

EXECUTIVE SUMMARY

Walker Lake is one of three desert terminus lakes in the western US that supports a fishery. Desert terminus lakes have no water outflow, so their size depends on the balance between water inflow and evaporation of water from the lake's surface. Over the past 100 years, lake levels have decreased about 150 feet, during which time the volume of the lake has declined from about 10 million to less than 2 million acre feet. During this decline, the total dissolved solids (TDS) of the lake have increased from about 2500 mg/l to greater than 16,000 mg/l. These changes have had far reaching impacts on the health of the lake and its associated ecosystem, such as a significant population decline of threatened Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*), a subspecies that is receiving considerable conservation and restoration attention.

Walker Lake is located in a watershed that supports significant agriculture activity. The primary source of the lake's water is snowmelt runoff from the Sierra Nevada Mountains, which flows through several agricultural valleys before reaching the lake. There are currently no water rights for the lake, so during low water years the lake receives little or no inflow.

In an effort to restore Walker Lake, Congress enacted a law in 2005 that created a program to acquire water rights from willing sellers in the Walker Basin. In order to enact an ecologically and economically sustainable program of water acquisitions, a large-scale integrated research program was established. The primary objective of this research program was to provide the hydrologic, ecologic, economic, and agricultural data needed to inform decisions related to water acquisitions.

LAKE AND RIVER STUDIES

One of the goals of the Walker Basin Project was to evaluate the present status of Walker Lake and Walker River in reference to its existing limnological condition and to evaluate changes in those conditions that may occur in response to changes in water delivery and management practices. The aquatic reports in this volume include summaries for 10 studies conducted by more than 15 scientists, notable because it is the largest study ever conducted examining the ecology of a mid-elevation western Great Basin river and its terminal lake. Each report stands alone, but the strength of this volume lies in the diversity of studies and commonality among findings through divergent methods. The integrated sum of information is vastly greater than the total of the individual parts.

Walker Lake was monitored and sampled during 2007–2008 for the purpose of describing current conditions and to calibrate an ecological model of lake response under different water delivery scenarios. Water quality samples collected from several sites in the lake were used to identify and assess ecological parameters important to lake ecosystem health. Physical, chemical and biological datasets were developed across depth profiles over time to explore factors governing intra-lake circulation and the resulting nutrient cycling, summertime oxygen minima, and accumulations of deleterious substances (e.g., ammonia and hydrogen sulfide). These data were combined with available historical data and used to parameterize the Walker Lake ecological model. Sensitivity analysis of the model was used to identify the factors most important to lake function and its ecological condition. These

results, and the professional judgment of participating researchers, have resulted in recommendations for long-term monitoring of the lake to provide a consistent and comprehensive dataset for evaluating environmental conditions in the lake over time. These monitoring recommendations include specific indicators that are vital to improving diagnostic models for Walker Lake assessment and management as future water acquisitions are evaluated.

As Walker Lake level has declined, both the chemistry and biology of the lake have been adversely impacted. The water quality is generally poor and declining with very high total dissolved solids (>16,000 mg/l), alkaline pH (around 9.0), and major-ion chemistry dominated by sodium, sulfate, chloride, and bicarbonate plus carbonate. Despite low lake levels and high salinity from reduced water inflows, Walker Lake still exhibited complete mixing (holomixis) during the winter and stratification during the summer. Anoxic conditions develop in the hypolimnion during the summer, resulting in high concentrations of ammonia. The high ammonia concentrations combined with elevated phosphorus levels in the lake produce large odiferous blooms of phytoplankton during the summer.

Observations and data analysis indicate that large nuisance blooms and deepwater hypoxia will continue in Walker Lake as long as enhanced internal nutrient loading through oxygen depletion in the hypolimnion continues. The volume and areal extent of the hypolimnion oxygen depletion has decreased over time simply due to the reduction in volume of the hypolimnion as lake level has declined. The production of organic matter leading to the hypoxia is sustained by exceedingly high levels of phosphorous (in excess of 20 uM) which sustain the N-fixing *Nodularia* blooms. If the current rate of lake level decline continues the lake may soon transition to a polymictic status. Even if the lake level rises, the hypolimnetic oxygen depleted zone is not likely to disappear any time soon unless the internal loading of nutrients is reduced.

Although fish species diversity is low in the lake, it did at one time support a robust fishery. Prior to lake level decline, Walker Lake supported a large population of Lahontan cutthroat trout, forage fish, tui chub (*Gila bicolor*), as well as other species. Cutthroat trout are currently maintained by an extensive stocking program and tui chub recruitment is limited by the saline conditions in the lake. Studies of the lake foodweb show that both species are mostly dependent on benthic production, which is consistent throughout the season. Pelagic production of edible phytoplankton and zooplankton is highly variable both spatially and temporally.

Paleoecology data for the lake indicate that past fluctuation in lake elevation and salinity occurred rapidly, possibly within several decades, particularly when the Walker River changed course and diverted flow from or returned flow to the lake. When lake levels rapidly recovered, certain taxa quickly colonized the lake. This rapid colonization is evidenced by the sudden occurrence or transition of ostracode and diatom taxa in the sediment record, suggesting that the taxa found in Walker Lake are adapted to rapid recolonization when conditions are favorable. Walker River is the lifeline which many Walker Lake taxa need to survive unfavorable lake conditions and it has served as such for many tens of thousands of years. Little information is available and few studies have been conducted on the Walker River most likely because its tremendous value in sustaining Walker Lake taxa has not been fully recognized.

Walker River studies quantitatively examined its physical characteristics, water chemistry and quality, and ecology (i.e., algae, macrophytes, macroinvertebrates, and fish communities) in different reaches of the river. These studies were designed to:

- define healthy and functioning conditions in the river
- predict changes in riverine ecosystems that can be anticipated from increased flow and change in the timing of delivery from water acquisitions
- integrate this information with future hydrology studies to help develop strategies that maximally increase ecosystem health and recreational opportunities.

Water quality, salient metrics describing physical characteristics of aquatic habitat, periphyton, and benthic macroinvertebrates (BMIs) were sampled at eight river sites during the spring, summer, and autumn of 2007 and 2008.

River water chemistry sampling results were compared to historical data and long-term trends in water quality were identified. Seasonal water quality changes along the length of the river were assessed. Mass loadings of important water quality constituents from the Walker River into Walker Lake were calculated based on measured river flows and constituent concentrations over the sampling period of this study. Results of this monitoring effort provide a basis for comparison for future potential changes in river water quality as new water acquisitions are introduced into the river. An examination of the major ions in the river and lake show that, although the river water becomes more concentrated downstream it is still low in TDS compared to the lake, so that an increase in stream flow would lower the TDS in the lake.

Biomass and community composition of periphyton in the Walker River was evaluated to establish present-day knowledge of algal taxa in different river habitats. Standing stocks of algal biomass were present at levels that often signify eutrophic conditions at the East Fork and Mason Valley sites. The river had high abundances of siltation-tolerant diatom taxa with the most notable abundances (exceeding 60 percent) at site locations farthest down the river towards the lake. The near ubiquitous presence of filamentous green algae (especially *Cladophora* and *Oedogonium*) throughout the system (except the West Walker) is indicative of a system having a high potential for nutrient-algal interactions that produce oxygen slumps during the summer months. Taxonomic richness and the community tolerance values of riffle and woody debris BMIs exhibited spatial and temporal trends. Both metrics show that ecological health of upstream river reaches is generally better than reaches through and below Mason Valley. Multivariate analyses found a strong relationship among water temperature, discharge (and factors that are affected by discharge such as current velocity, wetted width of the stream and water depth), nutrient concentrations, and BMI community structure. These strong relationships indicate that Walker River BMI communities are affected by activities that influence these factors, including water management, flow reduction, and livestock grazing and BMI communities may be useful as indicators of river pollution.

Ten species of fish were collected from eight electroshocking locations in the Walker River. Fifty percent of the species were native, with nonnative coldwater species (brown trout [*Salmo trutta*], rainbow trout [*Oncorhynchus mykiss*], etc.) captured in the upper river

reaches and warm water nonnative species (bass [*Micropterus dolomieu*], catfish [*Ameiurus nebulosus*], and carp [*Cyprinus carpio*]) captured in the middle to lower river reaches. Lahontan redbreasted sunfish (*Richardsonius egregius*), a forage fish for top predators, was the only native fish captured across most reaches. Otherwise, larger cold water predators (nonnative and native) such as brown trout, rainbow trout, and mountain whitefish, were found in upper, middle, and lower reaches, but they were not necessarily found at the same site.

The drop in Walker Lake level has caused Walker River to extend its length by about 20 km across the former lake bed. In addition to lengthening, the river has also severely down cut in response to lowering of base level (drop in the lake level). A study of the river using rectified aerial photographs from 1938 to the present, in combination with detailed topography from 1995, 1997, and 2005, documented the conditions under which lateral and vertical erosion have occurred. From 1995 to 1997, approximately 1.02 million metric tons (MT) of sediment was eroded from the bed and banks of the lowermost Walker River (about the last 20 km). Over the next seven years (1997 to 2005) about 430,000 MT of sediment was eroded. During the spring 2005 runoff season, approximately 477,000 MT of sediment was eroded and during the spring 2006 runoff season another 936,000 MT of sediment was flushed into the lake from bed and bank erosion.

The amount of erosion in a given year is directly related to the duration of the runoff event as well as peak discharge. A 2-D sediment transport model was used to simulate the amount of sediment transport and vertical erosion that may occur under a variety of flow scenarios. It is difficult to directly compare the estimates of erosion made from aerial photography to those calculated from modeling because the former is better at documenting lateral erosion and the latter focuses on vertical erosion. Nevertheless, the results from both of these approaches indicate that hundreds of thousands of metric tons of sediment are eroded from the bed and banks of the lower Walker River during an “average” runoff year, attesting to the instability of this system. Most of this instability is concentrated in the lowermost reaches of the river. If more flow becomes available in the Walker River in the future and the way that the flow is delivered to the lower Walker River can be controlled, instead of increasing peak flows down the river a more sound approach would be to increase the duration of spring runoff events or to establish minimum base flows that cumulatively would supply the additional water volume to the lake to minimize further erosion.

A pressing issue for the lower Walker River is the poor condition of the siphon. The siphon is holding in place the historic head cut that migrated upstream during the 1997 flood because of the lowering of Walker Lake from its historic high stand position in 1868. The failure of this structure would likely allow the rapid migration of this head cut upstream where it would threaten bridges and other infrastructure in Schurz, in addition to destabilizing the relatively intact Walker River reach that extends from Weber Dam downstream to the siphon. Stabilization of the siphon reach would also allow effective fish passage.

A HEC-RAS model was developed for the upper Walker River to evaluate stream bed and bank erosion for this part of the Walker River system. This model was run for various flow scenarios and constitutes another project related to the river. The predicted hydrodynamic characteristics of the flow (i.e., bed shear stress, mean velocity, water surface elevation, Froude number and maximum channel depth) were obtained from the model. A

number of methods were used to determine the susceptibility of sediments in the upper Walker River to be eroded and transported under varying flow conditions, and analyses consistently indicated that the sediments in the upper Walker River would be expected to be actively transported under most of the flow conditions anticipated as a result of the acquisition of additional water along the river. Model results were consistent with what was observed in the field at each of the locations where sediment samples were collected. Even at relatively low flow conditions, active sediment transport was visually observed. Particles were being transported along the surface of the sediment beds. If this particle load was determined to be detrimental to the lake, a potential solution for excessive sediment transport into the lower Walker River would be the installation of settling basins or grit tanks in series throughout the watershed to trap sediments being transported. Periodically, these basins would require cleaning to remove settled materials; these collected materials could potentially be repurposed for different types of building construction or road construction projects.

This modeling study also predicted that most of the upper Walker River can handle flows of up to 400 cfs (cubic feet per second) without excessive flooding, but the average annual maximum flow of 700 cfs would result in localized flooding at a number of locations

WATER FLOW MODELS AND THE DECISION SUPPORT TOOL (DST) MODEL

A computer-based decision support tool (DST) model capable of evaluating the efficacy of proposed water rights acquisitions in the Walker River basin was developed and tested. This DST model represents a major step forward in understanding the complex hydrologic relationships within the real system. Climate, streamflow, upstream storage areas, irrigation practices, crop and non-agricultural ET, groundwater-surface water exchange in the river corridor, groundwater pumping and recharge, and all known existing water rights (decree, storage, and flood; as well as supplemental groundwater) all play a role in the Walker River system and are simulated by the DST. The DST allows users to track water from the headwaters, where streamflow originates, through the complicated deliveries and returns in the heavily irrigated Smith and Mason valleys, to the USGS gauge near Wabuska.

Three different models were integrated to generate results for the DST project. The USGS's Precipitation-Runoff Modeling System (PRMS) was used to model the headwater supply areas of the Walker River basin. It performs well in the West Walker headwaters: timing of the annual hydrograph was well represented, although streamflow peaks were slightly underestimated by the model. The effects of reservoir operations and diversions for agricultural irrigation in the East Walker are not captured by the model, which causes poor representation of annual hydrograph timing as well as overestimation of streamflow peaks for the East Walker River. The East Walker model, or at least estimated inflows to Bridgeport Reservoir, might be improved by simulating additional subbasins utilizing historic streamflow data from discontinued USGS gauges.

MODFLOW is used to model the agricultural demand areas and groundwater-surface water interaction in Mason and Smith valleys. Mason Valley, in particular, is well modeled: low root mean square error (RMSE) values are calculated for water levels, streamflows, and river responses. The Mason Valley groundwater model suggests that groundwater fluxes into the river/drain network account for about 4 percent of the river's water budget during wet

periods, but nearly 25 percent during extended drought. Smith Valley is not modeled with the same degree of accuracy as Mason Valley, although contrasting the two provides insight to the system. The groundwater models are limited by their non-unique solutions, poor representation of water levels in parts of Smith Valley, and the unknown errors associated with the simulated groundwater-surface water interaction.

MODSIM simulates reservoir operations, streamflow routing, and water rights allocations in the Walker River basin from the headwaters to the Wabuska gauge. Given the complexity of the water distribution system in the Walker River basin, the results are reasonable. The model is able to maintain target volumes in the reservoirs while supplying water to downstream demands, which indicates that reservoir operations are simulated realistically. Generally, simulated water allocations correspond to historical allocations during the simulation period. In spite of the problems encountered with model calibration, the simulation model allocates the different categories of water reasonably well.

The DST project captures the spatial and temporal complexity of relationships among climate, evaporation, river flows, groundwater-surface water exchange along the river, irrigation practices and groundwater pumping. It uses information gained from other hydrologic modeling studies and incorporates state-of-the-art software and high-resolution spatial products to enhance the accuracy of predicted hydrologic responses. The modeling effort incorporates a geographic information systems (GIS) database of both surface and groundwater data developed by other investigators on the project.

The geographic information system (GIS) database of vector, raster and tabular data, developed as a separate project from the DTS described above, had a principal objective of acquiring, developing and analyzing the requisite spatial and tabular data needed to successfully support many of the Walker Basin Project components. In particular, a majority of the GIS development process focused on providing data for the DST water flow modeling effort described above. In addition to data sets for the DST, a wide variety of other spatial data sets were developed and integrated into the GIS database in support of other Walker projects (alternative agriculture and vegetation management; plant, soil and water interactions; health of Walker River and Lake; economic impacts and strategies; demographics and economic development), as well as outside entities requesting spatial data - the United States Fish and Wildlife Service [USFWS] restoration project; Western Development and Storage, the acquisitions team; and Jones and Stokes, the Environmental Impact Statement [EIS] development team).

Researchers constructed an extensive GIS database of the entire Walker Basin, with data sets from federal, state, and local agencies combined and integrated with derivative data sets. The result is a scalable, georeferenced collection of spatial data (i.e., geodatabases, shapefiles, rasters, and tables) representing a wide variety of spatial and temporal features, as well as tabular information for the entire Walker Basin. The principal base layer for the development, processing and analysis was one-foot natural color aerial photography, complemented by six-inch resolution imagery of the Yerington area. Infrastructure data included the Public Land Survey System (PLSS), land ownership, roads, topography and administrative boundaries. LIDAR imagery and USGS elevational data were integrated for groundwater modeling analysis. USDA agricultural and soils data were also integrated with geo-referenced spatial data and from this information attribute tables were generated.

Acquisition and development of surface and ground water data for the DST was time consuming as information was gathered from many sources, fieldwork was required and much of the data required digitizing or manually entering into digital format. However, the most critical factor in the GIS database was the establishment of a minimum mapping or modeling unit for the primary irrigation. Due to the sensitive nature of mapping at the farm scale, a data set that operated at the scale of each group of fields linked by a common ditch was developed for this project. This dataset is referred to as a Hydrological Response Unit (HRU). Forty-four HRUs were defined for this project and for each HRU water right and historic water diversion data were compiled into associated attribute tables. Tabular and shapefile data for the GIS task are included in the report on a USB flashdrive.

The GIS database includes both surface and groundwater distribution networks and water rights. These data were used as inputs for the DST model described above, providing spatial and tabular data to the supply, demand, and basin management components, as well as calibration data to assist in the validation of the models. The database might be used in the future by resource managers and researchers for investigating hydrologic, ecological and economical phenomena in the Walker Basin.

Another project that contributed to understanding the groundwater inflows and outflows to the Walker River was the distributed temperature sensing project. This project is important for understanding the hydrology of the basin and the accurate assessment and management of its water resources. Distributed temperature sensing analysis showed the groundwater-surface water interaction to be highly variable in both space and time. This project found that ground water inflows and outflows to and from the river were easily identifiable and quantifiable using the combination of the distributed temperate data and vertical temperature measurements. The distributed temperate measurements indicate gaining conditions over short periods of time and long spatial extent. These measurements permitted assessment of where gains to channel flow were occurring during the limited periods with gaining conditions. In agricultural areas, inflow zones to the river can be identified based on temperature differences, permitting efficient sampling for determining potential salinity loading to the river by groundwater at the resolution of individual fields and drains.

LAND USE CHANGE, VEGETATION MANAGEMENT AND PLANT SOIL WATER INTERACTIONS

Over the past 150 years, the Walker River riparian zone has experienced massive land cover conversion from native riparian vegetation to extensive agricultural landscapes characterized by irrigated pastures and alfalfa (*Medicago sativa*) fields. Much of the historical riparian area in the lower river was dominated by wet meadow and emergent wetland habitats. Ninety-five percent of this habitat has been lost, but only 41 percent was directly converted to agriculture. The rest was converted to more xeric communities. Cottonwood (*Populus fremontii*) forests were not as extensive along the Walker River as they were along the Truckee and Carson Rivers. The most extensive forest occurred at the former Walker River delta. Now there are numerous small patches and individual trees scattered around the former riparian zone resulting in more extensive, but also more fragmented forests. The

dominant direction of change observed in the historical analysis indicates a riparian environment that has become narrower, more channelized, and with reduced groundwater availability.

Water withdrawals and diversions for agriculture have greatly reduced flows of water to Walker Lake, influencing aquatic ecosystem integrity. River regulation and reduced in-stream flows have altered riparian vegetation even in locations not devoted to agricultural use. In response to recent environmental concerns, purchase of water rights from agricultural producers is under consideration. However, past abandonment of irrigated fields in the region has resulted in ecologically and economically undesirable effects, including surface soil erosion, salinization, and spread of invasive plant species. Careful orchestration is required for land use conversion to result in benefits for ecosystems and society.

The impending impact of water reallocation has stimulated renewed interest among the agricultural sector, not only in terms of alfalfa production but also with respect to alternative agriculture (e.g., biofuel crops and the production of low water use crops) and the restoration of abandoned agricultural lands. A parallel concern is the response of existing ecosystems to future changes in water availability, allocation, and management. About 50,000 acres in Lyon County are currently devoted to irrigated alfalfa production (personal communication; Nevada Cooperative Extension, Yerington, NV). Conversion of high water use alfalfa to lower water use alternative agricultural crops could have a significant impact on water resources, the local economies, and ecosystem stability.

Alternative low water use crops were investigated to determine likely responses by soils and vegetation to changes in water application and consumptive use, water table depth, and soil salinity in three key landscape circumstances: (1) currently irrigated and peripheral lands that may undergo lowering of water tables due to reduced irrigation; (2) the Walker River riparian zone that presumably would undergo an increase in water table levels and a change in the net direction of water movement with increased in-stream flows during the irrigation season; and (3) the lower Walker River, which currently suffers from soil salinization and infestation from invasive species. This investigation was accomplished through the measurement of important soil characteristics and parameters, such as soil moisture depletion and evapotranspiration, susceptibility to wind erosion, salinization, nutrient fluxes, temperature, and organic matter content, as they relate to water treatment and vegetative cover.

Five agricultural crops (teff [*Eragrostis tef*], buckwheat [*Fagopyrum esculentum*], amaranth [*Amaranth hybridus* x *hypochondriacus*], pearl millet [*Pennisetum glaucum*] and alfalfa [*Medicago sativa*]), nine biomass crops (switchgrass [*Panicum virgatum*], sand bluestem [*Andropogon hallii*], Indian grass [*Sorghastrum nutans*], prairie sandreed [*Calamovilfa longifolia*], bluestem [*Bothriochloa ischaemum*], tall wheatgrass [*Elytrigia elongata*], Basin wildrye [*Leymus cinereus*], Mammoth wildrye [*Leymus racemosus*], and tall fescue [*Festuca arundinacea*]) and five native species that can be used for re-vegetation (Indian rice grass, Basin wildrye, Beardless wheat grass [*Pseudoregneria spicata*], Western wheatgrass [*Pascopyrum smithii*], and Inland salt grass [*Distichlis spicata*]) were tested. These alternative crops and native species were planted at five sites under four different water regimes (0, 50, 75, and 100 percent [4 feet]). At each site, physical and chemical soil properties were analyzed and wind erosion, precipitation, and soil moisture were quantified. In addition, riparian zone de-nitrification was measured in the field and modeled. Finally, the ability of an

invasive species (for this experiment, tall white top) to use alternative deep water sources and thus out compete native species was investigated.

Of the alternative low water use crops, teff and amaranth were the highest performing annual crops, with seed production comparable to production elsewhere. Additionally, both species produced seeds at the lowest watering levels. Although above ground teff biomass yields were largest of the five crops, no differences in soil carbon content were found. In addition, the higher yields for teff did not translate into increased soil carbon dioxide (CO₂) efflux rates. Effects of vegetation on nitrogen (N) fluxes were not consistent. Perhaps most surprisingly, nitrogen (N) fluxes in alfalfa soils were not much different from switch grass and amaranth, despite alfalfa being an N fixing species.

Warm season biomass crops were generally not as successful as cool season crops, with the exception of old world bluestem. Additionally, bluestem was the top performing warm season grass in the lowest watering treatment. Cool season grasses established and grew well in both sites, and were very competitive with weeds. There was variability in performance of some species between sites, but tall wheatgrass was consistently a top performer, in both high and low water applications.

The establishment of multiple restoration species (a mix of native grasses and shrubs) were evaluated for an application rate of one foot per acre and with no water application. All native grasses established significantly better with water application, though there were differences in rank performance between sites. Indian rice grass was the best performer at one site, with the highest biomass and weed suppression as compared to the other grasses, whereas beardless wheat grass was the top performer at the other restoration site. Sagebrush survived transplanting significantly better than other species, and greasewood, although it had low survival, had the fastest growth rate and responded the most to water addition.

Application of none and 25 percent (one acre feet of normal four acre feet) of water for dust suppression was also evaluated for the plots. Overall, the 25 percent water treatments were far more effective at reducing dust generation and increasing dust deposition than the zero percent water treatments and, in some instances more so than even the controls. The zero percent water treatments were found to be far more erosive than natural conditions.

Groundwater flow modeling, using MODFLOW, showed that the residence time of water and nitrate removal rates are sufficient to remove nearly all nitrate from hypothetical “slugs” of water originating from the agricultural ditches and flowing through the riparian groundwater zone before entering the river.

Experiments with tall white top (*Lepidium latifolium*) show that it is able to utilize deep water sources. This may have impacts on late season surface water availability, but in competition experiments tall white top did not negatively impact the native grass (slender wheat grass [*Elymus trachycaulus*]).

Another project examined alternative crops that would enable producers to remain economically viable while using less water. The main crop grown in Mason and Smith Valleys is alfalfa, which yields high prices but is a high water user. If producers plan to continue growing crops with lower water use and potentially sell a portion of their water rights, they would have to be able to grow a crop that uses less water, yet yields equal or greater profits. Viable crops which merited study offer producers more than one option when

considering alternatives. These alternative lower water use crops include onions (*Allium cepa*), leaf lettuce (*Lactuca sativa*), wine grapes (*Vitis interspecific*), teff (*Eragrostis tef*), two-row malt barley (*Hordeum distichum*), Great Basin wildrye (*Leymus cinereus*), and switch grass (*Panicum virgatum*). In addition to different cropping practices a no-till option was also included models for all crops under consideration.

A combination of a crop yield model (WinEPIC) and a risk simulation model (SIMETAR) were used for analysis and to address agronomic and economic questions. Results showed that there are alternative crops that could be economically feasible in the Walker Basin. For producers able to obtain funding for capital investment and who are willing to hire additional labor, growing onions and leaf lettuce under rotation would yield substantial returns. With no additional capital or labor, the study recommended investigating contracts for growing two-row malt barley or Great Basin wildrye. These four crops use half the water needed for alfalfa (two feet rather than four feet), which would potentially allow producers to sell part of their water rights. The study also concluded that teff has potential for profit, but switch grass was not recommended. Wine grapes have a good profit potential, but they are demanding both fiscally and in terms of labor, and therefore require more risk-tolerance than other crops.

ECONOMICS AND SOCIAL HISTORY

In order to quantify any economic impact to the Walker Basin as the result of water right acquisitions, the current economic and demographic characteristics of the communities within the Walker Basin had to be developed and analyzed using local, state, and federal databases and geographic information systems software. Although agriculture is a predominant and traditional industry in the Walker Basin, employment and industry totals indicate a diverse economy. Almost a quarter billion in taxable sales is generated in the Walker Basin, with the majority of sales coming from retail industries. Another \$58 million in revenue is estimated to be generated from crop production in Mason and Smith valleys (Lyon County) from production on more than 50,000 acres. Current and future residential and commercial construction activity is mostly targeted for populated areas in the basin and is consistent with the current economic conditions.

The acquisition of water rights that have historically been used for agriculture could have a variety of economic and fiscal impacts in the Walker Basin. Cost and value for a number of crops, including alfalfa and onion, which are the main crops in the Walker Basin, as well as alternative crops (as discussed above), were assessed in conjunction with estimated reliability of water rights offset against hypothetical water rights sale income. Four scenarios related to how water rights might be acquired, along with the resultant potential uses for the land following water rights acquisition, and estimates of economic and fiscal impacts for those scenarios were evaluated. The four scenarios include: (1) agricultural land taken completely out of production (returned to native vegetation); (2) existing crop rotations and farming practices are altered to save water; (3) alternative crops that require less water are cultivated; and (4) other (non-agricultural) sources of water rights are purchased. Based on these scenarios, the study examined the potential economic impacts in the Walker Lake Basin assuming that sufficient water flows into the lake to save and maintain a fishery. Three different scenarios of the overall economic impact in Mason and Smith Valleys were

evaluated using different figures for acres taken out of production, modified crop rotations, and alternative low water use crops. Two scenarios indicate a projected loss to the regional domestic product, whereas the third scenario showed a positive economic impact to the region. The study concludes that the economic impact to the region is highly dependent upon where and how water rights are acquired and what happens to the land associated with the water right. A risk fund to assist farmers and reduce the perceived risk of growing alternative crops is suggested, in association with agricultural and business technical assistance programs.

Based on input received at community meetings, this project also makes some recommendations regarding economic development efforts in the Basin that would be consistent with the desire of citizens in the communities and that might tend to offset any economic dislocations that could result from the acquisition of water rights.

A social and political historical account of water rights acquisitions in the Walker Basin for ecosystem restoration will be published as a book when the overall water rights acquisition program is completed. Currently three chapters are completed; “Changing Contexts in Western Water Policy;” “The Past as Prologue—the Walker River Basin;” and “P. L. 109-103 and the Walker Basin Project.”

WILD HORSES AND BURROS

Wild horse and burro policy is currently driven by several goals that include the mitigation of damage to rangeland, the commitment to humane treatment of the animals, and the control of regulatory costs.

A study undertaken as part of the Walker Basin Project investigated alternative auction strategies that potentially could increase adoption rates of wild horses. Placing animals with private owners and raising revenue from the distribution of the horses complements all the goals of the current wild horse and burro policy. Forty experimental auctions for three alternative packages of goods were conducted. The auction items were comprised of: (1) hiking equipment, (2) an Apple iPod and speaker system and (3) high quality wines. Auction participants were provided with alternative low and high information about the goods offered. Two types of auctions were evaluated, a sequential or good-by-good method and a right-to-choose method, in which the highest bidder wins the right to choose from among the goods that are available. Results of auction type analysis indicate that revenues from the sequential method were slightly higher, but not statistically different from those generated by the right-to-choose strategy.

The wild horse and burro policy study also employed stochastic simulation procedures to provide wild horse adoption decision makers with a range of potential revenues for wild horse adoptions. This range of revenues combined with capital and operation cost estimates of a potential wild horse and burro interpretive center provides decision makers with information as to potential distribution of net returns. From the distribution of net returns, decision makers could decide on construction and operation of a national wild horse and burro interpretive center in a risk adverse vantage.

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