RESTORATION OF A DESERT LAKE IN AN AGRICULTURALLY DOMINATED WATERSHED: THE WALKER LAKE BASIN PHASE 3

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EXECUTIVE SUMMARY

Walker Lake is one of three desert terminus lakes in the United States that until recently supported a fishery. Over the past 100 years, lake levels have declined more than 160 feet and the volume of the lake has decreased from about 10 million to less than 1 million acre feet. During this decline the total dissolved solids (TDS) of the lake have increased from about 2,500 to 25,000 mg/l. These changes have had far reaching impacts on the health of the lake and its associated ecosystems. High TDS values have resulted in the collapse of the threatened Lahontan cutthroat trout (LCT) fishery in the lake. The last reported capture of an LCT from Walker Lake was in May 2009 (USGS, Nevada website). The LCT is a subspecies of cutthroat trout that is receiving significant conservation and restoration attention.

Walker Lake is located in a watershed that supports significant agricultural activity. The source of the lake's water comes primarily from snowmelt runoff from the Sierra Nevada, 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 from the Walker River. However, recently the National Fish and Wildlife Foundation (NFWF) has purchased water rights for the lake from willing sellers and is in the process of transferring these water rights to Walker Lake.

In an effort to save Walker Lake, Congress enacted a law in 2005 (i.e., H.R. 2419 Energy and Water Development Appropriations Act, 2006, Section 208), 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 goal of the Walker Basin Research Project was to provide the hydrologic, ecologic, economic, and agricultural data needed to inform decisions related to water acquisitions. This report is a product of the research program that was developed in response to direction provided in this federal legislation. Specifically, Desert Research Institute and University of Nevada, Reno faculty were funded to: (1) develop a method to optimize the purchase of water rights in the Walker River Basin, (2) evaluate options for practicing alternative agricultural practices, and (3) evaluate the impacts that water removal from crop-irrigated lands, to increase streamflow and deliver water to Walker Lake, will have on the spread of invasive plants, aquatic and terrestrial ecosystems, and the local economy.

Research during Phase III of the Walker Basin Research Project was supported by NFWF and has built upon work previously conducted during Phases I and II of the project. The major elements of our Phase III project include: 1) Walker Basin alternative agriculture and vegetation management; 2) an evaluation of the aquatic ecosystems of the Walker River, including trout habitat; 3) spatial analysis and mapping to support the decision support tool (DST) modeling efforts and NFWF water right acquisitions; 4) the DST, which includes many models on surface water and groundwater flows, water rights information, and ultimately, Walker River outflows from Mason Valley at the Wabuska gauge; 5) understanding past and future climate conditions in the Walker Basin; and 6) community economic development.

Walker Basin Alternative Agriculture and Vegetation Management

Restoring native shrub communities in former agricultural fields is challenging but the benefits include providing important wildlife habitat, protecting lands from erosion, and reducing populations of invasive weeds. Preliminary information on the effectiveness of seeding native shrubs in two former agricultural fields on the Rafter 7 Ranch and testing the effects of a variety of treatments is presented in the summary report. These include seeding shrubs with and without native perennial grasses, varying the seed source of shrubs and grasses, varying water amounts and timing, and using weed control efforts such as herbicide and mowing. We are also investigating how soil properties affect plant performance in these former agricultural fields. Additionally, we are gathering information on surrounding native reference communities with the goal of describing naturally occurring species composition, densities, and plant-soil relationships to provide information on realistic restoration targets in these systems. To date, the results in the restoration plots suggest strong effects of species and seed source on plant establishment, and contrasting effects of irrigation at the two field sites. In the natural reference communities, species composition and density vary across the Rafter 7 Ranch; our soil analyses are designed to provide information on species/soil associations that can be used to design seed mixes for different types of sites. After irrigation has ceased, monitoring over the next field season (2017) will be crucial for determining which restoration strategies are most effective.

Evaluating and Developing a Habitat Based Model for Trout that Includes Temperature, Flow, and Food Production

Environmental water purchases are increasingly used to restore flow regimes in impaired watersheds and have been implemented in the western US, Australia, Chile, Mexico, China, and South Africa. Considerable research exists on increasing streamflow to mimic a natural flow regime; however, the effects of increased streamflow on water quality, food webs, and trout habitat are not well understood. The objectives of this Walker Basin project were to expand habitat and water quality monitoring and modeling, understand Walker River environmental and biological relationships to guide restoration, and highlight Walker River reaches and time periods with suitable trout habitat that would benefit from water purchases. A quantitative and integrated assessment of the efficacy of potential water acquisitions and management alternatives for the health of Walker River ecosystems, based on streamflow, thermal dynamics, dissolved oxygen, and food production is provided by this research.

Stream temperatures were continuously monitored from 2007 to present and dissolved oxygen was continuously monitored from fall of 2013 through 2015. Overall, critically warm stream temperatures coincide with low flows, and thermal refugia exist in the east and west forks of the Walker River and their tributaries. Stream temperatures warm longitudinally and dissolved oxygen concentrations decline longitudinally. This results in poor environmental water quality conditions in the lower Walker River, which fragments aquatic habitats and limits native fish species, like Lahontan cutthroat trout (LCT) (*Oncorhynchus clarki henshawi*).

River monitoring showed that the East and West Walker Rivers (188.8 kilometers of habitat) and sometimes the mainstem Walker River just below the confluence provide suitable habitat to support native species. Aquatic habitat as a function of streamflow, stream temperature, DO concentration, and food availability is generally unsuitable from approximately the confluence of the East and West Walker Rivers to Walker Lake (111.7 kilometers). In general, the east and west forks of the Walker River and their tributaries are characterized by cobble size substrate, course particulate organic matter, stream temperatures and dissolved oxygen concentrations in suitable ranges to support trout, and higher quality BMI communities that provide food for trout. In downstream reaches, substrate is sandy and monotonous, contains fine particulate organic matter, and invasive species such as carp and catfish are widespread. Results from this study imply that an increase in discharge would result in a reduction of water temperature and nutrient concentrations, which would improve river conditions and concomitantly beneficially affect aquatic communities. Water purchases should prioritize passage through the lower Walker River to re-connect the river and lake ecosystems, rather than restore suitable trout habitat in the lower Walker River. The higher temperatures and smaller substrates downstream from the east and west forks of the Walker River create conditions that are poorly suited to trout spawning, and where there is limited food for fishes. Therefore, it appears that this portion of river is poor trout habitat, and that it is inappropriate to direct efforts to create this type of habitat through Mason Valley and downstream. It is more appropriate to create conditions whereby trout can pass through this reach on their migration upstream to habitat with cooler temperatures and larger substrate.

Water purchases could improve trout habitat by reducing maximum stream temperatures by up to 3 ºC and increasing minimum dissolved oxygen levels above approximately 5 mg/L. Cooler daily maximum stream temperatures are anticipated to extend stream miles with healthy mayfly (Baetis spp.) and BMI communities, which in turn, could increase habitat extent and quality by providing food for trout.

Spatial Analysis, Mapping, and Database Support

In Phase III of the Walker Basin Project, DRI faculty and staff provided specific spatial analysis, mapping, and database development support directly to the National Fish and Wildlife Foundation (NFWF). Desert Research Institute personnel used geographic information systems (GIS) as a framework for conducting spatial analysis and map development for NFWF's Walker Basin water acquisition program. Desert Research Institute assisted NFWF in establishing a new file-sharing system using Box for NFWF employees and subcontractors working on the Walker Basin Restoration Program. A wide variety of spatial analysis and mapping tasks were performed by DRI, including the development of water transaction maps and a triplet set of maps produced for a number of potential willing-seller properties in Mason Valley, Smith Valley, and the East Walker River corridor. Each triplet set consisted of a reference map, a surface water rights map, and a groundwater rights map for a particular property or set of properties. Other tasks included developing Ditch Order-Ownership maps for a number of irrigation water conveyance systems in Mason Valley and Smith Valley. These maps showed the ascending order of properties and owners along a primary ditch system relative to the take out from the river. These maps also showed the associated lateral ditches that come off the primary ditch and supply the agricultural fields for each property in the ditch conveyance system. Other mapping tasks included developing large-scale exhibit maps and display maps showing the major basins in the Desert Terminus Lakes Project area, and water rights acquisition maps for Mason Valley, Smith Valley, and the East Walker River corridor. Desert Research Institute also provided reference and field maps to be used at NFWF's newly acquired Rafter 7 Ranch in the East Walker River corridor. Spatial data used in the development of maps and digital versions of the maps have been archived by DRI and are available to the public, subject to the data-sharing protocol established for the Walker Basin Research Project and permission from NFWF.

DST Model Support – Spatial Data and Water Rights Information

In Phase III of the Walker Basin Research Project, DRI faculty and staff provided spatial analysis and water rights information support to the decision support tool (DST) modelers at DRI and UNR as part of an evaluation of the effectiveness of potential water right acquisitions in the Walker Basin. Desert Research Institute personnel used geographic information systems (GIS) as a framework for acquiring and developing the spatial and tabular data that are required inputs for the DST. Spatial data updates were performed as new and/or revised information was received by DRI from various federal, state, and local agencies, as well as local companies and landowners. Derivative data sets were also developed by DRI based on the integration of different data sets and field observations. Important spatial data sets that were developed and used for the DST included hydrologic response units (HRUs), the water conveyance system (points of diversion [PODs], ditches, and drains), groundwater places of use (POUs) and PODs, the C-125 Surface Water Decree, Lyon County parcel data, and digital elevation models (DEMs). Tabular data sets provided for the DST included surface water diversion data; groundwater well data, including water levels and pumpage values; and surface water and groundwater rights data. Analysis results included both surface water analyses and groundwater analyses that were used to provide additional derivative inputs for the DST. Desert Research Institute faculty and staff participated in the development of DST batch scenarios, storage water parameters, and net irrigation water requirement (NIWR) model parameters. Groundwater analyses included the development of multiscale DEMs for modeling the East Walker River corridor and estimating the primary groundwater irrigation acreage for Mason and Smith Valleys.

Walker Basin Decision Support Tool (DST)

With advances in computation and specialized modeling platforms, Decision Support Systems (DSS) have become more frequently developed and applied to inform water resource planning and management decisions. This project enhanced the Walker Basin Decision Support Tool (DST), an integrated surface-groundwater DSS that was developed to simulate the outcomes of water-right acquisitions by the National Fish and Wildlife Foundation (NFWF). The previous version (2.0) of the DST relied extensively on historical observations in simulation mode. Our primary goal for the enhanced version 3.0 DST was to develop a model capable of simulating the allocation of water rights and floodwater and reservoir operations using either historical demands or crop-based demands. Crop-based demands were estimated based on irrigated acreage, crop irrigation requirements, and system efficiency for each ditch service area. The DST version 3.0 uses custom modeling approaches and programming to significantly improve the simulation of reservoir storage and the allocation of decree, flood, and storage water when the historical diversions are used to define the service of water to each ditch. Crop-based demand simulations revealed that wet-year storage water use was adequately simulated by reducing estimated demand by 25 percent. Enforcing the historical apportionment in dry years produced additional improvement in the storage fits. A dry-year multiplier was applied to the historical apportionment to prevent the reservoirs from draining at the end of the irrigation season. A method to dynamically estimate the storage apportionment based on model state variables is needed to fully disconnect the demand-based model from historical operations.

The custom modeling approaches designed and applied in this effort produced significant improvement in the simulation of reservoir operations and the allocation of decree, flood, and storage water when the historical diversions defined the service of water to each ditch. The version 3.0 DST's dynamic ability to simulate storage and flood operations in response to changes in system conditions is a significant improvement from the modeling capabilities of the version 2.0 DST.

Demand-based testing was the most challenging aspect of our effort. Our results show that storage use can be limited in wet years by reducing the estimated ditch irrigation water requirement (DIWR) to a historical wet-year magnitude. When we combine reduced DIWR with unlimited wet-year use and enforce the apportionment in the dry years, reservoir storage is over allocated in dry years. Two reductions (75 and 85 percent) were applied to the apportionment in the dry years and in both simulations, the reservoirs maintained higher storage and were closer to the observations. Bridgeport simulated reservoir storage matched the historical dynamics more closely than Topaz. The exact reason for the difference in behavior between the two reservoirs is unclear at this time. Potentially, the processes, decisions, and behaviors that are integrated into the historical diversions are not fully captured by the demand-based model because of limitations in the information that drives the model or assumptions in the model approaches.

We believe the ability of the version 3.0 DST to represent the water allocation and operations in the Walker Basin is reasonable, particularly when the model demand is represented by the historical diversions. The next logical step in this effort should be focused on refining the simulated storage behavior in the demand-based DST mode and on developing a method to dynamically estimate the storage apportionment based on model state variables.

Better Understanding of Past, Present, and Possible Future Climatic Conditions in the Walker Basin

As a part of the Walker Basin Project Phase III, University of Nevada, Reno (UNR) faculty and staff focused on developing a better understanding of the past, present, and future climatic conditions in the Walker Basin. Specifically, we used a hydrologic model of the watershed and lake system, along with paleoproxy records, to estimate the climatic conditions associated with high and low levels of Walker Lake during the last 1,200 years. In addition, we used downscaled estimates of future climate predictions from the Intergovernmental Panel on Climate Change (IPCC) with the hydrologic model to better understand how predicted future climate change in the Walker Basin compares with climatic conditions during the megadrought period of the Medieval Climatic Anomaly (MCA) and the recent 2012-2015 California-Nevada drought. Our results indicate that the level of Walker Lake is very sensitive to the climatic conditions within the surrounding watershed and that the effects of using IPCC future climate projections on lake level are minimal compared to the climatic conditions associated with the current five-year drought and the two megadroughts that occurred during the MCA.

Project highlights include:

For the lake elevation of 1,250 m observed by Israel Russell in the early 1880s with a $\Delta T=0°$ we found $\Delta P=0.92$ (compared with the 1971-2000 climatology). This lake elevation is much greater than the current (March 2016) elevation.

For the baseline 1971-2000 climatology with $\Delta T=0°$ and $\Delta P=1$, we found the lake elevation to be 1,259 m, slightly higher than the 1880s elevation.

For the current drought ($\Delta T=1.6°$ and $\Delta P=0.61$) we found the lake elevation at steady state to be 1,190 m, just slightly lower than the level observed in March 2016. Note that this result suggests that if the current drought were to continue long enough for the lake to come to steady state, the lake would be lower than its present elevation without any consumptive use of water associated with agricultural and other human activities upstream of the lake.

The climate associated with the current drought is similar to the climate estimated for the MCA drought except that it is warmer in the current drought and the MCA conditions persisted for many more years than the current drought has so far.

For the period 2031-2060, we found a $\Delta T=2.3°C$ and $\Delta P=1.07$ (compared with the 1971-2000 PRISM climatology) and a corresponding lake level of 1,258 m. Note that in this scenario, the lake is nearly the same elevation as that estimated for the baseline conditions with no consumptive use of water associated with agricultural and other human activities upstream of the lake (see above.).

Economic Development Efforts Targeted Toward the Nevada Sub-regions within Walker Basin

Acquiring water rights that have historically been used for agriculture to increase the water flow into Walker Lake could have a variety of economic and fiscal impacts in the subareas within Walker Basin. The Walker Phase III summary report provides an overview of the project undertaken by the Center for Regional Studies, which involved providing outreach services intended to mitigate potential negative economic impacts through some direct stimulus (the microgrant program) and through several projects (a plan to develop a resource pool, a Comprehensive Economic Development Strategy [CEDS], and community assessments). The plans and reports were all completed to provide documents and infrastructure that could be used to support funding from other sources, including the Rural Nevada Development Corporation, U.S. Department of Commerce (through the U.S. Economic Development Administration) and other federal and state agencies.

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