

## **NLCS Research Support Program Proposal 2016**

**Project Title:** Hydrogeologic Study of the Surface and Groundwater Supporting Water Rights Acquisition at Las Cienegas National Conservation Area, Arizona.

**Abstract:**

Las Cienegas National Conservation Area (LCNCA) contains five of the most endangered habitats in the southwestern United States, including cienegas (wetlands) and cottonwood-willow riparian forests. These cienegas and riparian forests are biologically diverse, are critical habitat to seven species protected under the Endangered Species Act and are indicators of watershed health. Multiple threats, as a result of human activities outside of the NCA, imperil the water quantity and quality of these precious resources. Residential and agricultural development, the proposed Rosemont copper mine and long-term climate change put LCNCA at risk of long-term groundwater depletion. Land managers and agency regulators currently lack crucial and dependable baseline data with which to effectively model, monitor and manage these precious resources for the public as they are mandated to do. This baseline hydrogeological data is essential for securing both surface and groundwater water rights from the Arizona Department of Water Resources. Our proposed study builds on our previous work at LCNCA and aims to provide: 1) Crucial information on how sensitive these cienegas are to groundwater change by investigating the hydrologic connections between groundwater and surface water and how long it takes cienegas to be recharged; 2) An expanded monitoring network of water level data loggers to document short- and long-term groundwater trends; and 3) Important habitat quality data of open-water cienega habitat by using remote wildlife cameras to record their use by wildlife, especially waterbirds.

**Key words:** cienegas, groundwater, hydrogeochemistry, springs, water rights, wildlife

**Research themes:** Research Synthesis and Other Management-Driven Research

**National Conservation Lands Involved:** Las Cienegas National Conservation Area is located about 45 miles southeast of Tucson in southeastern Arizona in Pima and Santa Cruz Counties.

**Introduction:**

Las Cienegas National Conservation Area (LCNCA) contains five of the most endangered habitats in the southwestern United States, including cienegas (wetlands) and cottonwood-willow riparian forests. Several riparian- and cienega-dependent species protected under the Endangered Species Act are found along reaches of upper and lower Cienega Creek and in the nearby cienegas. Cienegas were historically more abundant within the Sky Island Region of southeastern Arizona and the arid-southwest. Their ecohydrological condition can serve as indicators of the status of arid and semiarid watersheds within the Madrean Ecoregion. Many factors have contributed to the decline of cienegas including the extirpation of beavers in the 19<sup>th</sup> century, overgrazing with the resulting downcutting of arroyos, surface water diversions and groundwater pumping. Currently population growth with concomitant well water extraction, cycles of drought, resource extraction (e.g., the proposed Rosemont copper mine) and climate change will place further stress on limited groundwater resources.

In order to assist land managers and policymakers in making informed decisions about how to effectively model, monitor and manage the precious water and habitat resources and to provide baseline hydrogeological data is essential for securing both surface and groundwater water rights from the Arizona Department of Water Resources, we propose to build on our previous work at LCNCA. Specifically, we plan to:

- 1) Determine how sensitive the cienegas are to groundwater change by investigating the

hydrologic connections between groundwater and surface water and how long it takes cienegas to be recharged.

2) Expand a monitoring network of water level data loggers to document short- and long-term groundwater trends.

3) Determine the habitat quality data of open-water cienegas by using remote wildlife cameras to record their use by wildlife, especially waterbirds.

This proposal directly addresses the “research synthesis theme” by generating and synthesizing a diverse array of scientific data in order to improve best management practices by directly informing pertinent and pressing management questions for the NCA.

#### **Research questions/hypotheses:**

*Water source and age* – The cienegas and Upper Cienega Creek may be fed by direct precipitation, shallow groundwater and/or more regional basin groundwater. To determine how sensitive these wetlands may be to changes in climate, land use and/or groundwater pumping, it’s important to distinguish the source of water to the wetlands; hydrologic connections between groundwater and surface water; and how long it takes for the wetlands to be recharged (i.e. water “age”). Groundwater “age” tracers, such as carbon-14 and tritium, can be used to determine the residence time of water from <5 years old to ~50,000 years old, when combined with major ion chemistry and carbon stable isotopes of dissolved inorganic carbon (DIC). Major ion chemistry (anions and cations) has been used in adjacent basins, such as the San Pedro River Basin, to distinguish monsoon flood recharge versus basin groundwater to stream discharge and floodplain aquifers. In addition, variability in climate between years (e.g. relatively wet winters or summers) may influence the source of water to the wetlands. This study utilizes solute chemistry and “age” tracers to determine the source of water to wetlands in the Upper Cienega Creek watershed, the residence time of shallow and deep groundwater, and hydrologic connectivity between surface and ground water.

*Groundwater levels* – It is essential to have reliable, accurate, and sustained groundwater monitoring to provide the necessary information to understand how groundwater systems respond to climate, land use and/or groundwater extraction. Long-term hydrographs with high measurement frequencies enable the comparison of drought-depressed water tables that are restored by post-drought rainfall versus long-term declining groundwater levels that are indicated by human-caused groundwater depletions from wells. This study aims to expand and fill-in gaps within an existing a network of water level data loggers at LCNCA (both those installed by us previously and those installed and monitored by BLM) to provide a robust monitoring framework as a key element of sustainable groundwater resource management.

*Wildlife use of cienegas* – Wetlands provide critical habitat for both aquatic and terrestrial wildlife. Yet, the long-term documentation of the use of cienegas by wildlife, especially waterbirds, is lacking in the scientific literature. The reduction in wetlands as wintering and migratory habitat in Arizona has been dramatic. Therefore, it is essential that management strategies include consideration of enhancing wetland habitat for all wetland species. This requires careful study of the basic habitat requirements of all waterbirds. This study seeks to use remote wildlife cameras to document the use of open-water cienega habitat by wildlife, especially waterbirds. The data acquired by the cameras can also be used to assess how disturbances, such as grazing and fire affect the “quality” of the cienega habitat for all kinds of wildlife. It is hypothesized that the importance of cienegas as wildlife habitat is considerably underappreciated

**Research methods:**

*Sample collection* – A total of 208 water samples will be collected. The samples will be collected four times a year, in the spring, summer, fall and winter, for two years from surface waters: six sample sites from along Upper Cienega Creek; eight sample sites from Cienegas; and five sample sites from springs. Water samples will be collected two times a year, in the summer and winter, for two years for shallow groundwater sources from fourteen sample sites.

*Field methods* – Groundwater and surface water samples will be collected following typical United States Geological Survey protocol. The location and elevation of samples will be recorded using GPS. Temperature, pH, dissolved oxygen and conductivity will be measured in the field using existing equipment from Dr. McIntosh's research group. Water will be filtered and preserved for laboratory analysis.

*Laboratory methods* – Water samples will be analyzed for major ion chemistry in Dr. McIntosh's water quality laboratory at UA in the Department of Hydrology and Water Resources. Alkalinity will be determined by Gran-Alkalinity titrations within 12 hours of sample collection. Anions will be analyzed using Ion Chromatography, while cations will be analyzed using Inductively Coupled Plasma (ICP)-Optical Emission Spectrometry. Sulfur and oxygen isotopes of sulfate, and tritium will be analyzed by isotope ratio mass spectrometry, and liquid scintillation spectrometry in the Environmental Stable Isotope Laboratory at UA, Department of Geosciences.

*Pressure transducers* – Seven Onset HOB0® water level data loggers (i.e., pressure transducers) will be installed in summer 2017 in cienegas, existing piezometers, and springs, to complement a network of eight existing transducers we have previously installed. Data will be downloaded two times a year and analyzed using HOB0ware software.

*Wildlife cameras* – Two Reconyx Hyperfire HC600 wildlife cameras will be installed in summer 2016. Both cameras will be placed such that they can capture wildlife using open-water cienega habitat. One camera will be installed at Cinco ponds, the other at Springwater Cienega. Camera cards will be downloaded and batteries will be replaced quarterly. Data analysis of the images will be conducted by DBG volunteer, David McCarrol, who has experience in bioinformatics.

**Results to date:**

Funds from a previous NLCS grant have enabled us to provide geospatial, water stable isotopes and wildlife use data of cienegas at LCNCA. We generated a ground-truthed GIS map of all the cienegas at LCNCA. Our measurements provided BLM with a highly accurate and quantifiable document of where these valuable cienegas are. With a total cienega area of just 32 acres out of 45,000 acres for the entire LCNCA these extremely rare habitats comprise just 0.071% of the landscape. The GIS shapefiles we generated were shared with BLM.

Preliminary water stable isotope data for the Cienegas, Upper Cienega Creek, springs, and local, shallow groundwater show evidence for hydrologic connection between the cienegas and creek with shallow groundwater (piezometers), and deeper basin groundwater (wells). The well water has a relatively wide range of  $\delta^{18}\text{O}$  and  $\delta\text{D}$  values from -12.4 and -81 ‰ to -6.1 and -50 ‰, respectively, clustered near the local meteoric water line (LMWL), suggesting possible mixing of various water sources (e.g. summer monsoon recharge versus winter precipitation and/or basin groundwater). There is no evidence of evaporation or a seasonality signature (Fig. 1a). Shallow groundwater has a similar range of  $\delta^{18}\text{O}$  values (-11.9 to -7.1‰) as deeper groundwater (Fig. 1b), suggesting shallow and deep groundwater in the alluvial aquifer are hydrologically connected. More seasonal sampling of the shallow piezometers, and comparison with local winter and summer precipitation, is needed to test this hypothesis and determine if shallow groundwater responds to seasonal changes in recharge. Groundwater age tracers, such as tritium and carbon-14, and major ion chemistry would also help

determine the residence time of the water and confirm that shallow and deep groundwaters are hydrologically connected in the study area.

The Cienegas and springs have a very wide range of  $\delta^{18}\text{O}$  and  $\delta\text{D}$  values (-10.4 to 8.6‰, and -71 to 13.7, respectively; Fig. 1c-d); the lowest values are within the range of local shallow and deep groundwater, while the highest values indicate significant evaporation during the warmer months (April-October), plotting to the right of the LMWL. Upper Cienega Creek has  $\delta^{18}\text{O}$  values (-9.9 to -4.2‰; Fig. 1e) within the range of shallow and deep groundwater although slightly more positive during the warmer months; this could be due to discharge of basin groundwater mixed with summer monsoon flood recharge (which is isotopically enriched compared to winter recharge), and/or evaporation. Additional seasonal sampling of the cienegas, springs and creek, and addition of major ion chemistry will help to distinguish the source, mixing, degree of evaporation, and relative “age” of waters.

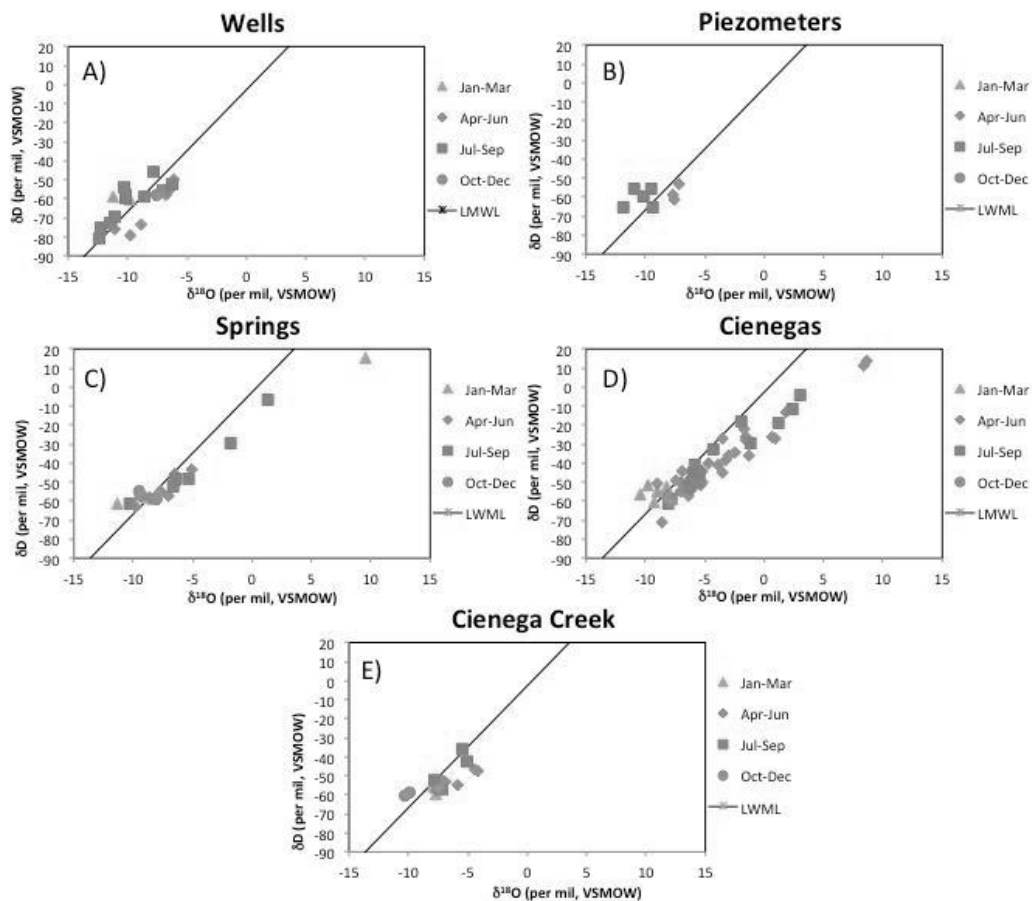


Figure 1. Preliminary oxygen and hydrogen isotope data of various water types in the Upper Cienega Creek watershed. Samples are divided by season and show relative to the local meteoric water line (LMWL) developed using precipitation isotope data for the eastern side of the Santa Rita Mountains (Hudbay Minerals, unpublished data).

Preliminary data from a remote wildlife camera set up at Empire 1 cienega indicates that the seasonally of open water habitat of even smaller cienegas is important for migratory waterbirds (Fig. 2). This data is important for land managers because some sort of disturbance (e.g. fire or grazing) is necessary to

decrease the vegetation encroachment on open water habitats. Additionally, a movie of the natural history of the cienega was made, using one image taken at the same time from every day of the year, as a means of easily seeing the seasonality of the water levels, wetland plant phenology, grazing intensity and water level fluctuations in response to rainfall. We show this movie to audiences when we give scientific and public presentations of our research and it has been very well received.

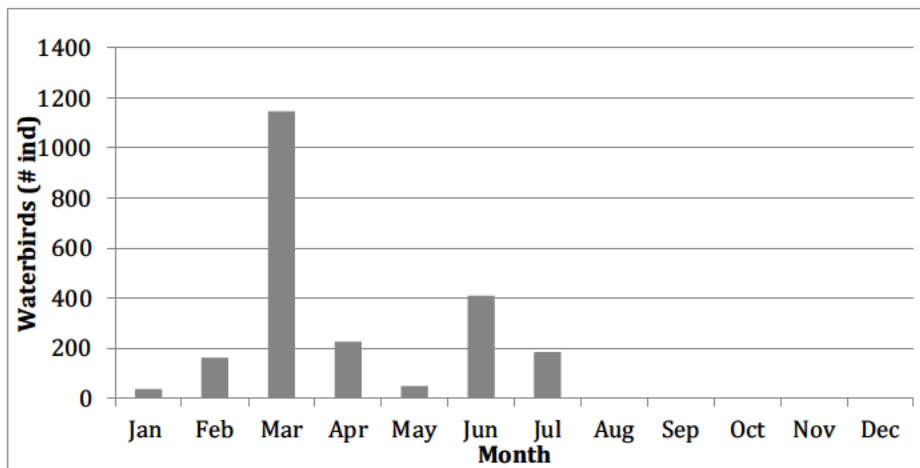


Figure 2. Two years of combined remote wildlife camera photographic documentation of waterbirds use of open water at Empire Cienega at Las Cienegas NCA showing the high use of cienegas by migratory waterbirds in the month of March. This cienega does not have open water habitat from August – November.

## Project Timeline

### Year 1 = 2017-2018

April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March
Collect water samples			Collect water samples			Collect water samples			Collect water samples		
	Analyze water samples										
	Present at Science on the Sonoita Plain	Water data interpretation									
		Install wildlife cameras				Download camera data & service				Download camera data & service	Submit Annual Progress Report
		Install pressure transducers								Download pressure transducer data	
										Analyze camera & transducer data	
										Interpret camera & transducer data	

**Year 2 = 2018-2019**

April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March
Collect water samples			Collect water samples			Collect water samples			Collect water samples		
Analyze water samples											
Present at Science on the Sonoita Plain	Water data interpretation										
	Download camera data & service			Download camera data & service			Download camera data & service		Download camera data & service	Submit Final Report & Manager's Summary	
	Download pressure transducer data	Develop draft manuscript for peer reviewed journal							Download pressure transducer data		
	Analyze camera & transducer data							Analyze camera & transducer data			
	Interpret camera & transducer data							Interpret camera & transducer data			

**Benefits of project for BLM management:**

Cienegas and Riparian Vegetation are two of the Conservation Values of Las Cienegas National Conservation Area. The objectives of this project help to support the unit's mandate in its enabling legislation to protect and enhance these Conservation Values and to maintain viable populations of Threatened and Endangered species that depend on these habitats. This research project would provide critical data to help inform efforts to conserve, protect and restore cienega habitat. Our work places emphasis on resources at risk and will benefit many "stakeholders" including Bureau of Land Management, U. S. Fish and Wildlife Service, Arizona Game and Fish Department, Pima County Flood Control District and Pima County Sonoran Desert Conservation Plan.

**Deliverables:**

- 1) Annual progress report, final report and manager's summary to BLM (see timeline).
- 2) Peer-reviewed manuscript on the hydrogeochemical analysis on the age and sources of the waters at LCNCA (Spring 2018).

**BLM point person for project:** Karen Simms, Assistant Field Manager, [ksimms@blm.gov](mailto:ksimms@blm.gov), 520-258-7233.

**Partner qualifications, affiliation, and contact details:**

**Andrew Salywon**, Ph.D., Desert Botanical Garden, 1201 N. Galvin Parkway, Phoenix, AZ 85008. Phone: (480) 481-8107. Email: [asalywon@dbg.org](mailto:asalywon@dbg.org)

Andrew Salywon is Assistant Herbarium Curator and Research Botanist with over 25 years of field biology experience in Arizona including riparian plant ecology. Specific experience includes remote camera trapping of wildlife and wildlife habitat, water quality and isotopic analysis and using GIS to provide geospatial information on the hydrogeology and ecology of wetlands, springs and groundwater at Las Cienegas National Conservation Area. He has worked closely with Jennifer McIntosh in

interpreting the initial water isotope dataset.

**Ronald Tiller**, Ph.D., Desert Botanical Garden, 1201 N. Galvin Parkway, Phoenix, AZ 85008. Email: [rl\\_tiller@hotmail.com](mailto:rl_tiller@hotmail.com)

Ron Tiller is a Plant Ecologist/Hydrologist with over 21 years of ecological research and monitoring experience in semi-arid riparian, grassland, wetland communities of southeastern Arizona. Researched riparian grassland ecology and plant water source acquisition via stable isotopic analysis across upper San Pedro River and upper Santa Cruz River watersheds, including Cienega Creek. Established a groundwater well and piezometer monitoring network across Las Cienegas National Conservation Area. Mapped riparian grasslands and classified their ecological site condition in the upper Cienega Creek basin. Mapped the extent and distribution of cienega wetlands and collected water samples for analysis of stable isotopes for determining cienega water sources. He has worked closely with Jennifer McIntosh in interpreting the initial water isotope dataset.

**Jennifer McIntosh**, Ph.D., Associate Professor, Hydrology and Water Resources, University of Arizona, Tucson, AZ 85721. Email: [jenmc@email.arizona.edu](mailto:jenmc@email.arizona.edu)

Jennifer McIntosh is an Associate Professor in the Department of Hydrology and Water Resources (HWR) at the University of Arizona, and joint faculty in Geosciences and the USGS. She also directs the HWR Water Quality Laboratory. Her areas of expertise include hydrogeochemistry, water quality, and isotopes. She has published over 57 articles in peer-reviewed journals using chemistry and isotopes to trace the origin, transport and reaction of fluids, solutes and gases in the environment. In SE Arizona, McIntosh used natural tracers to determine the source of recharge, flowpaths, and residence times of groundwater in the Middle San Pedro Basin; source of natural arsenic contamination in the Wilcox Basin; and affects of urbanization on groundwater quality and recharge rates along the Rillito Wash in the Tucson Basin. She has collected preliminary isotope and age tracer data from domestic water supply wells in the Davidson Canyon area of the Cienega Creek watershed working with a MS student (Rachel Tucci), and has worked closely with Ron Tiller and Andrew Salywon on interpretation of their initial water isotope dataset.