Technical Report

FY 1999

Introduction

Research Program

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Salinity Management in Western Wetlands:colon;colon; Effects of Irrigated Agriculture
Project Number	C-02
Start Date	09/01/1997
End Date	08/31/2000
Research Category	Biological Sciences
Focus Category #1	Wetlands
Focus Category #2	None
Focus Category #3	None
Lead Institution	Desert Research Institute

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Lewis W. Oring	Professor	Desert Research Institute	01
Kristina Hannam	Post Doctoral Student	Division of Hydrologic Sciences, Desert Research Institute	02
Susan Haig	Associate Professor	Oregon State University	03

Problem and Research Objectives

Methodology

Primary laboratory methodology involves incubating wild captured eggs in carefully controlled incubators, rearing resulting chicks in controlled saline environments representing fresh, brackish, saline and hypersaline conditions, and then measuring behavioral and morphological features of chicks reared in the various environments. Primary field methodology involves noting waterbird use of differing aquatic environments relative to salinity, and comparing known-age chicks in the wild with those reared in captivity.

Principal Findings and Significance

In our second year of the grant (1999) we focused primarily on laboratory studies that were aimed at elucidating the effects of saline and hypersaline rearing conditions on the growth, behavior and physiological stress of American Avocet chicks. Our preliminary results indicate that American Avocet chicks are stressed by hypersaline rearing environments when there is no access to freshwater. Growth, behavior and physiology of hypersaline-raised chicks all indicate that hypersaline rearing conditions result in a negative impacts on chicks that may lead to death. If our studies continue to support these findings, water resource managers who wish to promote shorebird reproductive success will have to ensure birds at hypersaline wetlands have access to freshwater resources during the breeding season. Laboratory Findings: We examined effects of environments ranging from freshwater to hypersaline on growth, behavior and physiological stress, as measured by circulating corticosterone levels, in American avocet chicks raised in the laboratory during days 0 (hatching) to 3. Preliminary results from the 1999 research season indicate that American Avocet chicks raised in hypersaline environments without access to freshwater showed physiological stress resulting from a water-balance problem. By the end of three days of life, chicks in hypersaline environments tended to lose mass compared to chicks from lower salinity environments. Although this trend was not significant, it was consistent throughout our trials (Kruskal-Wallis $p = 0.24$). In addition, skeletal growth was not stunted by high salinities indicating that hypersaline-raised chicks weighed less for their size and were in poorer condition than chicks in other treatments. Finally, chicks in hypersaline ponds tended to have higher hematocrit levels, which may indicate they were suffering from dehydration (Kruskal-Wallis $p = 0.08$). Behavioral observations too indicated hypersaline-raised chicks were stressed compared to chicks in lower salinity treatments. Two day-old avocets already exhibited behaviors common in stressed animals. Hypersaline-raised chicks spent significantly more time running (Kruskal-Wallis $p = 0.01$), and significantly less time feeding (Kruskal-Wallis $p = 0.03$) than chicks in other treatments. In addition, there was a trend for chicks from hypersaline ponds to spend a larger proportion of time vocalizing (Kruskal-Wallis $p = 0.15$) than chicks from other treatments. All of these behaviors (increased locomotion, increased vocalization, decreased feeding) are commonly found in stressed animals. Finally, we examined circulating corticosterone levels as a measure of physiological stress in chicks raised under different salinity regimes. Corticosterone levels are commonly used as an indication of physiological stress and are a widely accepted measure of stress resulting from environmental conditions. This is the first study to examine salinity as a stressor that might influence corticosterone levels. Preliminary results indicate that corticosterone levels increased with increasing salinity (Kruskal-Wallis $p = 0.19$). We are continuing these laboratory experiments during the final research season in order to increase sample sizes and enhance results. Field Findings: In collaboration with Dr. Xinhai Li, we have developed a spatially explicit population model (SEPM) exploring the effects of water quality and quantity on waterbird distribution in the Great Basin. This model was presented at the annual meeting of the Conservation Biology Society and is under continuing development prior to publication.

Descriptors

Wetlands, salinity, conservation, shorebirds, water quality standards, water reuse, conflict management, resource planning, wildlife management

Articles in Refereed Scientific Journals

J. Plissner, S. M. Haig and L. W. Oring. 1999. Within- and between-year dispersal of American Avocets among multiple western Great Basin wetlands. Wils. Bulletin, 111:314-320. J. Plissner, S. M. Haig and L. W. Oring. 2000. Postbreeding movements of American Avocets and implications for wetland connectivity in the western Great Basin. Auk, 117:290-298. J. Plissner, L. W. Oring and S. M. Haig. 2000. Space use of Killdeer at a Great Basin breeding area. J. Wildl. Mgmt., 64:421-429.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	A Multi-Level Approach to Modeling Ground- and Surface Water Exchange in Agriculturally-Dominated Settings
Project Number	C-03
Start Date	09/01/1998
End Date	08/31/2001
Research Category	Water Quality
Focus Category #1	Nitrate Contamination
Focus Category #2	Geomorpological and Geochemical Processes
Focus Category #3	Groundwater
Lead Institution	Division of Hydrologic Sciences, Desert Research Institute

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Alan McKay	Research Associate	Division of Hydrologic Sciences, Desert Research Institute	01

Problem and Research Objectives

Flood irrigation of field crops is believed to be linked to non-point source groundwater solute returns in the lower Truckee River Basin. The objectives of the research are to characterize the source of solutes to the lower Truckee River, and determine the potential benefits in converting land and water use from agriculture to urban and municipal uses. Additional objectives include characterizing the impacts of groundwater nutrient inputs on attached benthic algal communities in the river.

Methodology

Field studies, including drilling and coring activities, are being integrated with numerical groundwater flow & transport and surface water quality models.

Principal Findings and Significance

To-date, approximately 20 shallow and deep wells have been installed in the study area. These wells are providing valuable information on the nature and distribution of subsurface salts in the study area. Additionally, the wells are serving as monitoring wells for hydrologic and geochemical data collection. A computer geologic model of the study area has been completed. The numerical groundwater flow model has been developed; to-date, flow model boundaries and hydraulic parameters have been assign. The model has been calibrated to transient conditions. Bench-scale experiments addressing periphyton growth under varying groundwater fluxes have begun. The metabolism chambers appear to be working well, and will be transferred to selected field sites later this summer. Bio-mass monitoring has begun as well.

Descriptors

Surface-Groundwater Relationships, Subsurface Drainage, Water Quality Modeling, Groundwater Modeling, Irrigation, Algae

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Investigation of Mercury in Water, Sediment and Aquatic Biota Tissue from Seven Tributary Streams of the East Fork of the Carson River, California, 1999
Project Number	B-02
Start Date	03/01/1999
End Date	02/28/2000
Research Category	Water Quality
Focus Category #1	Hydrogeochemistry
Focus Category #2	None
Focus Category #3	None
Lead Institution	University of Nevada, Reno

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Mae Sexauer Gustin	Professor	University of Nevada, Reno	01
Peter Fischer	Student	University of Nevada, Reno	02

Problem and Research Objectives

This study investigated mercury in water, sediments, and whole aquatic insects from tributaries of the East Fork of the Carson River Watershed. Mercury concentrations measured in the Carson River upstream from the known contamination associated with the Carson River Superfund site range from 9 to 25 ng/L. These concentrations are above what is considered ambient background (1-3 ng/L) indicating there is an undefined mercury source(s) in the Upper Carson Watershed. Major tributaries that could be contributing to this increase in Hg into the East Fork of the Carson include Leviathan, Poison, Barney Riley, Bryant, Cottonwood and Mountaineer Creeks. The Leviathan/Bryant Creek tributary is known to be highly impacted by Acid Mine Drainage from Leviathan Mine. The entire Upper Carson watershed contains numerous small historic gold, silver and mercury mines. Preliminary measurement of mercury in waters of the some of the above mentioned creeks indicated that mercury concentrations in these waters are in the 10's to possibly 100's ng/L. In addition, analytical study of bottom sediment and crayfish tissue as part of the National Water Quality Assessment program demonstrated that concentrations of mercury in these media increased by 100 percent (or more) in the

East Fork of the Carson between the Markleville and Gardnerville Gage. Bryant Creek, which drains the majority of the streams in the study area and Cottonwood Creek enter the East Fork of the Carson between these two gage stations. The major objectives of this project were: 1. Determine mercury concentrations at sampling points, noted in Figure 1, during summer baseflow conditions, and in the fall and early winter when flows should be lowest. This data will help to assess the sources of mercury being transported to the East Fork of the Carson River. 2. Assess the form of the mercury being transported by determining if the mercury is dissolved or particulate bound, and at a few sites whether methyl mercury is present. 3. Measure total mercury concentrations in sediments at all water sampling sites as well as methyl mercury in sediments at select sites. 4. Collect and analyze for total mercury aquatic insects from all sites that support an invertebrate population. The hypothesis being tested was that naturally enriched substrate in the watershed of the East Fork of the Upper Carson River is the cause of elevated mercury concentrations reported for water and organisms in the Upper Carson River.

Methodology

Both filtered and non-filtered water samples and sieved sediment samples were collected using clean handling protocols and analyzed at UNR facilities. Samples collected for methyl mercury analyses were collected using standard clean handling protocols and shipped to Frontier Geosciences on dry ice. An aquatic insect species, Stonefly, that was common to all sites was collected and analyzed as single and composite samples after freeze drying. At selective sites, methyl mercury in whole insects was determined by Frontier Geosciences. Insects were starved prior to digestion to allow purging of mercury that may be contained in the gut. Total mercury of filtered and unfiltered water samples, as well as insect tissue, following appropriate digestion, were determined by dual amalgamation cold vapor atomic fluorescence spectrometry at the UNR biogeochemistry laboratory. Sediment samples were digested in aqua regia and analyzed by cold vapor atomic absorption spectroscopy and analyzed by the Nevada Bureau of Mines and Geology.

Principal Findings and Significance

In general, mercury concentrations in waters of tributaries of the East Fork of the Upper Carson River were similar to what are considered background concentrations for December (2- 4 ng/L) and slightly elevated in June (2 -10 ng/L) and more so in September (8-15 ng/L) . This trend may be explained by snowmelt dominating the streamflow in December and groundwater becoming important in June and then predominating in September. Mercury concentrations in sediments of the tributaries were not enriched in mercury above background values, and methyl mercury concentrations in sediments were highest for Mountaineer > Poison> Leviathan Creeks. The Cottonwood Creek watershed has consistently and significantly higher mercury and methyl mercury concentrations in insect tissue than any of the other tributaries studied. This tributary did not have anomalous mercury concentrations in water and sediment. One explanation for the higher mercury concentrations in the insects in Cottonwood Creek may be that they were frequenting groundwater seeps that had high mercury concentrations relative to surface waters. In general mercury concentrations in waters of the tributaries of the East Fork of the Upper Carson River exhibited a seasonal trend. This has significant implications for determining natural background levels of aquatic contaminants. This highly significant difference in insect mercury concentration at Cottonwood Creek also indicates that small subsets of insects from discrete areas may be unrepresentative of the system whole. Despite the slightly elevated mercury concentrations in waters in the fall the stream sediments showed no indication of mercury enrichments. Data also indicates that there may be a small contribution of mercury to the tributaries of the East Fork of the Upper Carson River from natural sources.

Descriptors

Contaminant transport, mining, Indian water issues, mercury, methyl mercury, bioaccumulation, aquatic insects, Stoneflys (Order Plecoptera, Family Perlidae, Genus Doroneuria sp.), and East Fork of the Carson River

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Fischer, Peter and Mae Sexauer Gustin, 2000, Mercury in Water, Sediment and Aquatic Biota from Seven Tributary Streams of the Upper East Fork of the Upper Carson River, California, Division of Hydrologic Sciences, Desert Research Institute, Reno, NV, 17 p.

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Determination and Source Apportionment of Polycyclic Aromatic Hydrocarbons (PAHs) from Watercraft in Recreational Lakes in Northern Nevada and Eastern California
Project Number	B-04
Start Date	03/01/1999
End Date	02/28/2001
Research Category	Ground-water Flow and Transport
Focus Category #1	Water Quality
Focus Category #2	None
Focus Category #3	None
Lead Institution	Desert Research Institute

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Glenn C. Miller	Professor	University of Nevada, Reno	01
Cynthia Hoonhout	Post Doctoral Student	University of Nevada, Reno	02
Mary Miller	Research Associate	Division of Hydrologic Sciences, Desert Research Institute	03

Problem and Research Objectives

This project seeks to examine the emission of PAHs and gasoline hydrocarbons from a variety of watercraft into high elevation oligotrophic lakes in Nevada and eastern California. We will compare a variety of 2-cycle and 4-cycle engines and characterize concentrations of various PAHs and gasoline hydrocarbons in water following passage of these watercraft. This will include the older carbureted two-cycle engines, the new direct fuel-injected two-stroke engines and four-stroke engines. We will also determine ambient concentrations of PAHs in areas of recreational lakes that have high and low watercraft usage. This project will be conducted as an extension to an ongoing project on the emissions of volatile hydrocarbons from watercraft, which was funded by the Lahontan Regional Water Quality Control Board. Tests were conducted during the summer of 1999 at the California Air Resources Board Laboratory (CARB) in El Monte California on four different engines to examine the release of polycyclic aromatic hydrocarbons (PAH) and volatiles from each engine type, including 2-stroke carbureted 90 hp, 2-stroke direct fuel injected 90 hp, 4-stroke 90 hp and a 2- stroke carbureted 110 hp PWC. In addition, a limited number of samples were collected at Lake Tahoe to determine if PAH concentrations were observed in a variety of locations at Lake Tahoe and whether volatile concentrations at two locations at Lake Tahoe had been lowered following regulation of carbureted 2-stoke engines. The results presented below are preliminary findings. The data have not been completely analyzed or subjected to thorough quality assurance review. However, the initial trends are indicative of the relative magnitude of different engine emissions.

Methodology

I. Polycyclic Aromatic Hydrocarbons: Each of the four engines discussed above was placed in a 2600 gallon tank of water at the CARB facility and operated with a duty cycle of 10 minutes idle, 10 minutes of operation and an additional 20 minutes of operation. Samples were collected prior to engine operation, and after each operational period. Following each engine test, the water was drained, the tank cleaned and refilled with fresh water. The sampling consisted of passage of 800-1800 mL of water through a solid phase sampling C18 disk which is designed to remove non-polar organics (i.e. PAH) from the sample. The disks were either extracted at the CARB facility or brought back to UNR for extraction. Additional samples in 2L bottles were also collected and taken back to UNR for extraction. Each of the samples was analyzed by HPLC using a fluorescence detector for quantitation. Instrumental issues initially caused a series of problems in regard to detection limits, followed by non-reproducibility of retention times during a 24 hour run. The latter problem became critical when it was found that the chromatographic profiles consisted of a very large number of closely-eluting peaks. Thus, compound identification by retention time was possible only if the chromatographic conditions were stabilized.

Once this was accomplished, the samples were analyzed. II. Volatiles During the same sampling period at CARB, volatiles samples were collected in order to compare the results of these volatile emissions to data obtained during 1998 at Lake Tahoe. This "tank test" has the advantage of substantially greater control of variables, although it also continuously purges the water and potentially removes volatiles at the same time it is adding them to the water. Samples were analyzed by standard gc-ms methods at the Desert Research Laboratory using the same techniques previously described for the work at Lake Tahoe. Because these tests were in a tank, the concentrations observed by much higher than at Lake Tahoe. Table 3 presents a summary of the results. Each engine was tested twice, and the sampling times are the same as indicated above.

Principal Findings and Significance

I. Polycyclic Aromatic Hydrocarbons:

The data have revealed the complexity of the compound profiles. Several of the peaks eluting in the profiles have not yet been identified, due to the lack of standards. Further analysis by gc-ms will decrease the number of unidentified components. Each peak in each HPLC chromatogram was compared to profiles in similar standard chromatograms in order to ensure that the correct peak was being quantitated. Each of the 2-16 compounds for which standards were available was quantitated by external standards.

Each engine was tested twice, except for the personal watercraft (PWC), which was only tested once, and the 90 hp direct fuel injected engine, which was erroneously operated at 20 % throttle during the first run compared to the other 90 hp engines, which were operated at 60% throttle. During the second run, the direct fuel injected engine was operated at 60% throttle. The data from that run have not been completely analyzed.

A large number of compounds were detected for each engine. We have provided data for fluoranthene and acenaphthylene. The compounds which elute later in the chromatograms are the largest compounds and are generally the most phototoxic. Fluoranthene (Table 1) is of particularly interest and comparisons of the compound in each a sample provide a rough indication of the relative emission of each engine. As can be observed, each engine releases fluoranthene, with the two-stroke engines released greater amounts. Acenaphthylene is an additional compound which exhibits phototoxicity. Results for this compound are presented in table 2. The results are consistent with the fluoranthene data; the carbureted two-stroke engines release substantially greater amount of acenapthylene than the 4-stroke engine.

Samples were also collected and analyzed at Lake Tahoe. While these data are still preliminary, we observed higher concentrations of PAH at high use marina areas and at a high use area in Emerald Bay. No identifiable PAH were observed in the center of Lake Tahoe, which is consistent with the relative use of these different areas. Thus, PAH does appear to be associated with watercraft usage, although we have not attempted to associate PAH concentrations with any engine type at Lake Tahoe.

Table 1. Fluoranthene concentrations (ng/L) in water following operation at a variety of engine speeds		
	10 minute operation	30 minute operation
90 hp carbureted	4100	9000
90 hp direct injected*	690	870
90 hp four-stroke	160	220
110 hp 2-stroke carbureted PWC	2000	8000
*This engine was operated at 20% full throttle for the operation, instead of 60% throttle used in the other engines. Thus, this sample is not		

*This engine was operated at 20% full throttle for the operation, instead of 60% throttle used in the other engines. Thus, this sample is not directly comparable to the other samples. A second run, (data not yet analyzed) was operated at 60% throttle.

Table 2. Acenapthylene concentrations (ng/L) in water following operation at a variety of engine speeds		
	10 minute operation	30 minute operation
90 hp carbureted	23,000	34,000
90 hp direct injected*	770	3,300
90 hp four-stroke	n.d.	210
110 hp 2-stroke carbureted PWC	25,000	67,000
*This engine was operated at 20% full throttle for the operation, instead of 60% throttle used in the other engines. Thus, this sample is not directly comparable to the other samples. A second run, (data not yet analyzed) was operated at 60% throttle.		

Discussion:: These preliminary results are consistent with previous suggestions that two-stroke engines release larger amounts of PAH than do the 4-stroke engines. Additional data are required to make any assessment on the direct-injected 2-stroke engine, since the data analyzed to date was not obtained under identical conditions to the other engines. Two caveats are important to mention for these data also. First, the assignments of structure for the compounds are based on HPLC retention time only, which is not considered a confirmation. Thus, these data are tentative at present. Second, only one engine of each type was used, and we cannot make any judgements of different engines or manufacturers.

II. Volatiles

As can be observed, the concentrations (expressed in μ g/L, or ppb) range from a low of <1 ppb to over 5000 ppb, depending on the engine type. If we used the 10 minute operation values as a comparison for each engine type, we can observe that the 4-stroke engine again released the least amount of volatiles, and the direct fuel inject 2-stroke engines release the second lowest amount of gasoline. The carbureted 90hp and 110 hp release the greatest amounts. These results are similar to what was observed at Lake Tahoe during 1998.

Table 3. Concentrations of toluene and MTBE (μ g/L) in water following 10 minutes of operation of each engine at 60% throttle.		
	toulene	MTBE
4-stroke 90 hp	74 54	37 34
2-stroke D.I. 90 hp	359	535
2-stroke carb 90 hp	672	2700

	723	2390
110 hp 2-stroke carbureted PWC	727	4620

Descriptors

Polycyclic aromatic hydrocarbons, two-cycle engines, four-cycle engines, gasoline, surface water quality

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Development of a Prototype System Dynamics Based Decision Support System to Aid in Integrated Watershed Planning for the Lake Tahoe Watershed
Project Number	B-03
Start Date	03/01/1999
End Date	02/28/2001
Research Category	Water Quality
Focus Category #1	Management and Planning
Focus Category #2	None
Focus Category #3	None
Lead Institution	Division of Hydrologic Sciences, Desert Research Institute

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
John C. Tracy	Professor	Division of Hydrologic Sciences, Desert Research Institute	01

Problem and Research Objectives

During the last half of the twentieth century the management of the United State's western watersheds has become an increasingly complex task. Initially, the development and operation of the watersheds were dictated by each basin's hydrologic characteristics and the economic benefits produced through hydropower generation, enhanced water availability and flood protection. Thus, the primary method of managing western watersheds was through the development of operating criteria that were based on maximizing the short term economic benefits of water operations within the basin. However, in more recent times, the long term economic and environmental consequences of operating watersheds in this fashion have come to light. Altered stream flows have had significant impacts on the morphology of stream beds, resulting in alterations in channel shapes and the sediment loads entering lakes and reservoirs. These changes have lead to modifications in the ecology of many western watersheds. This in turn has resulted in intangible economic losses, such as endangering the sustainability of some plant and animal species; to more tangible economic losses, such as the degradation of lake clarity or increase in fire risk within the Lake Tahoe Watershed. These effects have demonstrated that the operation of controlled watersheds is an extremely complex issue, and that more advanced modeling and analysis tools are required by personnel charged with the planning and management of water resources within these watersheds. For most larger western watersheds the decision making forum for watershed policies is somewhat centralized in large federal institutions, such as the Bureau of Reclamation, the Army Corps of Engineers, or the U.S. Forest Service. The larger federal agencies typically have the resources to develop decision support systems that employ relatively sophisticated models. For example, the Bureau of Reclamation is currently funding the development of the Upper Snake River decision support system for use in aiding integrated watershed management approaches for the Upper Snake River Basin. The U.S. Army Corps of Engineers is beginning a collaborative effort with the Bureau of Reclamation to attempt to develop an integrated watershed management plan for the Sacramento River Basin. While at the current time no formal plans for the development of a decision support system have been stated, it is anticipated that a rather sophisticated modeling effort will be undertaken. The U.S. Forest Service is currently funding a project that is performing a watershed assessment for the Lake Tahoe Watershed. There are a variety of products that will be produced from this assessment, with one of the products being models to predict the state of hydrologic, water quality, forest health, biodiversity and socio-economic processes within the watershed. These agencies will receive a significant amount of input from stakeholders in the watershed of interest when water resources plans are being developed. Thus, the stakeholders have some input to the decision making process, but could not presently be considered decision makers in the watershed planning process. However, recently, there has been a movement towards devolving the centralized control of western watersheds. Thus, the decision makers of the near future will change, with many of the current stakeholders within the watersheds becoming these decision makers. This is especially true in the Lake Tahoe watershed where the U.S. Forest Service is just one of a multitude of federal and regional agencies with decision making authority within the watershed. This situation is recognized in the Forest Services Watershed Assessment project, with one of the goals of the project being to develop modeling tools that can be used by all decision making entities within the watershed. However, not all entities will be able to employ large scientific staffs that are required to maintain and operate the process models being developed as part of the Watershed Assessment. Rather, these smaller agencies will have to rely on their intuitive understanding of the watershed and how predictions of watershed behavior will affect their decision making process. Thus, it is likely that simpler models of watershed processes will be preferred by the majority of decision making entities within the watershed. Thus, it is the purpose of this project to aid in the development of a land use Decision Support System for the Tahoe Regional Planning Agency in conjunction with Dr. R. Bernknopf of the USGS Mapping Division in Menlo Park, CA. Dr. Bernknopf has previously developed an economic decision making model for aiding in land development planning in the Upper Truckee watershed in the Lake Tahoe basin. This model links the environmental attributes of the watershed to individual parcel property values. The objective the model is to maximize the property values of parcels within the watershed subject to meeting water quality standards associated with the designated beneficial uses of water bodies within the watershed. Since this project proposes to develop a prototype decision support system, only the total suspended sediment water quality standard was chosen for use as a constraint in the land use decision making model. Total suspended sediment is a good indicator of the condition of many of the other water quality parameters in the Upper Truckee River, and a relatively good record of total suspended sediment data exists near the outlet of the Upper Truckee River. Thus, the objective of this project is develop a model that describes the effect that land use changes have on total suspended sediment loads within the Upper Truckee River. The model formulation must be able to be linked to attributes of individual parcels within the watershed that relate to the parcel's valuation. In this fashion, an explicit link between the value of a parcel (either developed or preserved) and the environmental consequences of developing that parcel is created. This in turn allows for watershed scale land planning decisions that can be made with an understanding of the tradeoffs that exist between environmental and economic concerns.

Methodology

The approach that is used in this project to develop a model that simulates the yearly sediment load in the Upper Truckee River is to relate the runoff and sediment yield from each parcel in the watershed to the natural and land development characteristics of the parcel. In this fashion, the land development system that is in place within the Lake Tahoe basin, referred to as the IPES program, can be directly related to one of the environmental characteristics used to assess the health of the basin, this being the yearly sediment load to Lake Tahoe from the Upper Truckee Watershed. Following this approach, the spatial distribution of sediment yield for each water year is computed on a parcel by parcel basis. A variety of models have been developed to describe the sediment yield from a watershed. Some of these models include the USLE (Wischmeier and Smith 1978), the MUSLE (Williams 1975), the MUST and MUSS (Mitchell et al. 1997) and MUSI (Mitchell et al. 1997). All of these models can be expressed in a general form describing the unit sediment loss for a given area as a function of the flow off the parcel and landform characteristics of the parcel. These landform characteristics are the erodibility of the soil, the land slopes and type of disturbance on each parcel. The Tahoe Regional Planning Agency (TRPA) has developed a system that quantifies these characteristics into a score that is related to the potential environmental degradation that could be caused by developing a parcel. This system is referred to as the Individual Parcel Evaluation System (IPES) and is used by TRPA to determine which parcels are developable within the watershed without causing adverse environmental consequences. The two most important elements of the IPES score that relate to the total suspended sediment load in the Upper Truckee river are the Runoff Potential (RP) and the Relative Erosion Hazard (REH). The RP score for a parcel can be directly translated into parameters that are used for an SCS runoff procedure ( ). The REH score is directly translatable into parameters that can be used in a generalized USLE model. Thus, the approach taken in this project is to develop runoff and erosion models for each parcel in the Upper Truckee watershed using SCS runoff and generalized USLE models. An 18 year record of stream flow and sediment load data is available at the outflow of the Upper Truckee River to Lake Tahoe, with the runoff and erosion models requiring the calibration of only two parameters each. The two runoff model parameters are a uniform yearly water loss parameter and a precipitation station index parameter. The two erosion model parameters are linear and power coefficients that relate the sediment load to runoff for each parcel.

Principal Findings and Significance

The yearly stream flow records at USGS Gage 10336610 were used to estimate the runoff model parameters related to the water loss throughout the basin and the precipitation index value. These parameters were estimated by minimizing the sum of errors squared between the simulated and measured total yearly flow for water year 1981 through 1998. The best estimates of these parameters resulted in a standard error of model prediction, 8,970 acre-ft, which is approximately 10 percent of the average annual flow for the Upper Truckee River. A comparison of the predicted and reported total yearly streamflows for USGS shows that the developed model does a reasonably good job of predicting the total yearly streamflow for the Upper Truckee watershed. The sediment loading parameters were estimated minimizing the sum of deviations squared between the reported and simulated yearly sediment loads at USGS Gage 10336610 on the Upper Truckee river in South Lake Tahoe. During the estimation exercise it was found that a fundamental change in the relationship between the sediment load and streamflow within the watershed occurred in the Upper Truckee watershed between the 1980s and the 1990s. Identification of this change is supported by the results of another study (Tracy 2000). Thus, to better represent the current sediment loss conditions in the watershed, the sediment load data for water years 1989 through 1998 were used to estimate the sediment loading parameters. The best estimate of these parameters resulted in the model having a standard error of sS = 873 tons/yr, which is approximately 20 percent of the average yearly sediment load in the Upper Truckee River. A comparison between the predicted and reported yearly sediment loads for the Upper Truckee watershed shows that the model does not predict the yearly sediment loads as well as it predicts the yearly streamflows. However, it does provide a reasonable prediction when considering the uncertainty associated with the reported yearly sediment load and the uncertainty associated with the parameters used to generate the relative erosion hazard factors throughout the watershed. The total suspended sediment loading model is currently being integrated with the property value models in the land use decision model developed by Dr. R. Bernknopf at the USGS in Menlo Park. A prototype of the land use decision model is nearly complete and will be presented to the Tahoe Regional Planning Agency in the near future. The significance of this prototype is that it will allow for an explicit evaluation of the tradeoffs that exist between increased environmental standards and the impacts these new standards will have on economic conditions within the watershed. Once this prototype has been fully developed it is anticipated that additional economic and environmental parameters will be included in the land use decision model to provide a more comprehensive assessment of the impacts of land use plans within a watershed. References: Mitchell, G., Griggs, R. H., Benson, V. and Williams, J. 1997 EPIC On-Line Documentation, http://www.brc.tamus.edu/epic/documentation/, 1997. Tracy, J. C. 2000. A Statistical Evaluation of the Effectiveness of the IPES Program in Relation to Suspended Sediment Loads in Lake Tahoe's Tributaries, Draft report submitted to TRPA, 31 pps., in review. U.S. Department of Agriculture, Soil Conservation Service. 1972. National Engineering Handbook, Hydrology Section 4, Chapters 4-1O. Williams, J.R. 1975. Sediment yield prediction with universal equation using runoff energy factor. U.S. Dept. Agric., Agric. Res. Serv., ARS-S-40. Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall erosion losses, a guide to conservation planning. U.S. Dept. Agric., Agric. Handbook No. 537.

Descriptors

Decision Models, Planning, Systems Engineering, Model Studies, Computers, Ecosystems

Articles in Refereed Scientific Journals

Book Chapters

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Water Resources Research Institute Reports

Conference Proceedings

Tracy, J. C., Bernknopf, R. A., Forney, W. and Hill, K. 2000. A prototype for understanding the effects of TMDL standards; Tying property values to sediment loads in the Lake Tahoe basin. To be published in the Proceedings of the Conference on Watershed Management and Operations Management 2000, June 21 through 24, 2000, Ft. Collins, CO.

Other Publications

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Estimation of Groundwater Recharge Using Environmental Tracers and Comparison of Results to Other Estimation
Project Number	B-01
Start Date	03/01/1999
End Date	02/28/2001
Research Category	Ground-water Flow and Transport
Focus Category #1	Groundwater
Focus Category #2	Water Quantity
Focus Category #3	None
Lead Institution	Division of Hydrologic Sciences, Desert Research Institute

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
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Problem and Research Objectives

Nevada and other areas of the desert southwest United States rely heavily on groundwater resources for municipal, domestic, and industrial needs. An accurate estimate of the available resource is essential to planning community growth and development. In Nevada, a state-wide reconnaissance assessment of water resources was undertaken during the 1960's and early 1970's (Shamberger, 1962 and 1991). Results continue to provide the basic information for planning and development decisions faced by resource managers. New assessment tools have often indicated that significantly more water is available in central Nevada (Nichols, 1994) and in southern Nevada (Russell and Minor, 1998) than previously believed. It is essential to develop more accurate estimates of groundwater recharge in order to make appropriate planning and development decisions. Specific objectives of this research include: 1. Estimation of groundwater recharge in Steptoe Valley, eastern Nevada, using environmental tracer enrichment methodologies. 2. Comparison of reconnaissance level estimates of recharge completed in 1967 (Eakin and others, 1967), discharge-based estimates recently prepared by the USGS (D. Maurer, personal communication, 1998), and estimates made using environmental tracer enrichment methodologies. 3. Validation of the environmental tracer enrichment methodology in additional areas of Nevada.

Methodology

The concentration of three environmental tracers (chloride, deuterium, and oxygen-18) in spring discharge is used to estimate groundwater recharge in Steptoe Valley, eastern Nevada. Steptoe Valley is chosen for the study because: 1) there appears to be little underflow entering or leaving the valley; 2) a large number of springs, exhibiting a wide range of elevation, location and catchment size, are available for sampling; 3) the USGS has recently used the discharge-based method to estimated recharge in the valley. The vertical and horizontal distribution of chloride in soil in arid and semi-arid areas has been shown to be related to the amount of local precipitation and recharge (Eriksson, 1969; Fouty, 1989; Lyles and Tyler, in preparation). In addition, Claassen and others (1986) have quantified recharge by comparison of the relative mass of chloride in spring water and precipitation. Recently, the chloride tracer method for estimating groundwater recharge has been applied at the Nevada Test Site in southern Nevada. In this application, an elevation-dependent mass balance analysis based on spring data was utilized to estimate recharge (Russell and Minor, 1998). Using a chloride input function developed for northeastern Nevada and chloride concentrations at springs of various elevations, chloride enrichment factors will be developed for each of the springs. The chloride enrichment factor is equivalent to the ratio of precipitation to groundwater recharge, thus, when precipitation is known recharge may be estimated. Chloride concentration associated with infiltrating precipitation will be determined by direct field measurement. Collectors, installed at selected springs, will contain silica sand which will retain the chloride when precipitation is evaporated. Chloride in groundwater water will be determined by analysis of spring discharge samples. These data will be extrapolated to estimate groundwater recharge in the

spring catchment area and Steptoe Valley using regional precipitation data available via the Prism Map. The temperature influence on stable isotopic ratios of a water mass may reflect elevation, climate, and latitude conditions at the time of the phase change. Recognition of these influences permits use of isotopic signatures for precipitation, well water, and local and regional spring discharge in delineation of groundwater recharge source areas (Hershey, 1989; Smith and others, 1992; Thomas and others, 1997; Pohlmann and others, 1998). Stable isotope data from the springs will be used to determine the climatic conditions under which the water entered the groundwater system. Comparison of the stable isotope signature in spring flow to that of modern precipitation will facilitate evaluation of the catchment area supplying the springs.
References: Claassen, H. C., M. M. Reddy, and D. R. Halm. 1986. Use of the chloride ion in determining hydrologic-basin water budgets, A 3-year case study in the San Juan, Mountains, Colorado, U.S.A. Journal of Hydrology, 85:49-71. Eakin, T. E., J. L. Hughes, and D. O. Moore. 1967. Water-Resources Appraisal of Steptoe Valley White Pine and Elko Counties, Nevada. Report 42, Water Resources-Reconnaissance Series, Department of Conservation and Natural Resources, Carson City, Nevada. Eriksson, E., and V. Khunakasem. 1969. Chloride concentrations in groundwater, recharge rate and rate of deposition of chloride in the Israel Coastal Plain. Journal of Hydrology, 7:178-197. Fouty, S. C. 1989. Chloride mass-balance as a method for determining long-term groundwater recharge rates and geomorphic-surface stability in arid and semi-arid regions, Whiskey Flat and Beatty, Nevada. Unpublished MS Thesis, University of Arizona, Tucson, Arizona. Hershey, R. L. 1989. Hydrogeology and hydrogeochemistry of the Spring Mountains, Clark County, Nevada. Unpublished MS Thesis, University of Nevada, Las Vegas, Nevada. Lyles, B. F., and S. W. Tyler. 2000. Preliminary recharge estimates based on the chloride mass-balance from perched groundwater at the Nevada Test Site. Water Resources Publication 45117, Desert Research Institute, Las Vegas and Reno, Nevada (in preparation). Nichols, W. D. 1994. Ground-water discharge by phreatophyte shrubs in the Great Basin as related to depth to ground-water. Water Resources Research, 30(12):3265-3274. Pohlmann, K. F., D. J. Campagna, J. B. Chapman, and S. Earman. 1998. Investigation of the origin of springs in the Lake Mead National Recreation Area. Water Resources Center, Desert Research Institute, Publication #41161, 51p. Russell, C. E., and T. Minor. 1998. Reconnaissance estimate of recharge based upon an elevation-dependent chloride-enrichment method and comparison to a previous reconnaissance method for estimating recharge. Desert Research Institute, Publication #45164. Shamberger, H. A. 1962. A proposed ten-year cooperative water resources program between the State of Nevada and U. S. Geological Survey. Water Resources Information Series Report 4, Nevada Department of Conservation and Natural Resources, 18 p. Shamberger, H. A. 1991. Evolution of Nevada's water laws, as related to the development and evaluation of the State's water resources, from 1866 to about 1960. Water-Resources Bulletin 46, Nevada Division of Water Resources, 100 p. Smith, G. I., I. Friedman, J. D. Gleason, and A. Warden. 1992. Stable isotope composition of waters in southeastern California: part 2, Groundwaters and their relation to modern precipitation. Journal of Geophysical Research, 97(D5):5813-5823. Thomas, J. M., A. H. Welch, and M. D. Dettinger. 1997. Biochemistry and isotope hydrology of representative aquifers in the Great Basin region of Nevada, Utah, and adjacent states. Professional Paper 1409-C, U. S. Geological Survey.

Principal Findings and Significance

Twenty-five springs in Steptoe Valley were selected for sampling (Table 1). Criteria used in the spring selection included: elevation, aspect, and geology. Elevation and surficial geologic environment were generally determined at the spring orifice. In instances were the orifice occurred at a geologic contact the geology of the presumed catchment area was determined. Aspect was characterized as the principal compass direction toward which the spring catchment area faced. Each characteristic was determined from 1:100,000 scale topographic maps.

The lowest point in Steptoe Valley, approximately 1780 m, is centrally located near the north end of valley. The highest points are North Schell Peak, at 3622 m, in the Schell Creek Range on the east side of the valley and Ward Mountain, at 3293 m, in the Eagan Range on the west side of the valley. Elevation of selected springs ranges from 2025 to 2850 m.

Table 1. Steptoe Valley Springs Selected for Sampling

Name	Location*	Elevation	Aspect	Geology+
Rosebud	13N 65E 10ba	2300	NW	Pzc
South Taylor	14N 65E 15ba	2450	SW	Pzc
Summit	15N 65E 22cb	2600	SW	Pzc
North	15N 65E 12bc	2700	W	Pzc
Sage Hen	16N 64E 12ab	2650	NE	Pzc
Steptoe	16N 64E 3cd	2450	W	Pzc
North Fork Berry Creek	17N 65E 12cd	2850	W	Pzc
Camp	24N 65E 11ab	2750	NE	Pzc
Moonshine	28N 63E 34db	2150	E	Pzc
Cheat Grass	26N 63E 3cb	2150	E	Pzc
Pipe	21N 62E 11bd	2650	E	Pzc
Meadow	21N 62E 14ca	2550	W	Pzc
Riepe	16N 62E 36dc	2350	NE	Pzc
Log Cabin	25N 63E 32bd	2400	SE	Pzc
Indian Creek	21N 65E 32aa	2650	W	Pzc
Timber Creek	18N 65E 25ab	2850	W	CpCc
Axehandle	17N 64E 11bd	2375	E	CpCc
Kid	18N 63E 14cb	2150	E	CpCC
Goat	18N 63E 34cd	2025	SE	TKi
North Creek	20N 65E 27cc	2675	S	TMv
Queen	22N 65E 18da	2250	W	TMv
Upper Schellbourne Pass	22N 65E 7aa	2175	W	TMv

Long Gulch	23N 64E 13aa	2225	W	TMv
Cherry	23N 65E 6dd	2250	N	TMv
Lookout	26N 67E 30da	2037	NW	TMv
*from USGS 1:100,000 topographic maps - metric: Currie (1987), Kern Mountains (1988), and Ely (1987). +CpCc = Cambrian / Precambrian clastic rocks; Pzc = Paleozoic carbonate rocks; TKi = Tertiary / Cretaceous volcanic rocks; TMV = Tertiary / Mesozoic volcanic rocks; based on Eakin, Hughes, and Moore (1967).				

Steptoe Valley is orientated north-south. Thus, drainage basins emanating from the mountains have predominately east-west orientations. Spring catchment exposures reflect this general pattern. Thirteen spring catchments exhibit a westerly exposure; 10 springs exhibited an easterly exposure. Northerly or southerly orientations were each exhibited at one spring.

Surficial geology of Steptoe Valley is dominated by four major rock types. The valley floor consists of alluvial sediments. Paleozoic carbonate rocks predominate in the southern half of the Schell Creek Range on the east side of the valley and throughout the Egan Range on the west side of the valley. The northern half Schell Creek Range and the Antelope Range at the north end of the valley expose Tertiary/Mesozoic volcanic rocks. These and Tertiary/Cretaceous volcanics also occur in smaller outcrops in the Egan Range and the southern half of the Schell Creek Range. Finally, there are a small number of exposures of Cambrian/Precambrian clastic rocks on both sides of the valley in the central portions of the Egan and Schell Creek Ranges. Orifices and/or catchment areas for 15 of the sampled springs occur in Paleozoic carbonate rocks. Seven sampled springs occur in Tertiary volcanic rocks. Three sampled springs occur in Cambrian/Precambrian clastic rocks. Although there are numerous occurrences, no springs located in alluvial material were selected for sampling.

Spring sampling was done in late October and early November. Two of the springs were dry. Four springs exhibited warm temperatures, indicating discharge from regional flow systems. These warm springs will not be included in the analysis of recharge. Samples are currently undergoing chloride and stable isotope analysis.

Precipitation collectors have been installed. Accumulated precipitation will be collected for stable isotope analysis following the fall/winter and spring/summer precipitation seasons. The combined stable isotope data will provide the input signal for the stable isotope analysis.

Simple chloride collectors have been installed and will be left in the field for a year to accumulate wet and dry fall chloride. These data will be used to indicate the input signal for the chloride enrichment evaluation.

Descriptors

Groundwater Recharge, Arid Climates, Springs

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Information Transfer Program

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	N/A	N/A	N/A	3
Masters	3	2	N/A	N/A	5
Ph.D.	N/A	1	N/A	N/A	1
Post-Doc.	N/A	1	N/A	N/A	1
Total	N/A	N/A	N/A	N/A	N/A

Awards & Achievements

Publications from Prior Projects

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