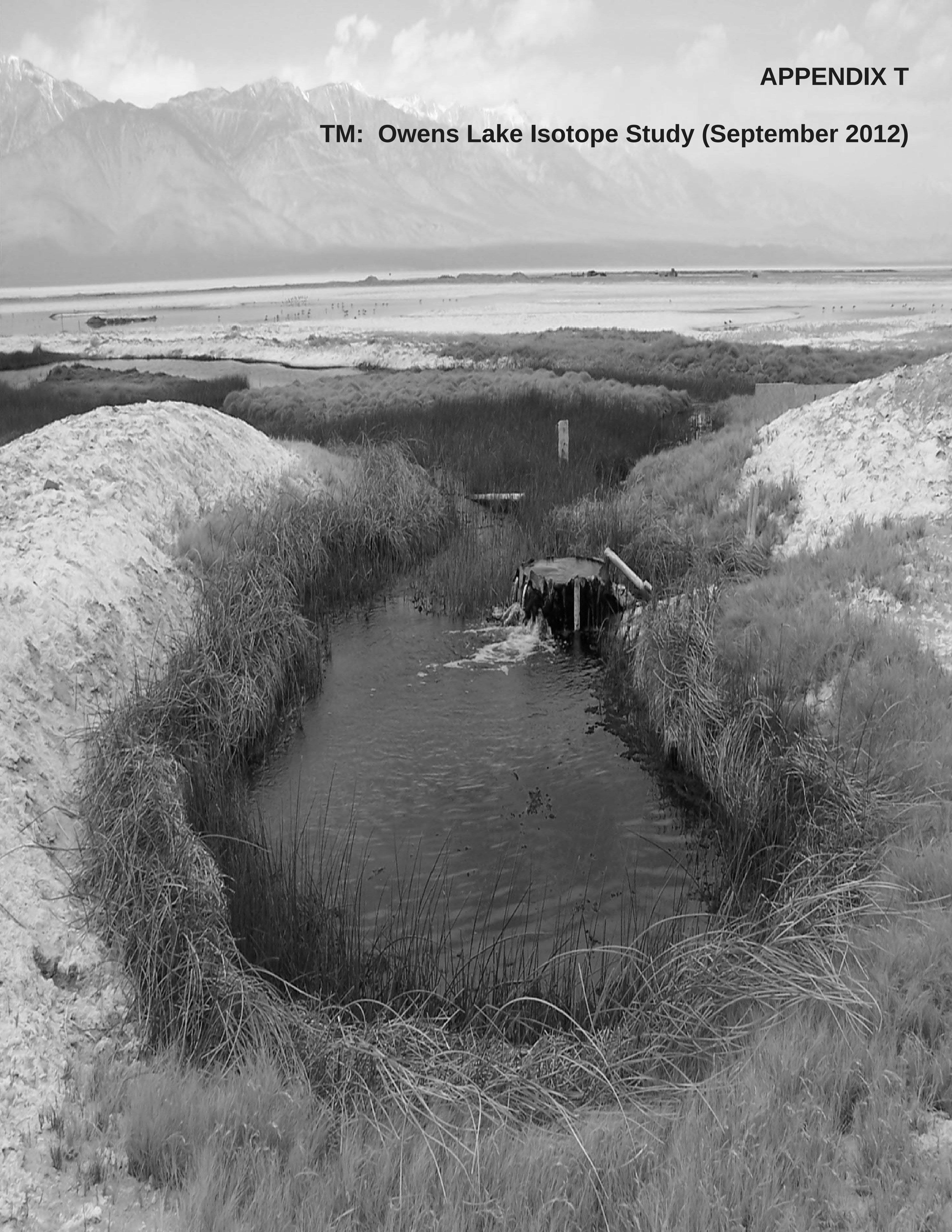
APPENDIX T

TM: Owens Lake Isotope Study (September 2012)



September 2012

Owens Lake Isotope Study Technical Memorandum

DEPARTMENT OF WATER AND POWER

MWH.

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LIST OF ACRONYMS AND ABBEVIATIONS

^{12}C	carbon-12
^{13}C	carbon-13
^{14}C	radiocarbon
^{16}O	oxygen-16
^{18}O	oxygen-18
^{3}H	tritium
^{3}He	a naturally-occurring rare isotope of helium
^{4}He	a naturally-occurring abundant isotope of helium
Ar	argon
Cl	chloride
CSD	community service district
D	deuterium
DIC	dissolved inorganic carbon
fmsl	feet above mean sea level
GAMA	Groundwater Ambient Monitoring and Assessment
GMWL	Global Meteoric Water Line
H	hydrogen
He	helium
Kr	krypton
LADWP	Los Angeles Department of Water and Power
meq	milli-equivalents
mg/L	milligram per liter
NA	sodium
Ne	neon
NG	Noble Gas
OLGEP	Owens Lake Groundwater Evaluation Project
PDB	PeeDee Belemnite
per mil	parts per thousand
pmc	percent modern carbon
R	isotope ratio
SAP	Sampling and Analysis Plan
SMOW	Standard Mean Ocean Water
STP	standard temperature (20°C) and pressure (1 atmosphere)
TM	Technical Memorandum
TU	tritium units or number of ^{3}H atoms per 10^{18} hydrogen atoms
uS	microSiemens
USGS	U.S. Geological Survey
Xe	xenon
$\delta^{13}C$	carbon-13 as a per mil deviation from standard
$\delta^{18}O$	oxygen-18 as a per mil deviation from standard
δD	deuterium as a per mil deviation from standard

EXECUTIVE SUMMARY

The purpose of this Technical Memorandum (TM) is to present the results of the Isotope Study conducted under Task 401.1.9.2 of the Owens Lake Groundwater Evaluation Project (OLGEP). The location for this investigation is the Owens Lake study area bounded by approximately Lone Pine to the north and Haiwee Reservoir to the south. Groundwater, surface water, and/or spring water from twenty-eight sites was sampled in July 2012 for a combination of:

- Cations and anions,
- Stable isotopes,
- Radiocarbon,
- Tritium, and/or
- Noble gas.

Isotope measurements in groundwater are conducted for two specific reasons: 1) to determine the source region of groundwater recharge and 2) to determine the age of the water. Prior to sampling, a Sampling & Analysis Plan was developed (MWH, 2012) that outlined the specific goals of the study, including:

1) Determine how uniform groundwater isotopic signatures were in groundwater beneath Owens Lake,
2) Define the isotopic character of springs and shallow wells on the west side of Owens Lake and how they may be related to deeper groundwater beneath the lake, and
3) Determine the isotopic character of shallow groundwater on the east side of the lake.

The SAP provided an initial interpretive model based on pre-existing data in the study area. Based on the results of the sampling and analysis program, this TM articulates findings relative to the goals of the study and further advances the interpretation of recharge sources and ages and how they inter-relate.

To summarize, this limited isotopic study was successful in meeting the goals outlined in the SAP and improved the hydrogeologic conceptual model in several ways. Selected key findings that contribute to an update of the conceptual hydrogeologic understanding of the study area include:

1) The δD-$\delta^{18}O$ results demonstrate that the dilute west side waters are recharged by stream channel infiltration originating from the higher elevations of the eastern Sierra Nevada. This is further supported by the similarity in isotope abundances between measured creek samples and local groundwater and springs.
2) The δD-$\delta^{18}O$ of sampled OLGEP monitoring wells (except site DWP-7) demonstrates that they are not recharged locally, but rather their lower isotopic values are consistent with isotopic values of recharge sources further north. In other words, water in OLGEP monitoring wells is consistent with a down-valley flow source.

3) Based on the δD-$\delta^{18}O$ results, it can be concluded that groundwater at OLGEP well site DWP-6 located in the southeastern portion of Owens Lake was recharged by significantly evaporated surface water. This suggests that historically, ponded water may have recharged groundwater aquifers locally in the southern portion of the Owens Lake area.
4) Based on the geographic distribution of groundwater $\delta^{18}O$ values in the OLGEP study area, mapped faults beneath the western side of Owens Lake are likely limiting groundwater movement between west side recharge and down-valley flow sources.
5) The δD-$\delta^{18}O$ values for springs and shallow wells located on the east side of Owens Lake are generally the same as those for OLGEP monitoring wells recharged by down-valley flow, which indicate a similar isotopic and geochemical character. However, there are some differences observed in the isotopic values, such as in DWP-3/T899, that suggest locally-recharged groundwater does contribute to some recharge on the east side.
6) Groundwater ages measured for springs and shallow wells on the west side of Owens Lake were found to be less than 300 years old.
7) Groundwater from three sites (Cottonwood Spring NW, LADWP Cottonwood Plant Well, and Cartago-CSD) was found to be less than 50 years old.
8) Calculated ^{14}C groundwater ages ranged from approximately 6,800 years to greater than 40,000 years in OLGEP monitoring wells that are recharged by down-valley flow, as well as sample sites on the east side of Owens Lake.
9) The ^{14}C measured in OLGEP well site DWP-9 was heavily influenced by active methane production at depth, and age-dating is highly uncertain.

Future isotopic and general water quality sampling and analysis may prove useful for shedding light in key areas:

1) Previous sampling by GBUAPCD, LADWP, and others utilized varying sample suites for cations and anions. A uniform sampling and analysis plan for general minerals (cations and anions) across the study area could provide a useful baseline of water quality. General minerals could also be used as a simple monitoring tool for potential migration of saline water into less saline groundwater following a change in groundwater use patterns.
2) Better resolution for recharge sources of down-valley could be provided by additional measurements of δD and $\delta^{18}O$ conducted on a number of surface and groundwater sites in suspected recharge areas and along flow-paths leading to the OLGEP study area.
3) Better age-dating of down-valley flow may be provided by sampling for ^{14}C and noble gases at OLGEP monitoring well sites DWP-1 and DWP-11 (or similarly accessible wells with well-known depths) and/or down-valley flow sites east of the Owens River where there is well construction data and control on the depth of sampling. However, the sampled wells should be absent of free gas of the type that was observed in site DWP-9.
4) Faulting in the eastern side of Owens Lake that influences groundwater migration could be further defined by additional samples collected for δD and $\delta^{18}O$, particularly for any wells that might be upgradient of the lake level or adjacent wells with distinctly

different depths. This will help establish the influence of any locally recharged groundwater flowing towards Owens Lake, and whether this locally-recharged groundwater comingles with down-valley flow.

5) Because δD-$\delta^{18}O$ measurements are diverse enough among the different recharge sources, additional measurements could be used as a simple and inexpensive groundwater recharge mapping tool.

1.0 Introduction and Study Goals

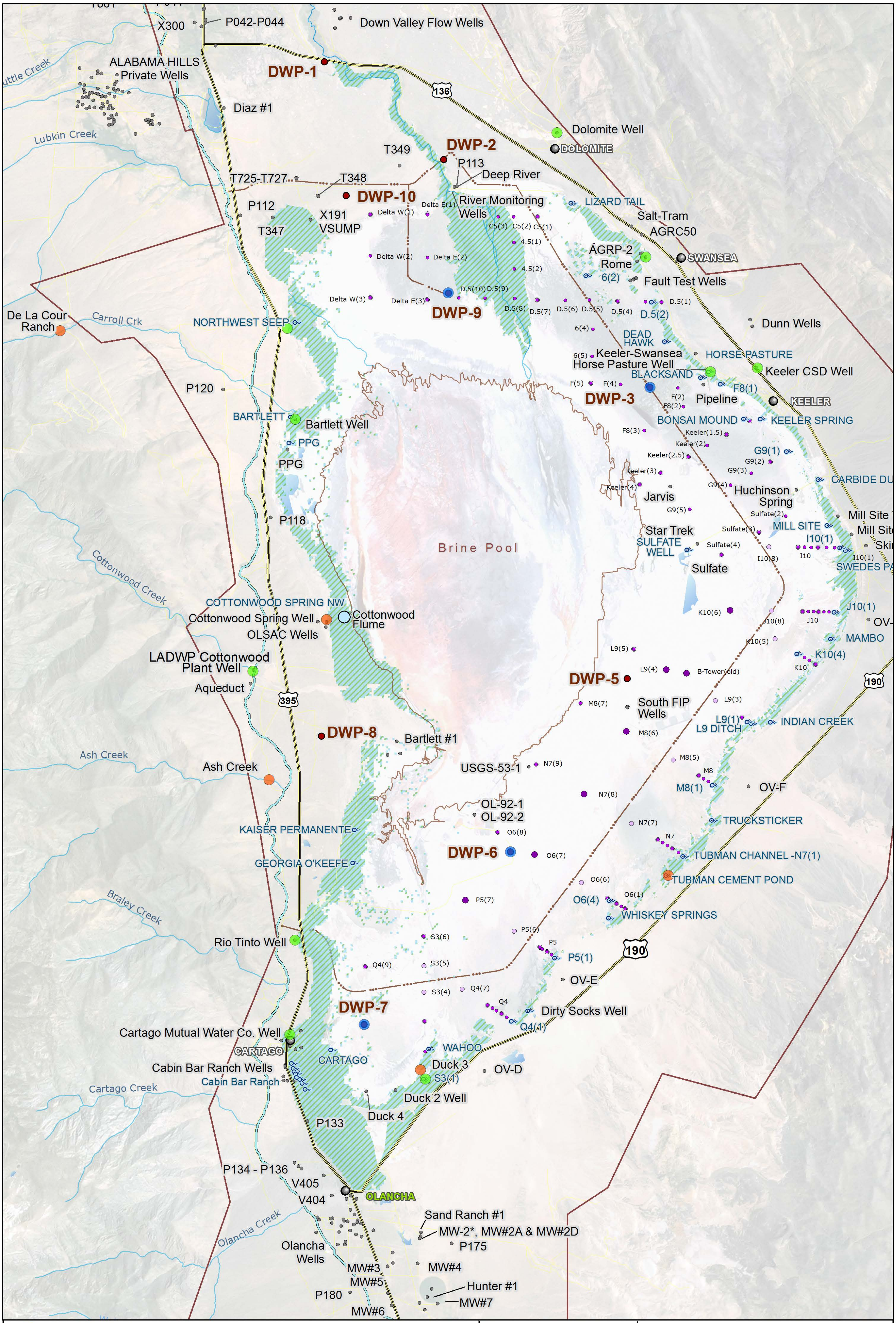
The Owens Lake Groundwater Evaluation Project (OLGEP) was initiated in March of 2009. This project involves 10 tasks:

Task 401.1.1	Data Compilation
Task 401.1.2	Data Evaluation and Identification of Data Gaps
Task 401.1.3	Assist in the Collection of Field Data
Task 401.1.4	Update Conceptual Hydrogeologic Model
Task 401.1.5 and 401.1.10	Numerical Groundwater Model Update and Development
Task 401.1.6	Model Simulations and Alternative Analysis
Task 401.1.7	Develop and Implement a Public Outreach Plan
Task 401.1.8	Project Meetings/Final Report
Task 401.1.9	Geophysical Analysis and Isotope Analysis

The first six tasks are generally sequential, while the last two tasks have periodic activity throughout the project. A preliminary groundwater model and associated model documentation technical memorandum (TM) was completed in February 2012 for the OLGEP study area (see **Figure 1**) and for review by Partner Agencies and the Blue Ribbon Panel. The model was used to evaluate alternatives for production of groundwater at Owens Lake. At present, this model is being updated and will be used for defining and selecting a preferred alternative.

Recent meetings with Partner Agencies and other stakeholders highlighted the need to characterize groundwater recharge sources and age. This is particularly important in understanding the source waters for springs and seeps, and ultimately, improvement of the conceptual understanding and numerical modeling of the effects that pumping has on groundwater discharge areas.

Sampling of surface and groundwater for a variety of constituents (including isotopes) has been used successfully to evaluate the origin of water flowing to springs or seeps, or to characterize mixing (or lack of mixing) of separate hydrostratigraphic zones in other locations in the Owens Valley (MWH, 2004). The installation of 28 new deep monitoring wells during earlier phases of the OLGEP project (hereby referred to OLGEP wells) provides an opportunity to characterize deeper groundwater and correlate this groundwater with surface discharge sources.



- 🟠 Stable Isotope Sampling
- 🟢 Stable Isotope, Radiocarbon, Tritium Sampling
- 🔵 Stable Isotope, Radiocarbon, Tritium, and Noble Gas Sampling
- ○ Flume Sampling
- • Piezometer - 4ft
- ○ Piezometer - 10ft
- ● Piezometer - 30ft
- ● OLGEP Monitoring Well Cluster
- • Existing Well
- ● Town
- ▨ Wetland
- ▭ OLGEP Study Area
- ▭ Other Water Bodies
- — Mainline
- — Highways
- — Los Angeles Aqueduct
- — River/Stream
- — Road

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Sampling and Analysis Plan for
Owens Lake Groundwater
Evaluation Project

Site Location Map Showing Isotope Study Sampling Locations

Los Angeles Department of Water & Power

Figure 1

MWH

This map has been designed to print size 11'' by 17''.

The purpose of Task 401.1.9.2 entitled, *"Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas"* was to:

1) Review previous isotopic and contemporaneous associated general mineral sampling in the OLGEP study area and develop an isotope conceptual model for the study area.
2) Based on this data, develop a sampling and analysis plan (SAP) (MWH, 2012) to characterize the source waters of the most significant aquifers at depth and the most significant groundwater discharge locations, better define recharge amounts and sources, and to understand the source water or origin of springs.
3) Perform targeted sampling of selected monitoring wells and surface discharge areas at locations shown on **Figure 1**.
4) Evaluate and report the sampling results in a technical memorandum (this document) detailing new information provided by the sampling that improves the understanding of the age and origin of deep groundwater and selected springs and seeps.

Implementation of this task serves as a pilot study to demonstrate the feasibility of isotopes for characterization of spring sourcing in the OLGEP study area and is not intended to be an exhaustive investigation.

This TM represents the final deliverable of the Isotope Study (Item No. 4 above). The TM takes into consideration and is complementary to previous isotopic and general chemistry sampling performed by Lopes (1988), Font (1995), MWH (2004), Great Basin Unified Air Pollution Control District (2009), Densmore et al. (2009), and LADWP (reported by MWH, 2011).

2.0 Background

Isotope measurements in groundwater are conducted for two specific reasons:

- To determine the source region of groundwater recharge, and
- To determine the age of the water.

The most common isotope measurements for determining recharge source are deuterium (D) and oxygen-18 (^{18}O). These measurements prove useful because they are intrinsic properties of the water molecules; they are stable and do not undergo atomic change as in radioactive isotopes; and their abundances systematically vary in atmospheric precipitation with changing latitude (i.e., temperature) and elevation.

For age-dating of groundwater, the most commonly used tools are radioactive isotopes of tritium (^{3}H) and radiocarbon (^{14}C). Tritium has a radioactive half-life of 12.43 years, making it ideal for dating recharge less than 50 years old. Radiocarbon has a half-life of 5,730 years and has been used to distinguish much older groundwater at depth, particularly in regional groundwater systems. Inherent problems with ^{3}H age dating is the fact that accurate ages require knowing how much ^{3}H was in the water at the time of recharge. Unfortunately, with surface testing of nuclear weapons in the 20th century, atmospheric ^{3}H varied over an order of magnitude, heavily influencing input values of recharging groundwater. Consequently, the presence or absence of ^{3}H in a groundwater has been the default method for determining whether recent recharge (<50 years old) is incorporated in particular water, but with no particular date of recharge.

Radiocarbon is a common tool in archeological and tree ring studies, and has been used extensively in groundwater. The ^{14}C is measured in the dissolved inorganic carbon (DIC). Unfortunately, DIC can easily undergo reactions in aquifers such as precipitating carbonate minerals, dissolving ^{14}C-absent carbonate minerals within the host lithology, or simply exchanging with them. When carbonate is present in soils or aquifer rocks (very common in the western US), DIC will react readily with them, resulting in decrease of the ^{14}C abundance that is unrelated to radioactive decay. The stable isotope carbon-13 (^{13}C) can be used to determine the extent of these reactions, providing they are isotopically distinct from the original DIC ^{13}C abundance at the time of recharge. Note that for ^{3}H, geochemical reaction is not a problem because ^{3}H is part of the water molecule (see Clark and Fritz, 1997 for additional background information).

More recently, the measurement of noble gases (helium, neon, krypton, and xenon) that naturally dissolve in recharging groundwater have provided additional recharge source and age-dating methods. An accurate measurement of helium isotopes allows the determination of the amount of ^{3}H that has already decayed because ^{3}H radioactively decays to the stable helium-3 (^{3}He) isotope. Consequently, the amount of ^{3}H that was present at the time of recharge can be calculated and accurate age dates can be determined. Furthermore, the amount of stable helium-4 isotope (^{4}He) dissolved in groundwater can be a semi-quantitative age-dating method of a similar range as ^{14}C. The ^{4}He originates from steady-state accumulation in groundwater due to production and diffusion upward of uranium and thorium alpha particle decay (alpha particles are ^{4}He atoms) in crustal rocks. Note that in areas of active volcanoes, the ^{3}He and ^{4}He can be significantly altered by emission of volcanic gases in the subsurface. This will usually dissolve an abnormal amount of He in the groundwater with an excess of ^{3}He compared to crustal rocks. Lastly, because the absolute noble gas abundance dissolved in water is temperature dependent, a method has been developed to also determine the recharge temperature of a groundwater. In the case of geographic areas like Owens Valley, that recharge temperature will be largely elevation dependent (see Mazor, 2003 for additional background information).

An accepted approach for reporting the abundance of D, ^{18}O, and ^{13}C entails reporting them as a ratio to their abundant isotope in the element (H, ^{16}O, and ^{12}C) and converting the ratio to a parts per thousand (per mil) deviation from internationally recognized standards. This per mil deviation defined as

$$\delta = \left(\frac{R}{R_s} - 1\right)1000,$$

where δ (del) is the per mil deviation, R is the isotope ratio (D/H, $^{18}O/^{16}O$, or $^{13}C/^{12}C$) measured in a sample, and R_s is the isotope ratio of the standard. For D and ^{18}O, the standard is Standard Mean Ocean Water (SMOW), and for ^{13}C is PeeDee Belemnite (PDB, a marine calcium carbonate). Because continental water is usually depleted in D and ^{18}O relative to ocean water, the δ values are commonly negative. The remainder of this TM will refer to stable isotope results in δ form and per mil as commonly reported in the literature.

3.0 Previous Work

Table 1 lists the reports reviewed as part of this study. Each report is briefly summarized herein and was used to develop a preliminary interpretive model presented in the SAP (MWH, 2012) and the updated interpretive model presented in this TM.

Table 1
Summary of Previous Isotopic Studies Reviewed

Study	Isotope Measurements	Basis
Inyo/LA Geochemical Cooperative Study (MWH, 2004; Bassett et al., 2008)	δD, $\delta^{18}O$, $\delta^{11}B$, $\delta^{34}S$, 3H	Investigated possible influence of groundwater pumping on associated spring flows and provide supportive evidence for hydrogeological model.
U.S. Geological Survey (Densmore et al., 2009)	δD, $\delta^{18}O$, 3H, $\delta^{13}C$, ^{14}C, NG	Performed for State Water Resources Control Board's GAMA program: http://www.swrcb.ca.gov/gama/
Font (1995)	δD, $\delta^{18}O$, $\delta^{13}C$, ^{14}C, $^{87}Sr/^{86}Sr$	Trace sources of recharge and develop evaporation model for Owens Lake.
Lopes (1988)	δD, $\delta^{18}O$	Develop hydrologic mass balance of Owens Lake and process of salt crust formation.
Ingraham and Taylor (1991)	δD, $\delta^{18}O$	Sampled precipitation along transects from coastal California to western Nevada.
Friedman et al. (1970; 1992; 2002)	δD, $\delta^{18}O$	Comprehensive precipitation collection and measurements through southeastern California and Nevada.

The most comprehensive isotope investigation of groundwater in the Owens Valley was conducted as part of the Inyo/LA Geochemical Cooperative Study, which investigated the possible influence of groundwater pumping on associated spring flows and provided additional supportive evidence for hydrogeological modeling. The study was confined to the upper and middle parts of the Owens Valley and does not overlap the lower Owens Valley/Lake area in this present study. However, some important conclusions were developed in this study. For instance, the presence of measureable ^{3}H in many of the well waters collected indicated that relatively young groundwater was being produced. Many wells had large screened intervals that intersected shallow depths, supporting the conclusion that sampled groundwaters were a mixture of younger and older water. The presence and absence of ^{3}H in springs was diagnostic of deeper versus shallow groundwater discharge. However, the δD and $\delta^{18}O$ values were not diagnostic of different recharge sources, nor based on the report's conclusion, indicative of evaporation. Reliance on the $\delta^{11}B$ and $\delta^{34}S$ values subsequently provided much of the geochemical evidence of similarities and differences between spring discharge and wells, as well as the influence of local faults on groundwater flow.

A more recent groundwater investigation by the U.S. Geological Survey (USGS) collected groundwater from 53 individual wells throughout the Owens Valley, including the Owens Lake area (Densmore et al., 2009). This work was performed under the State Water Resources Control Board's Groundwater Ambient Monitoring and Assessment program (GAMA). Analysis included a full suite of isotope data involving δD, $\delta^{18}O$, $\delta^{13}C$, ^{14}C, and noble gases. All data except for the noble gas results have been published, but data interpretation by the USGS is forthcoming. Nevertheless, data have been tabulated and independently interpreted for the purposes of this study.

Font (1995) and Lopes (1988) independently conducted graduate thesis research of shallow groundwater below Owens Lake. Both studies sought to understand water mass balance, and in the case of Font (1995) to determine source regions of recharge. Font used a method to calculate the extent of water evaporation from the evaporated values of δD and $\delta^{18}O$. Font also used strontium isotope measurements to delineate recharge derived from the Sierra Nevada to the west from that derived from the east. In the case of Lopes (1988), limited stable isotopes of water were measured, and only general statements about possible origins of recharge were proposed. The main body of work was dedicated to evaporative enrichment and salt chemistry.

Several studies measuring δD and $\delta^{18}O$ of atmospheric precipitation in the Sierra Nevada, southeastern California, and Nevada have been conducted. Friedman et al. (1970) did initial work characterizing the change in rain and snow isotope abundances on the western slope of the Sierra Nevada and showed the systematic depletion of these abundances with increasing elevation. Ingraham and Taylor (1991) mapped similar trends for three transects extending from coastal California through Nevada. The southernmost transect passes through the Owens Valley. Friedman et al. (1992; 2002) collected and measured δD and $\delta^{18}O$ values for integrated precipitation samples throughout southeastern California and Nevada over multiple years. They showed that a systematic depletion of values with increasing elevation did not occur systematically in these regions as was observed on the western slope of the Sierra Nevada Mountains.

The preliminary interpretive conceptual model presented in the SAP (MWH, 2012) has been updated using new data and results from this study (Section 7 - Update of Interpretive Model).

4.0 Sample Collection

Samples collected for this investigation involved surface water runoff, springs, production wells, and monitoring wells as summarized in **Table 2** and shown in **Figure 1**. Details of each collection site are included in **Appendix A**, whereby a site summary sheet presents key information by site (location coordinates, elevation, well information, field data recorded, samples submitted to laboratory, air photo location map, and site photos).

Surface runoff was collected at Carroll Creek (De La Cour Ranch) located northwest of Owens Lake and another at Ash Creek further south along the west side of Owens Lake (**Figure 1**). These samples likely represent baseflow conditions for the streams. Samples for δD and $\delta^{18}O$ were collected at these sites. Sampling entailed filling of a 4-oz glass bottle with a conical-shaped plastic insert inside the cap to provide an air-tight seal. Water was collected from flowing currents in the stream bed to avoid bias from pools undergoing evaporation.

Springs and seeps that were sampled are located in all areas surrounding Owens Lake with the exception of the north side. Spring collection was focused on the western side as well as one location to the southeast. Spring sites were chosen to generate isotope data in areas lacking sufficient coverage in previous studies. Four springs in total were sampled. Three of these springs had somewhat of a diffuse discharge, whereas the fourth location had flowing water from an open standpipe. For diffuse sites, the wettest area was determined, usually designated by saturated soil conditions, and a hand-dug hole approximately 3-feet deep was dug. Water from the hole was bailed, refilling rates were observed, followed by sample collection. Samples for δD-$\delta^{18}O$, ^{3}H, and $\delta^{13}C$ and ^{14}C were collected at these sites. The δD-$\delta^{18}O$ samples were collected in 4-oz glass bottles as discussed above. Tritium was collected in 16-oz glass bottles, and $\delta^{13}C$ and ^{14}C in a single 8-oz glass bottle, both with the same conical-shaped plastic insert inside the cap. Samples were filled after completely submerging bottles underwater and filled gently to avoid air entrainment. For water flowing from a stand-pipe, the same collection method was used, with care taken not to entrain air.

Remaining samples were collected from wells. Five of these were domestic supply wells, four of which had pressurized storage tanks. For smaller tanks (i.e., 20-40 gals) the well was operated for a period of time to discharge stored water so that the most recently pumped water was collected. Cartago CSD fed a much larger storage tank that was impractical to discharge, and stored water likely influenced the collected samples. However, all pressurized tanks were isolated from the surrounding air, and exchange with the water was inferred to be minimized. Rio Tinto was also a domestic supply well, but had no pressurized storage tank at the point of sampling. Two wells were dedicated for agricultural purposes and samples were collected from high volume discharge emitted from a large diameter horizontal pipe downstream of the pump.

In addition, samples were collected for general minerals by LADWP on various surface waters, springs, and wells on the west side of the OLGEP. Data from these samples along with previously-generated water quality data in the OLGEP study area were compiled and are briefly discussed in the context of the isotope results.

Monitoring wells that were sampled include new OLGEP monitoring well clusters completed at different depths in the same location. These were drilled by LADWP specifically for the purposes of hydrogeologic characterization and water quality monitoring associated with the OLGEP. All monitoring wells sampled were artesian, and discharge was collected from a sample port through a 90° ball valve assembly. Wells were purged for approximately 20 minutes until field measurement parameters stabilized. In several of the wells, free gas was associated with the discharge. It was concluded that the gas was associated with aquifer water and not related to well construction or water collection. Methane discharge from deep groundwater beneath Owens Lake is not uncommon. Samples were collected by the same method in glass bottles as discussed above. In two of the three wells from each cluster sampled, noble gases were also collected. This was accomplished by connecting to the sampling port a 3/8” barbed taper fitting that was joined to a flexible 3/8” Tygon tubing and sealed with a hose clamp. The other end of the tubing was sealed to a 3/8” copper tube with a hose clamp. The copper tube was positioned into a dual pinch-clamp assembly that can sequentially create a gas-tight closure of the copper by a cold pinch seal. Downstream of the copper was attached an additional 3/8” Tygon tubing connected to a second 90° ball valve. Water was flowed through the tubing and copper tube at a laminar flow rate. The downstream ball valve was closed down far enough to re-dissolve any free gas in the water. All free air from all tubing was removed by agitation followed by pinch clamping the downstream end of the tube. The upstream end was then clamped to seal an air-free sample inside the copper tube between the two clamps. All noble gas samples were collected in duplicate. Noble gas samples were collected only from OLGEP monitoring wells (see **Table 2; Figure 1; Appendix A**). All samples except DWP-3/T901 were collected successfully with a high degree of certainty that air bubbles were not entrained in the sample. For DWP-3/T901, the free gas present in the water during sampling was excessive, and some level of uncertainty about the quality of the sample was noted.

Table 2
Summary of Isotope Study Sampling Locations

Location	Field Label	Spring	Surface Water	Well	Cations/Anions	Stable Isotopes		Radiocarbon	Tritium	Noble Gas	Rationale
						δD and $\delta^{18}O$	$\delta^{13}C$				
West Side (from north to south)											
De La Cour Ranch (Carroll Creek)	Carroll Crk		x		1	1					Further characterize water on the west side.
Northwest Seep	NW Seep	x			1	1	1	1	1		
Bartlett Well (BRTLTPW)	Bartlett-CW	x		x		1	1	1	1		
Cottonwood Spring NW	Cottonwood Spring	x			1	1	1	1	1		
Cottonwood Spring Well	Cottonwood-Well			x		1					
Cottonwood Flume	N/A (Field data only)		x								
LADWP Cottonwood Plant Well	Aqueduct Well			x	1	1	1	1	1		
Ash Creek	Ash Crk		x		1	1					
Rio Tinto Well	Rio Tinto-SW			x	1	1	1	1	1		
Cartago CSD	Cartago-COM			x	1	1	1	1	1		
Deep Wells (from north to south)											
DWP - 9 T896	DWP - 9 T 896			x		1	1	1	1	1	Determine the source and age differences between aquifer 1 and aquifer 5, or in other words shallow and deep aquifers.
DWP - 9 T897	DWP - 9 T 897			x		1					
DWP - 9 T898	DWP - 9 T 898			x		1	1	1	1	1	
DWP - 3 T899	DWP - 3 T 899			x		1	1	1	1	1	
DWP - 3 T901	DWP - 3 T 901			x		1	1	1	1	1	
DWP - 6 T912	DWP - 6 T912			x		1	1	1	1		
DWP - 6 T911	DWP - 6 T911			x		1	1	1	1	1	
DWP - 6 T913	DWP - 6 T913			x		1	1	1	1		
DWP- 7 T908	DWP- 7 T908			x		1	1	1	1		
DWP- 7 T909	DWP- 7 T909			x		1					
DWP -7 T910	DWP -7 T910			x		1	1	1	1	1	
East Side											
Dolomite Well	Dolomite			x		1	1	1	1		Supplemental data for east side: 1) high discharge spring age and source; 2) up gradient well for recharge source determination; 3) groundwater sample furthest east in the basin for comparison with west side
AGRP Well	Agr-2	x				1	1	1	1		
Keeler CSD Well	KCSD-PW	x		x		1	1	1	1		
Horse Pasture Well (Abandoned)	Horse Pasture			x		1	1	1	1		
S3 (1) (SE Piezometer)	S31			x	1	1	1	1	1		
Duck 3 Well	Duck-CN			x		1					
Tubman Cement Pond	Tubman-CP	x				1					
				TOTAL:	**8**	**27**	**20**	**20**	**20**	**6**	

5.0 Analytical Methodology

Samples were packaged and shipped within 48 hours to Isotech Laboratories Inc. for δD, δ^{18}O, δ^{13}C, and ^{3}H analyses, and preparation of samples for ^{14}C analysis. Noble gas samples were shipped to the Dissolved and Noble Gas Lab in the Geology and Geophysics Department of the University of Utah, Salt Lake City.

The δD-δ^{18}O were measured simultaneously on a Picarro cavity ring-down spectroscopic analyzer, which interrogates water vapor directly through long path length absorption of near-infrared energy emitted by a tunable diode laser system (www.picarro.com). Multiple replicates and internal standards are analyzed daily and calibrated against internationally recognized standards monthly. Precision of δD is ±1 per mil, and for δ^{18}O ±0.1 per mil. The δ^{13}C sample is prepared by acidifying an aliquot of water under closed vacuum conditions to strip dissolved inorganic carbon from the water as carbon dioxide. The carbon dioxide is purified and then run separately on a dual inlet isotope ratio mass spectrometer that sequentially measures ^{13}C/^{12}C ratios of the sample and an internal standard carbon dioxide gas. Precision of the analysis is ±0.1 per mil. Note that for those samples with a suspended sediment load in the bottle, the sample was filtered in the lab prior to acidification to prevent isotopic bias from any carbonate sediments.

The ^{3}H was measured by scintillation counting of the natural beta particle radioactive decay following electrolytic enrichment. This enrichment entails placing a cathode and anode in the water along with a strong electrolyte. The sample is kept sealed from the atmosphere while a current is induced through the water causing water molecules to dissociate into hydrogen and oxygen. The hydrogen gas that evolves has significantly less ^{3}H than the remaining water, resulting in a stronger beta counting signal. Samples with electrical conductivities exceeding approximately 5,000 microsiemens (uS) required vacuum distillation prior to enrichment.
The ^{14}C was measured by first extracting carbon dioxide from a water sample using the same method as for ^{13}C discussed above. The purified carbon dioxide was sealed in a glass ampule and shipped to Beta Analytic radiocarbon dating facility (www.radiocarbon.com). The ampule is opened under vacuum and reacted with hydrogen gas in the presence of an iron catalyst and converted to graphite. The graphite is packed into an aluminum target and placed on the source end of an accelerator mass spectrometer. The graphite is sputtered in the source, releasing ionized carbon atoms. The atoms are accelerated and separated by isotope by an electromagnet, and the ^{14}C atoms are counted in a gas-filled detector. The ^{14}C atom abundance is compared to standards and converted to a percent modern carbon (pmc). The pmc is percentage of the carbon relative to atmospheric carbon dioxide ^{14}C abundance in ca. 1950, prior to any nuclear weapons testing influences. A ^{14}C pmc of ≥100 is considered modern. A pmc <100 can be converted to an apparent age using the radioactive decay equation

$$Age = -8267 \ln(^{14}C/^{14}C_i)$$

where age is in years, ^{14}C is the pmc of the sample, and $^{14}C_i$ is the initial pmc at the time the sample was initially isolated from the modern carbon input and begins radioactive decay. In the case of an apparent age, $^{14}C_i$ is 100 pmc.

For noble gas measurements, the copper tubes were fitted to an evacuated container under high vacuum. The copper cold seal formed during sampling is uncrimped and the water sample is released into the evacuated container where the water is subsequently degassed. A portion of the gas is separated and individual gas abundances are measured on a quadrupole mass spectrometer. The remaining gas is reacted with catalysts to remove nitrogen, oxygen, carbon dioxide, and hydrocarbon gases. The remainder is the noble gases. The isotopes of helium are measured specifically in this remaining gas on a magnetic sector mass spectrometer and detected using a Faraday cup detector. Results are reported as cubic centimeters of a specific noble gas per liter of water (ccSTP/g). The helium isotopes are also reported as a ratio of $^{3}He/^{4}He$ relative to the $^{3}He/^{4}He$ ratio in air. This ratio provides an indication of whether there is an excess of either ^{3}He or ^{4}He relative air. The dissolved noble gases are reported in addition as an amount of excess air in a sample (as excess neon, or %ΔNe) and the calculated recharge temperature. The excess air results from entrainment of air during piston-type recharge, which dissolves air in excess of an equilibrium solubility.

6.0 Results

Samples were collected and analyzed for δD and $\delta^{18}O$ to delineate sources of recharge, and $\delta^{13}C$ to determine source of dissolved inorganic carbon. In addition, analysis was conducted on ^{14}C and ^{3}H to constrain the possible ages of groundwater recharge. Noble gas data measured at OLGEP monitoring wells serves the purpose of both a possible recharge source indicator and age constraint. Tabulated general water quality data is presented in **Table 3** and arranged into three groupings (Brine Pool, East Side, West Side) using a combination of pre-existing data and new data from this isotope study. Newly-acquired isotope data and general water quality data collected as part of this isotope study are shown on **Table 4**. Actual laboratory deliverables are included in **Appendix B** along with chain-of-custody documentation.

On **Table 4**, data are categorized into three groups comprising data from:

1) Springs and wells collected on the west side of Owens Lake,
2) OLGEP monitoring wells, and
3) Springs and wells on the east side of Owens Lake.

Sample sites were separated into these three categories based on the a) type of sample site, b) geographic area, and c) their relative differences in water quality as determined from field measurements. For example, on the west side, samples consisted of surface water, springs, and shallow wells. In contrast, the OLGEP monitoring wells sampled in the isotope study are nested, multi-level wells that are all artesian. East side samples included both shallow wells and springs, but measured field electrical conductivities were typically >1,000 uS compared to west side samples, which were below 1,000 uS. Furthermore, the isotopic data supports separation of the west side samples from the other two categories.

6.1 General Water Quality

Average concentrations of major cations and anions along with electrical conductivity and total dissolved solids are tabulated in **Table 3**. These data were compiled from existing water quality records derived from either LADWP and/or GBUAPCD and combined with data generated from the July 2012 sampling as part of the isotope study. The data are partitioned between east side and west side samples (as well as the brine pool itself) defined in general by sample location on either side of mapped faults along the west side of Owens Lake (**Figure 1**).

Table 3
Tabulated General Water Quality Data

Sample Location Type	Average Ca (mg/L)	Average Mg (mg/L)	Average Na (mg/L)	Average K (mg/L)	Average Alkalinity (mg/L)	Average Cl (mg/L)	Average SO$_4$ (mg/L)	Average Electrical Conductivity (uS)	Average TDS (mg/L)	No. of Samples
Brine Pool										
Brine Pool			116,800	4,840	89,600	120,600	25,200			5
East Side										
Piezometers	6	26	15,480	488	12,088	13,715	3,467	48,975		4
Springs	22	52	1,099	67	1,425	840	231	4,998		12
OLGEP Wells		66	885		1,534	482		4,182	2,577	22
Other Wells	25	51	865	39	1,355	521	80	3,797		18
West Side										
OLGEP Wells		2	739		929	534		3,024	1,775	6
Springs	19	5	145	6	261	68	37	769	254	6
Other Wells	14	2	24	3	76	13	13	200	105	5

Table 4
Tabulated General Mineral and Isotope Data Measured on Samples Collected in July 2012

Field Sample Name	Sampling Date	Field Temp. (°C)	Field Electrcal Conductivity (uS)	Field pH	Field Dissolved Oxygen (mg/L)	TDS (mg/L)	Ca (mg/L)	Na (mg/L)	Mg (mg/L)	K (mg/L)	Alkalinity (mg/L)	HCO_3 (mg/L)	CO_3 (mg/L)	SO_4 (mg/L)	Cl (mg/L)	δD H_2O (per mil)	$\delta^{18}O$ H_2O (per mil)	Tritium (TU)	Std. Dev.	$\delta^{13}C$ DIC (per mil)	^{14}C DIC (pmc)	Std. Dev.	N_2 total (ccSTP/g)	Ar total (ccSTP/g)	Ne total (ccSTP/g)	Kr total (ccSTP/g)	Xe total (ccSTP/g)	^4He (ccSTP/g)	R/Ra	Rech. Temp (°C)	ΔNe (%)	Notes
West Side																																
Carroll Crk	7/23/2012	15.6	133.0	8.4	9.1	69.0	12.8	4.9	1.5	0.6	42.0	42.0	0.0	10.7	7.2	-120.5	-15.94															
NW Seep	7/24/2012	20.9	882.0	6.4	0.5	409.0	28.2	116.0	5.5	5.4	178.0	178.0	0.0	48.1	49.2	-121.4	-15.80	< 1.00		-8.9	57.5	0.2										
Bartlett-CW	7/24/2012	22.2	517.0	8.4	3.7											-123.3	-16.16	< 1.00		-9.3	52.8	0.2										
Cottonwood Spr	7/24/2012	21.5	467.0	7.3	0.0	230.0	26.5	29.0	7.2	3.6	70.0	70.0	0.0	23.9	42.3	-120.4	-15.47	7.46	0.20	-15.7	88.9	0.3										
Cottonwood-Well	7/24/2012	23.5	6030.0	9.1	0.4											-103.5	-12.01															
Aqueduct Well	7/24/2012	14.5	97.0	5.9	6.7	56.0	7.2	4.2	1.8	1.4	30.0	30.0	0.0	9.9	7.1	-119.3	-15.40	3.82	0.17	-15.1	106.5	0.4										
Ash Crk	7/24/2012	19.6	260.0	7.9	8.3	122.0	23.7	8.0	3.7	1.9	60.0	60.0	0.0	29.0	7.4	-111.2	-14.56															
Rio Tinto-SW	7/24/2012	19.5	301.0	7.7	0.0	158.0	17.0	25.9	2.1	3.3	94.0	94.0	0.0	15.7	7.9	-114.5	-14.88	< 1.00		-9.8	56.1	0.2										
Cartago-COM	7/23/2012	18.0	253.0	8.3	6.3	138.0	24.4	12.1	2.1	2.0	80.0	80.0	0.0	14.6	7.4	-112.1	-14.71	1.76	0.15	-10.4	61.3	0.3										
S31	7/24/2012	20.0	1100.0	9.4	0.6	555.0	1.7	179.0	0.1	15.8	150.0	90.0	60.0	79.5	92.8	-110.2	-14.28	< 1.00		-3.7	25.5	0.2										
Duck-CN	7/24/2012	21.1	900.0	9.2	1.6											-111.7	-14.82															
OLGEP Monitoring Wells																																
DWP-9 / T 896	7/23/2012	19.2	1460.0	9.2	0.0											-129.5	-16.55	< 1.00		21.7	2.9	0.1	1.05E-02	2.91E-04	1.27E-07	2.84E-08	1.28E-08	1.69E-05	1.52	-	-19.46	Large amount of excess He; poor gas model fit; sample stripped
DWP-9 / T 897	7/23/2012	19.3	1770.0	9.3	0.0											-131.8	-16.96															
DWP-9 / T 898	7/23/2012	19.9	1340.0	9.3	0.0											-129.4	-16.74	< 1.00		5.0	7.2	0.1	1.10E-02	3.83E-04	2.02E-07	1.12E-07	2.06E-08	4.38E-06	0.88	-	18.30	Large amount of excess He; poor gas model fit
DWP-3 / T 899	7/23/2012	19.4	1250.0	9.0	0.0											-123.3	-15.68	< 1.00		-1.5	3.8	0.1	1.16E-02	3.17E-04	1.84E-07	4.41E-08	1.17E-08	1.04E-05	0.91	-	5.23	Large amount of excess He; poor gas model fit
DWP-3 / T 901	7/23/2012	19.8	3570.0	9.3	0.0											-125.8	-16.11	< 1.00		0.7	1.8	0.1	8.60E-02	1.18E-03	3.12E-06	1.26E-07	1.33E-08	3.59E-06	1.17	-	1726.90	Large amount of excess He; poor gas model fit; excess air
DWP-6 / T 912	7/23/2012	20.0	5580.0	9.2	0.0											-132.7	-16.59	< 1.00		-0.2	1.7	0.1										
DWP-6 / T 911	7/23/2012	19.0	9820.0	8.8	0.0											-114.2	-13.25	< 1.00		-7.7	1.2	0.1	3.78E-02	3.15E-04	1.57E-07	7.00E-08	1.45E-08	7.84E-05	1.26	-	-9.37	Large amount of excess He; poor gas model fit; sample stripped
DWP-6 / T 913	7/23/2012	20.4	38900.0	9.2	0.0											-88.0	-8.28	< 1.00		0.9	0.5	0.1										
DWP-7 / T 908	7/23/2012	19.0	1680.0	9.2	0.0											-108.9	-14.34	< 1.00		-8.1	4.4	0.1										
DWP-7 / T 909	7/23/2012	19.1	747.0	9.3	0.0											-109.0	-14.38															
DWP-7 / T 910	7/23/2012	18.8	401.0	9.0	0.0											-110.1	-14.62	< 1.00		-6.0	36.7	0.2	1.21E-02	3.68E-04	2.29E-07	3.12E-08	1.04E-08	5.63E-07	0.81	16.9	36.07	Large amount of excess He; OK gas model fit
East Side																																
Dolomite	7/23/2012	25.1	1400.0	7.6	0.0											-127.6	-16.29	< 1.00		-7.6	5.6	0.1										
Agr-2	7/23/2012	20.3	1650.0	7.6	5.6											-125.0	-16.13	< 1.00		-5.8	3.6	0.1										
KCSD-PW	7/23/2012	22.3	1590.0	7.6	0.0											-124.5	-16.09	< 1.00		-5.5	4.4	0.1										
Horse Pasture	7/23/2012	22.1	2910.0	7.8	0.0											-130.9	-16.70	< 1.00		-5.1	1.9	0.1										
Tubman-CP	7/24/2012	26.4	8760.0	7.9	2.8											-128.8	-15.66															

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With the exception of Na, cation data was generally lacking for several types of samples, which makes their comparison difficult. Anion data for alkalinity and Cl were more complete. In general, available data shows a systematic increase in Na, Cl and alkalinity from west side to east side samples. The highly evaporated brine pool shows the highest concentration, followed by east side piezometers and springs. East side wells are lower in these constituent concentrations. This general trend in east side samples is consistent with a process of relatively low salinity groundwater from depth (as recorded in wells) discharging to shallow springs and piezometers. During this discharge process, they are subjected to evaporative enrichment of their dissolved salts.

Comparison of the east side water chemistry to west side water chemistry shows much lower Na, Cl, and alkalinity concentrations, with concentrations of these analytes from wells being the lowest. This is consistent with the concept that west side groundwater is not being influenced by higher salt loads inherent in the subsurface below Owens Lake, and it implies that for the most part, groundwater beneath Owens Lake does not influence groundwater in west side wells and springs.

In **Table 4**, the OLGEP monitoring wells sampled in this study are treated as a third category because they penetrate well characterized hydrogeologic layers and by virtue of their exclusively artesian character. Because the general water quality data suggest distinct water quality types based on geography, the goal of the isotope data results is to determine if these distinct types are related to different recharge areas and different groundwater residence times.

6.2 Stable Isotopes of δD and δ^{18}O

The δD-δ^{18}O values were measured on a total of 27 samples collected in the OLGEP study area. Values range from -16.96 to -8.28 per mil in δ^{18}O, and -132.7 to -88.0 per mil δD. This range is consistent with values generated and reported in previous studies in the Owens Valley region (MWH, 2004). The δD and δ^{18}O data collected in this study are plotted in **Figure 2**. Also plotted for reference on this figure is the Global Meteoric Water Line (GMWL). This line is a linear fit to δD-δ^{18}O values of precipitation collected through different parts of the world. Most unevaporated precipitation should conform to this line. The OLGEP δD-δ^{18}O data are shown segmented into the three groupings in **Figure 2**. Note that the west side samples (red circles) partition into two distinct zones. The west side zone with higher isotopic values is all the sample sites located south of LADWP’s Cottonwood Plant Well, whereas the lower isotopic zone includes samples collected north of Ash Creek. This division generally corresponds to a significant change in watershed source water. To the south, the highest elevations of the watershed are generally less than 10,000 feet above mean sea level (fmsl), whereas north of Ash Creek upper elevations draining into Carroll and Cottonwood creeks exceeds 10,000 fmsl. Recall as a general rule, higher elevation precipitation typically is associated with lower stable isotope values (see **Appendix C**).

One sample from the west side (Cottonwood Spring Well, adjacent to Cottonwood Spring) has a much higher isotopic value and lies further to the right of the GMWL. This position relative to the GMWL is consistent with water that has undergone significant evaporation that is believed to occur in the open standpipe of the abandoned well, which was not possible to purge prior to sampling. It is believed, therefore, that this isotopic value is not representative of underlying groundwater.

Isotopic values of OLGEP monitoring well samples shown in **Figure 2** (black circles) are predominantly lower than those of west side samples, with the exception of DWP-7. Values from DWP-7 are consistent with west side values south of LADWP Cottonwood Plant Well. This is not surprising because DWP-7 is geographically located in the same region as these west side samples.

In contrast, the three sampled monitoring wells from site DWP-9 wells had some of the lowest isotopic values. Isotopic values for the intermediate level of site DWP-6 wells (T912 - shallow portion of aquifer 5) were low similar to DWP-9. However, the deep and shallow at this site (aquifer 1 and deeper portion of aquifer 5) have significantly higher values that together form a linear evaporation slope projecting back to the intermediate level values. This indicates that not only is there evaporated water residing in the upper and lower sample levels of this well cluster, but also that the evaporated water evolved exclusively from the water in the intermediate level. This is why all three isotopic values line up along a straight line in **Figure 2**, consistent with evaporation. The isotopic values of the two levels sampled at site DWP-3 are somewhat higher than values at site DWP-9, and the intermediate level of site DWP-6. The isotopic values of the two levels sampled at site DWP-3 are somewhat higher than values at site DWP-9 and the intermediate level at site DWP-6. The deeper level of DWP-3 was highest. Note that both levels of site DWP-3 plot just below the west side cluster comprised of Carroll Creek, Northwest Seep, Bartlett Well, Cottonwood Spring NW, and LADWP Cottonwood Plant Well, whereas DWP-9 and DWP-6 are much lower. This does not imply that DWP-3 water is recharged from the west side, but rather it is likely recharged in part from a source with similar isotopic values, possibly derived from local east side recharge.

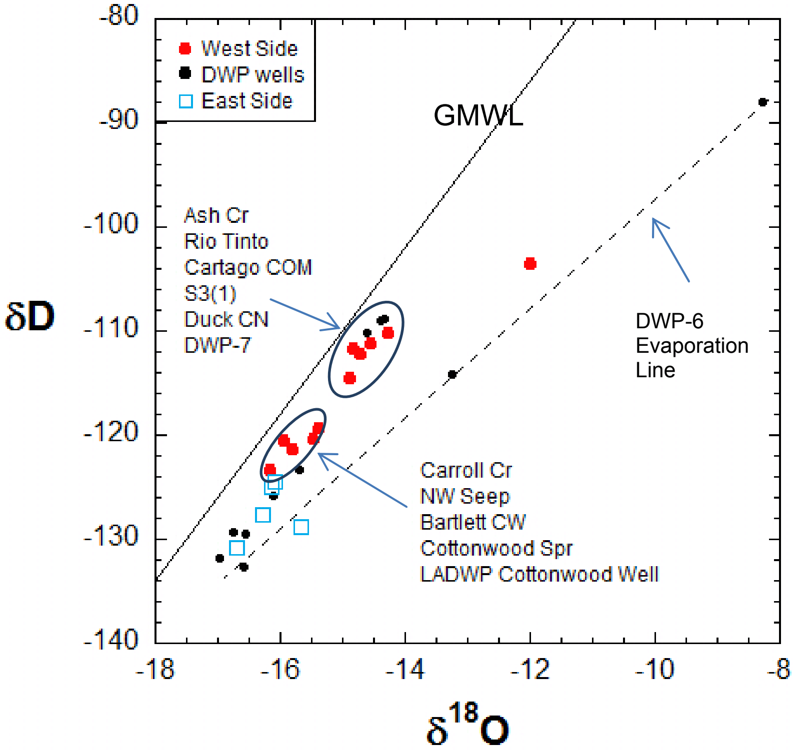


Figure 2
δD-δ^{18}O Plot of OLGEP Samples

Note: The δD and δ^{18}O values for samples collected in July 2012 show distinct populations of surface and groundwater separating those sampled on the west side of Owens Lake area from those of the OLGEP monitoring well sites DWP-9, DWP-3, and DWP-6, as well as springs and groundwater sampled on the east side.

The isotopic values of the east side samples in **Figure 2** (blue squares) consistently overlap the lower isotopic values for the OLGEP wells. Their similarity suggests that they belong to the same population of groundwater in OLGEP monitoring wells with the exception of DWP-7.

The data plotted in **Figure 2** are also plotted against data from previous isotopic studies in **Figure 3**. Data from samples on the west side generally overlap with data presented in Lopes (1988) for samples that he collected on the west side. Likewise, the range in isotopic values of the OLGEP monitoring wells and east side samples are consistent with the range measured by the USGS throughout the Owens Valley. However, data from OLGEP monitoring wells and east side samples plot somewhat further to the right of the GMWL than the USGS data, suggesting that recharged groundwater under Owens Lake has undergone slightly more evaporation. Lastly, evaporated water in DWP-6 and Cottonwood Spring Well (adjacent to Cottonwood Spring NW), shown in **Figure 3**, overlap the region of evaporated water measured in piezometers presented in Font 1995 (data not shown).

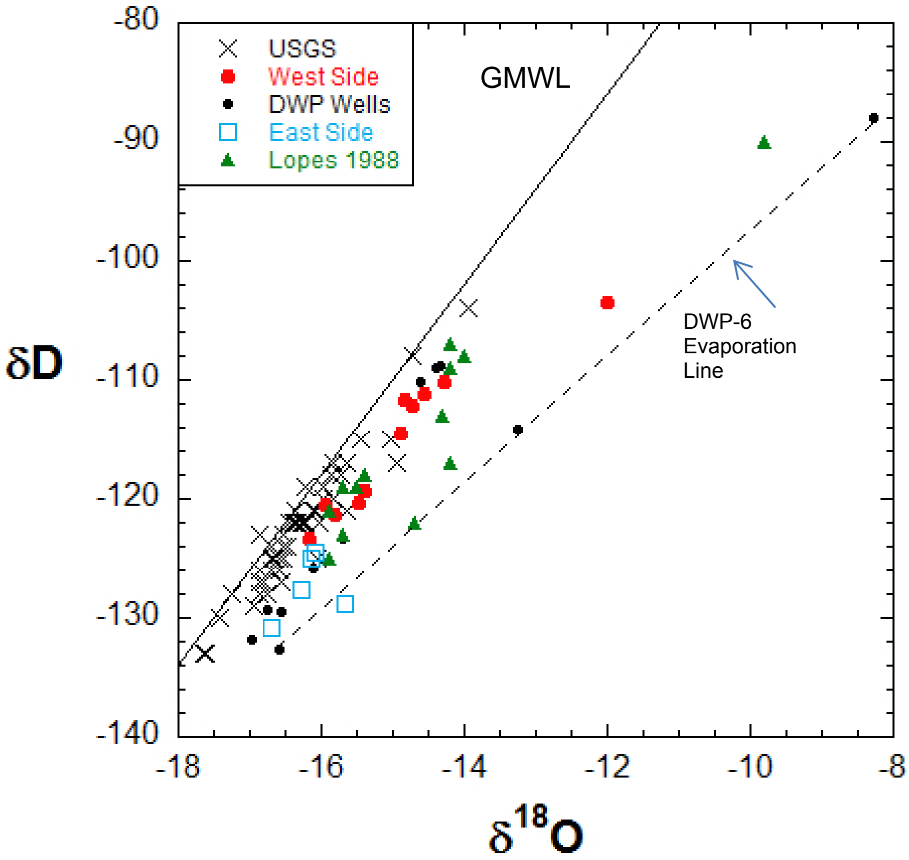


Figure 3
δD-$\delta^{18}O$ Plot of OLGEP Data Compared to Previous Studies

Note: The range in isotopic values measured on samples collected in July 2012 generally overlap those presented in previous work by the USGS, Font (1995) (not shown), and Lopes (1988). OLGEP monitoring well sites DWP-3, and -6, as well as east side samples plot more to the right of the GMWL than USGS data, suggesting groundwater recharged under Owens Lake underwent slightly more evaporation.

Further consideration of the highly evaporated water residing within deeper aquifers sampled from DWP-6 is warranted. Care was taken to purge wells sufficiently before sampling to prevent any compromise of isotopic results. In addition, because the well is artesian, no open air exchange was possible to evaporate water within the well casing. However, an interesting comparison can be made between Owens River water and groundwater from DWP-6. **Figure 4** plots data from Coplen and Kendall (2000) that measured δD and $\delta^{18}O$ values of the Owens River at various times over nearly two years. Their samples were collected in the same spot each time below Tinemaha Reservoir near the town of Big Pine. The data form a general evaporation trend as would be expected from impounded surface water open to air exchange.

The slope of the Owens River evaporation trend is 5.37, suggesting that this is an average evaporative slope of surface water on a δD-$\delta^{18}O$ plot for this geographic region. Surprisingly, the linear fit of the three isotopic values of DWP-6 data is exactly the same (5.37), which is consistent with surface evaporation. This indicates that surface water that was significantly evaporated recharged aquifers intersecting DWP-6. The isotopic values of evaporated water in DWP-6 do not overlap with Owens River near Big Pine, and are therefore of a different source. The field electrical conductivity measurements are a further corroboration because they increase with increasing $\delta^{18}O$, consistent with evaporative enrichment of dissolved salts.

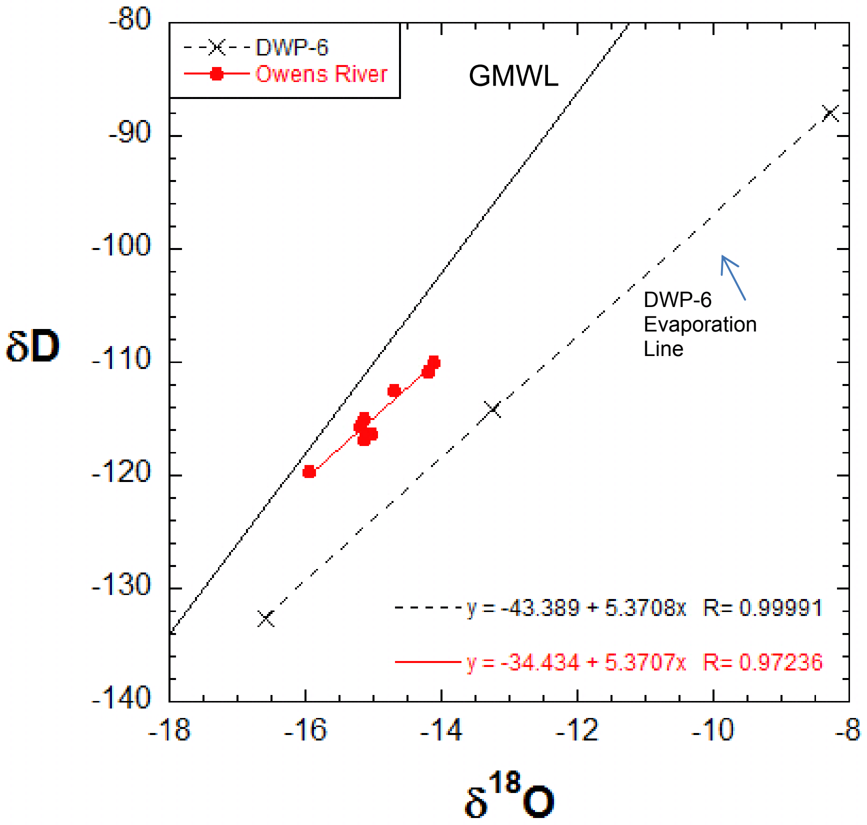


Figure 4
δD-$\delta^{18}O$ Plot Comparing Owens River to DWP-6

Note: Owens River water analyzed by USGS over various times of the year from 1984-1986 forms a surface water evaporation slope of 5.37. Surprisingly, a linear fit of the DWP-6 samples forms the exactly same slope, consistent with surface water evaporation, but from a water of a different source.

6.3 Isotopes of Carbon (^{14}C and $\delta^{13}C$) and Tritium

A total of 20 samples were measured for ^{14}C, $\delta^{13}C$, and ^{3}H. The ^{14}C values range from <1 to >100 percent modern carbon (pmc). The pmc value is a measure of the relative percent of the modern atmospheric carbon dioxide incorporated in the sample. Values greater than 100 pmc record abnormal ^{14}C amounts introduced into groundwater recharge from surface testing of nuclear weapons. Values lower than 100 pmc either have undergone radiometric decay and/or have incorporated dissolved carbon from a ^{14}C-absent source. Values at or below 1 pmc are essentially too low for practical groundwater age dating. **Figure 5** shows the distribution of ^{14}C values partitioned among the three groupings used in **Table 4**. Note that the highest ^{14}C values are associated with the west side samples, ranging from >100 to 26 pmc. The OLGEP monitoring wells and east side samples on the other hand are all below 10 pmc, with the exception of the shallow level of DWP-7 (T910) at 37 pmc.

Tritium levels in all but 3 of the 20 samples were below detection limit of 1 tritium unit (TU). This is equivalent to one tritium atom per 10^{18} hydrogen atoms. The 3 samples where ^{3}H was present were Cottonwood Spring NW, LADWP Cottonwood Plant well, and Cartago CSD. These 3 samples also had the highest ^{14}C values. In general, the presence of ^{3}H in a groundwater is usually an indicator of recharge, at least in part, of precipitation <50 years old, which is the time when surface testing of nuclear weapons occurred, and then left an annually decreasing residual ^{3}H in the upper atmosphere.

The $\delta^{13}C$ values have a wide distribution, ranging from -15.7 to +21 per mil. The lowest value is consistent with dissolved inorganic carbon of shallow groundwater in isotopic equilibrium with soil carbon dioxide. This low value, as well as that of -15.1 per mil, is associated with samples Cottonwood Spring NW and LADWP Cottonwood Plant Well. The highest $\delta^{13}C$ values were measured for well DWP-9/T896 (+21 per mil) and DWP-9/T898 (+5 per mil). These high values are unusual for groundwater, which more often has an observed high value around 0 per mil, particularly for aquifers formed from carbonate rocks. However, a high value such as +21 per mil is not uncommon for dissolved inorganic carbon measured in oil and gas fields where methane is produced.

In DWP-9 samples, the $\delta^{13}C$ values are unusually high, indicating a carbon source distinct from sources contributing to the other wells.

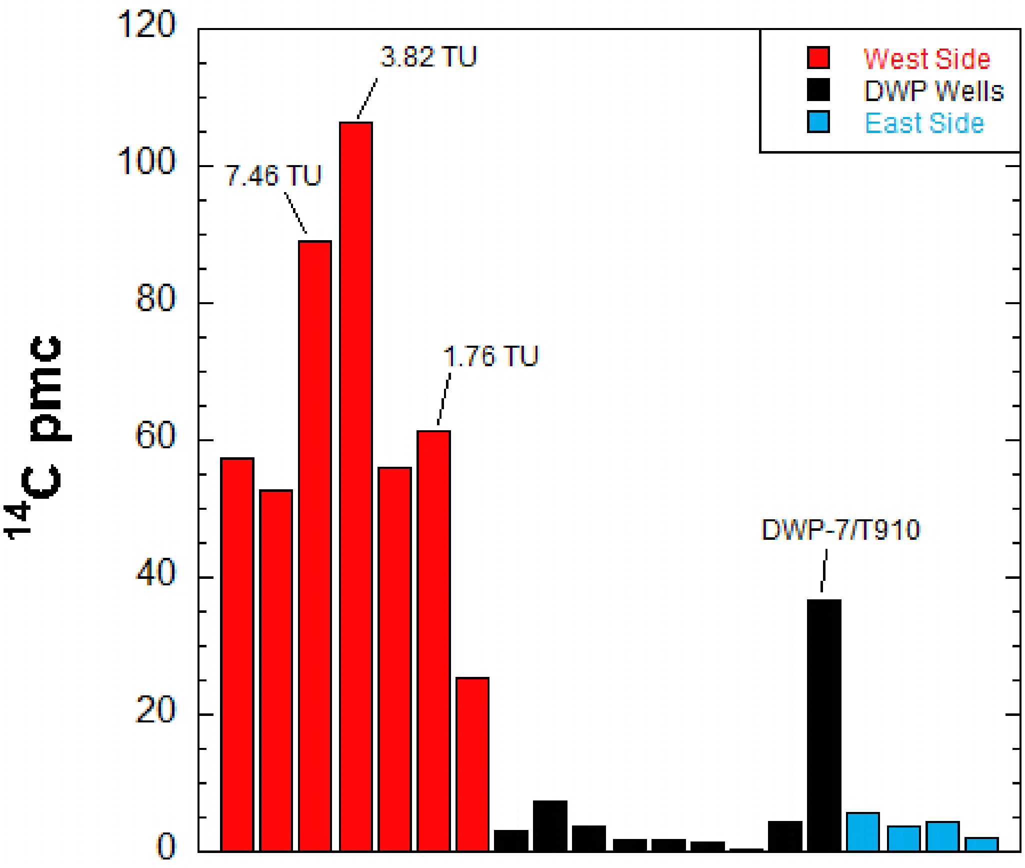


Figure 5
^{14}C Comparison of OLGEP Samples

Note: The ^{14}C values are highest in the west side samples and contrast those of the OLGEP monitoring wells (except for DWP-7/T910) and the east side samples. Only 3 samples had detectable ^{3}H, which were Cottonwood Spring NW, LADWP Cottonwood Plant well, and Cartago-CSD.

The relationship between ^{14}C and δ^{13}C is shown in **Figure 6**. It is interesting to note that a linear correlation occurs among the west side samples, as well as DWP-7/T910. The upper end-member of this correlation is Cottonwood Spring NW at 89 pmc and -15.7 per mil. The line extrapolates to a lower end-member between 0 and 1 per mil and 0 pmc. This lower end-member, defined by the low ^{14}C and high δ^{13}C values observed in wells DWP-6/T913 and DWP-3/T901. The remaining samples plot to the left and below the line, with the exception of DWP-9, which plots to the right of the correlation. Samples that conform to this line could only a have undergone ^{14}C reduction in proportion to δ^{13}C increases, indicating that no radiometric decay has taken place and only reaction with a ^{14}C-absent, higher δ^{13}C source has occurred. Samples that plot below this line have likely undergone some radiometric decay, but the magnitude of decay cannot be determined simply from this plot because the extent of reaction with a ^{14}C-absent source is not known.

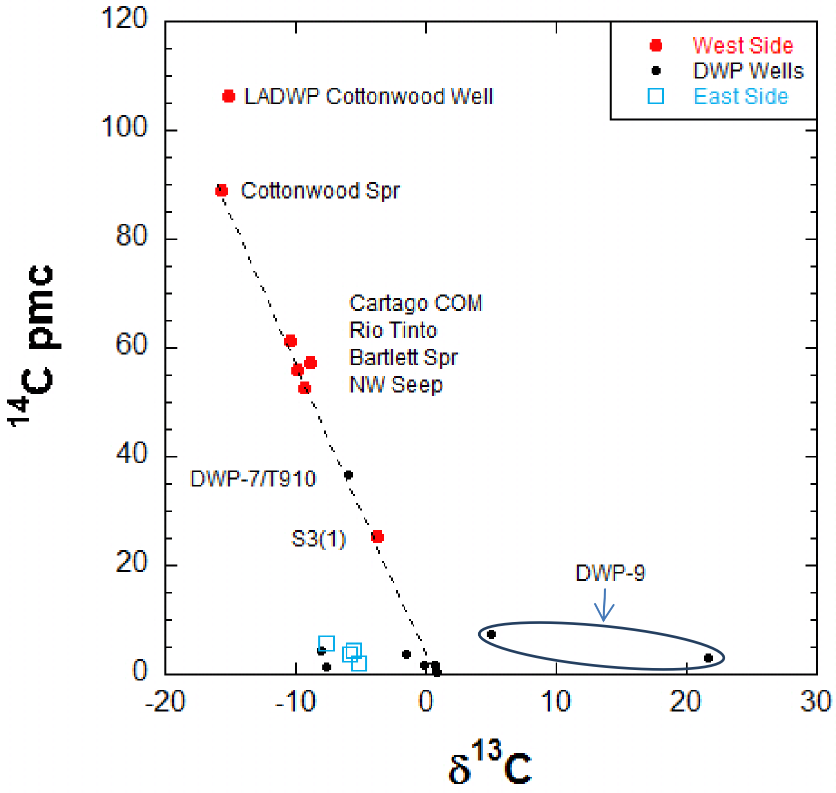


Figure 6
^{14}C-$\delta^{13}C$ Plot of Samples Collected

Note: West side samples and DWP-7/T910 form a linear correlation between $\delta^{13}C$ and ^{14}C with the upper end-member defined by Cottonwood Spring NW and the lower extrapolated end-member at $\delta^{13}C$ between 0 and 1 per mil and ^{14}C at 0 pmc. Some OLGEP monitoring wells conform to this lower end-member while others plot to the left and below the correlation. DWP-9 $\delta^{13}C$ values are consistent with a dissolved inorganic carbon in isotopic equilibrium with methane.

6.4 Noble Gas Results

The dissolved noble gases of helium (He), neon (Ne), argon (Ar), krypton (Kr), and xenon (Xe) were measured in groundwater on six individual samples collected at 4 separate OLGEP monitoring well sites. In addition, dissolved nitrogen was also measured. Nitrogen is a general measure of the amount of air dissolved in a groundwater. However, Ne is a better measure of dissolved air because nitrogen can periodically undergo reaction, such as in groundwater lacking dissolved oxygen. Consequently Ne is used in this data set as a quantitative measure of dissolved air. The other feature of Ne (and He) is that its solubility in water is relatively insensitive to temperature compared to Kr and Xe, which can change significantly with temperature (see **Appendix C**).

An approach then is to quantitatively gauge the amount of air dissolved in excess of equilibrium solubility in the water using Ne. Kr and Xe then is used to determine recharge temperature. The ^{4}He concentration is used to estimate groundwater age based on its steady-state accumulation from crustal sources. The ^{3}He is typically used for measuring the amount of ^{3}H that has decayed since recharge.

Noble gas concentrations are reported as cubic centimeters of gas at standard temperature (20°C) and pressure (1 atmosphere) per gram of water, or ccSTP/g. The ccSTP is a volume of gas that would exist in air.

The Ne concentrations range from 1.27e-7 ccSTP/g in DWP-9/T896 to 3.12e-6 ccSTP/g in DWP-3/T901. This range is unusual for Ne because the solubility of Ne in water at STP is approximately 1.8e-7 ccSTP/g. The lowest concentration of 1.27e-7 ccSTP/g, as well as the concentration in DWP-6/T911 at 1.57e-7 ccSTP/g, suggests Ne is below equilibrium solubility, which is difficult to achieve in natural recharge conditions. The remainder of the samples exceeds equilibrium solubility. This is not unusual for groundwater, which often incorporates excess air during recharge. However, for sample DWP-3/T901, the excess amount is quite unreasonable and suggests entrainment of air by other means. This sample was noted for a high level of free gas in the water, and it was difficult to remove during the copper tube sampling. Consequently, given the abnormally high Ne concentration, it is likely that air bubbles were entrained in this sample, rendering the data unusable for further analysis. **Table 4** calculates the percent difference in Ne (%ΔNe) relative to equilibrium solubility to provide an easy method for assessing the amount of excess air. For the OLGEP monitoring well samples, only DWP-3/T899, DWP-7/T910, and DWP-9/T898 have reasonable excess air levels.

The He concentration measured as ^{4}He in the samples ranged from 5.63e-7 ccSTP/g in DWP-7/T910 to 7.84e-5 ccSTP/g in DWP-6/T911. The equilibrium solubility of ^{4}He at STP is approximately 4.9e-8 ccSTP/g, which indicates that OLGEP groundwater samples have excess ^{4}He amounts ranging from about 10 to >1000 times equilibrium solubility. This excess amount of ^{4}He far exceeds the excess amount of Ne measured in some of the samples, indicating that the ^{4}He is from another source.

The ^{3}He can be used as a ratio to ^{4}He to indicate the source of the excess ^{4}He. The ^{3}He/^{4}He ratio is shown as R/Ra in **Table 4**, which is the ^{3}He/^{4}He ratio of the sample normalized to the ^{3}He/^{4}He ratio of air. Note that equilibrium solubility concentration of 3He from air is approximately 7e-14 ccSTP/g. Helium derived simply from dissolution of air, R/Ra will be 1.0. The R/Ra will be <1.0, when He accumulates from crustal rocks only (alpha decay products). However, when the He is derived in part from active volcanic gas emission in the subsurface, R/Ra will be >1.0. The R/Ra of the OLGEP monitoring wells ranged from 0.81 to 1.52, suggesting that the excessive amounts of He dissolved in the groundwater are not solely from crustal accumulation since R/Ra would have been <<1.0. Consequently, it is highly probable that the excess dissolved He is from volcanic gas emission in the subsurface with R/Ra values >1.0. It may also be possible that active faults below Owens Lake are sources of deep He emissions.

Unfortunately, the Ne in some samples was below equilibrium solubility, and He was dissolved in excessive amounts. Normally Ne will always be at or above equilibrium solubility, and ^{4}He concentration will be proportional to excess air amounts plus any small amount accumulated from crustal emission. In the OLGEP monitoring wells, ^{4}He far exceeds normal crustal accumulated amount. Furthermore, because Ne is below solubility in some samples, excess air calculations are not possible. This also makes the remaining samples suspect that some Ne loss may have occurred as well. Most of the OLGEP monitoring wells sampled had some amount of free gas in the water during sampling. Anecdotal evidence suggests this free gas is methane. Excess amounts of methane in the groundwater could be preferentially removing Ne and Ar over Kr and Xe during its ascent up the well bore. Ne and Ar are less soluble than Kr and

Xe and would be remove more readily. Consequently, it is probable that the free gas in these wells have disrupted the relative abundance of noble gases measured.

Only in the case of DWP-7/T910 is the excess He and excess Ne reasonable enough that excess air can be determined and recharge temperature calculated. The recharge temperature reported is 16.9°C (**Table 4**). The measured water temperature during sampling was 18.8°C. The implications of this calculated recharge temperature are discussed in section 7.1.

7.0 Update of Interpretive Model

In the SAP (MWH, 2012), general interpretive conclusions were drawn from previous isotope studies in the Owens Valley. Early work by Lopes (1988) suggested that δD-$\delta^{18}O$ measurements of springs and wells around the perimeter of Owens Lake showed differences that likely were related to different recharge sources. Font (1995) measured δD-$\delta^{18}O$ in shallow piezometers installed around the perimeter of Owens Lake and showed that much of the shallow groundwater was evaporated. The slope of the evaporation line on a δD-$\delta^{18}O$ plot was approximately 4.3, consistent with shallow subsurface evaporation. The data all seemed to be extrapolating back to a fairly uniform source consistent with deeper groundwater in the eastern portion of the lake measured by the USGS (Densmore et al., 2009).

Using ^{14}C and $\delta^{13}C$ data, previous studies further determined that there appeared to be a fairly uniform reaction between young recharge (with higher ^{14}C and low $\delta^{13}C$ values) and a ^{14}C absent source (with higher $\delta^{13}C$ values), and that this reaction would largely control apparent groundwater age calculated from ^{14}C measurements.

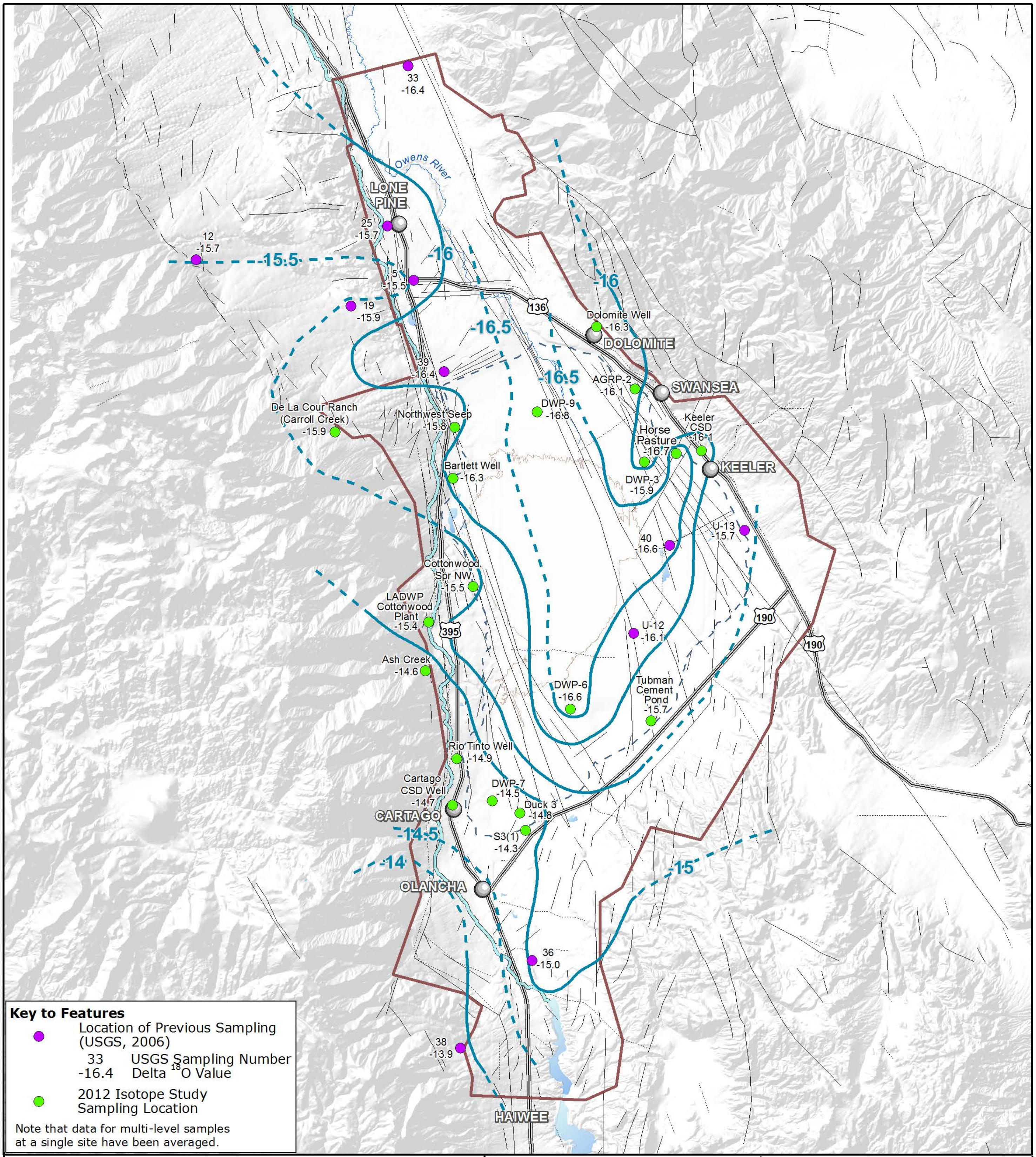
The SAP also defined three main goals of the sample collection program:

1) Determine how uniform groundwater isotopic signatures were in groundwater beneath Owens Lake,
2) Define the isotopic character of springs and shallow wells on the west side of Owens Lake and how they may be related to deeper groundwater beneath the lake, and
3) Determine the isotopic character of shallow groundwater on the east side of the lake.

This TM articulates findings relative to the goals of the study and further advances the interpretation of recharge sources and ages and how they inter-relate.

7.1 Sources of Recharge in the OLGEP Study Area

The variation in the δD-$\delta^{18}O$ values of surface and groundwater in the Owens Lake area serves as a foundation for interpreting sources of recharge. When the $\delta^{18}O$ values are viewed in map form and contoured, the variation reveals a systematic pattern that illustrates different sources contributing to recharge (**Figure 7**). For instance, the lowest $\delta^{18}O$ values (-16.5 per mil) occur as a tongue leading from north to south. These lower $\delta^{18}O$ becomes higher on the west, south, and east sides of Owens Lake. Increase in $\delta^{18}O$ is controlled by local recharge around the lake. **Figure 7** also includes data from the previous USGS study (Densmore et al., 2009) .



Key to Features

● Location of Previous Sampling (USGS, 2006)

33 USGS Sampling Number
-16.4 Delta ^{18}O Value

● 2012 Isotope Study Sampling Location

Note that data for multi-level samples at a single site have been averaged.

●	Town
═	Highways
═	Los Angeles Aqueduct
▭	OLGEP Study Area
▨	Water Bodies
—	Isotope Contour
—	Owens River
—	Fault Source: USGS; State of California, OLGEP Phase II Geophysics, 2011
- - -	Fault Approximately Located Source: USGS; State of California
·····	Fault Concealed Source: USGS; State of California

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Technical Memorandum for the Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas

Contours of Equal Delta ^{18}O Isotope (Per Mil) in OLGEP Study Area Groundwater

Contoured delta ^{18}O values of groundwater samples reveal a tongue of lower delta ^{18}O water in most of the DWP wells intermingling with higher delta ^{18}O groundwater originating as local recharge around the perimeter of Owens Lake.

Los Angeles Department of Water & Power

Figure 7

MWH.

This map has been designed to print size 8.5'' by 11''.

Note that the lowest $\delta^{18}O$ values in the map are controlled exclusively by OLGEP monitoring well water, with the exception of site DWP-7. All three depths sampled and measured at DWP-9 (located at the head of this tongue) show a relatively uniform $\delta^{18}O$ value. In contrast, DWP-3 on the eastern side of the tongue, has a lower value at its shallow depth (T901: 150-170 foot depth screened in Aquifer 1), but somewhat higher at its deepest (T899: 920-960 foot depth screened in Aquifer 5). The three sampled depths at DWP-6, located on the south end of the tongue, have large $\delta^{18}O$ variations due to recharge of highly evaporated water from a single source. Only the mid-level has been used in **Figure 7** to avoid weighting of the $\delta^{18}O$ toward an evaporated value. It is not difficult to see the gross similarity in the distribution of this low $\delta^{18}O$ tongue and the terminus of the modern Owens River. The low $\delta^{18}O$ values in this groundwater are unrelated to any surface water and shallow groundwater in the immediate surroundings of Owens Lake based on data presented above. Consequently, modern recharge sources for this low $\delta^{18}O$ water require a source further upgradient of Owens Lake area. Hence, this low $\delta^{18}O$ water defines the down-valley flow component characterized in the Updated OLGEP Conceptual Model Report (MWH, 2011).

One alternative interpretation of the low $\delta^{18}O$ values seen in OLGEP monitoring wells is the possibility that they are an isolated pocket of pluvial period recharge. In other words, they are ancestral recharge, or connate waters remaining from a different historical climatic regime. This interpretation is commonly forwarded where groundwater with isotopic values that are appreciably lower than shallow groundwater locally recharged . This interpretation is only valid when all other potential sources can be ruled out. However, the interpretation is commonly employed without thorough analysis, and the research literature is fraught with such erroneous results (see Davisson et al., 1999 for further discussion). In the OLGEP study area, numerous upgradient recharge sources with the low $\delta^{18}O$ values are possible as source water for low $\delta^{18}O$ groundwater in OLGEP monitoring wells.

Recall that the δD- $\delta^{18}O$ values of surface water and shallow groundwater along the western side of Owens Lake suggest that mean elevation of upgradient runoff control their variation, illustrated by distinct isotopic populations north and south of Ash Creek (**Figure 2**). The lower $\delta^{18}O$ values of De La Cour Ranch/Carroll Creek, Northwest Seep, and groundwater in the Alabama Hills (from USGS study data) are not sufficiently low enough to be a reasonable recharge source for the low $\delta^{18}O$ groundwater beneath Owens Lake, as observed at site DWP-9, in particular. Further north of the OLGEP study area, even lower isotopic values occur in runoff and shallow recharge, as shown by previous isotopic measurements in the Inyo/LA Cooperative Geochemical Study (MWH, 2004). Results of that study found that surface water and shallow groundwater on the west side of Owens Valley consistently showed $\delta^{18}O$ values ranging less than -17 per mil. It is likely that mean $\delta^{18}O$ of runoff from the Sierran watersheds decreases from south to north along Owens Valley. This decrease provides some geographic control on defining recharge sources in areas where mixtures of local and more regional groundwater occur.

Another factor in considering an upgradient recharge source is the fact that the lowest $\delta^{18}O$ groundwater beneath Owens Lake also has significantly lower ^{14}C and higher $\delta^{13}C$ values. Regardless of whether this is due mostly from radiometric decay or from contribution of ^{14}C-absent sources, data indicates that this groundwater has been isolated sufficiently long enough to have undergone gross geochemical changes compared to groundwater on the west side of Owens Lake.

The distribution of low $\delta^{18}O$ water on the east side of this tongue is somewhat complicated by the fact that at site DWP-3 shallow (T901) (-16.1 per mil) and deep (T899) levels (-15.7 per mil) are different (these values were arithmetically averaged for the contour map). The deeper, higher $\delta^{18}O$ water may be due to infiltration of more local recharge in this area. However, no further conclusions can be drawn about local recharge here except that the higher $\delta^{18}O$ water is similar to that found further south and northwest side of Owens Lake.

One of the most important features is the general correspondence between the distribution of the low $\delta^{18}O$ groundwater tongue and the position of mapped faults. This correspondence is most remarkable where faulting in the southwestern portion of Owens Lake occurs between OLGEP monitoring well sites DWP-6 and DWP-7. Recharge sources of these two sites are distinctly different. DWP-7 is clearly recharged from local sources (similar to Ash Creek) that also recharge wells Rio Tinto, Cartago-CSD, S3(1), and Duck 3. DWP-6, on the other hand, has an unevaporated signature similar to groundwater in wells at site DWP-9. It is reasonable to assume that the northward extension of this fault group in the western portion of Owens Lake also contributes to the segmenting of western shallow recharge from deeper groundwater beneath Owens Lake.

On the east side of Owens Lake, correspondence between faulting and $\delta^{18}O$ values of groundwater is less certain. Much of this uncertainty may be due to lack of enough shallow collection sites and data on the east side compared to the type of samples on the west. Nevertheless, the fact that groundwater at site DWP-3 did show isotopic layering between one depth and another might suggest a lack of fault control and more control by hydraulic conductivity. Until further data can be generated, east side fault control of groundwater flow is uncertain at this time.

It is useful to discuss the recharge temperature that was successfully calculated for OLGEP well DWP-7/T910 from the noble gas results. The calculated recharge temperature was 16.9°C. In order to assess this calculated temperature and its implication for recharge source, a temperature/elevation curve needs to be constructed in this general region of eastern California. This can be accomplished by plotting mean annual air temperatures measured at various meteorological stations in California. This was done for 14 different stations, within or close to Owens Valley, ranging from <2,000 to >12,000 fmsl (**Appendix D** and **Figure 8**). A linear regression was fit to the data.

Mean air temperatures of 14 meteorological stations at various elevation are correlated to yield a linear regression and slope that indicates approximately 2°C change in temperature occurs for every 1,000 feet of elevation change. Data were obtained through the Western Regional Climate Center (http://www.wrcc.dri.edu/summary/Climsmcca.html) and are tabulated in **Appendix D**.

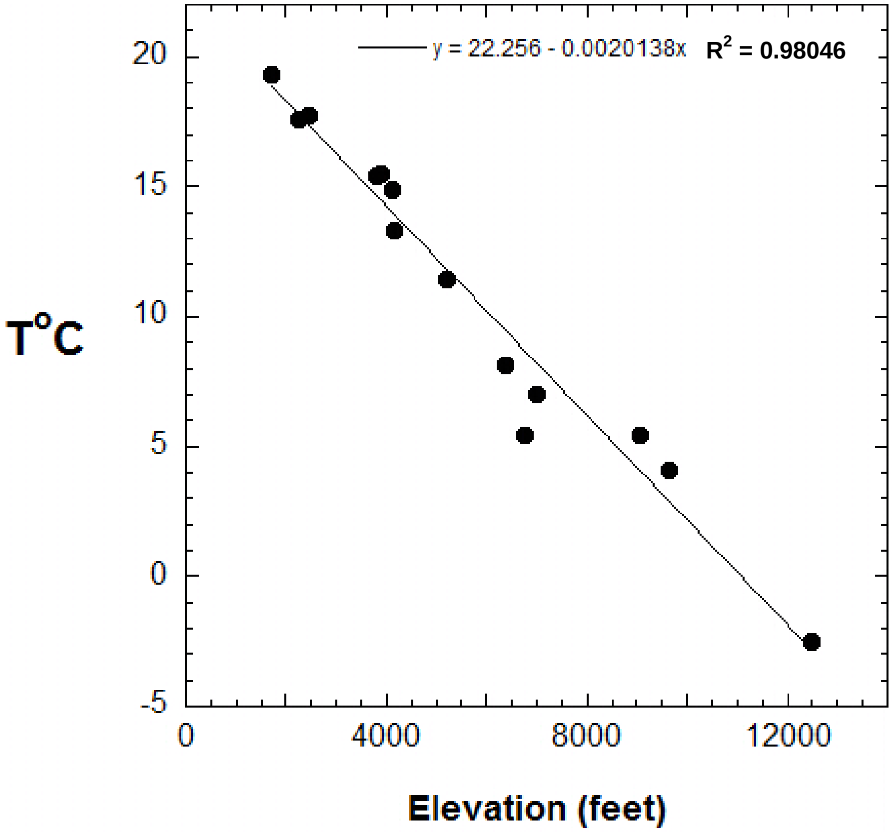

Figure 8
Elevation-Mean Air Temperature Plot for the OLGEP Region

This linear regression is used to compute an elevation from the noble gas recharge temperature. The calculated elevation is approximately 2,700 fmsl using the regression in **Figure 8**. Unfortunately, this elevation is below the ground surface of Owens Lake and suggests an additional consideration is needed in order to derive a recharge elevation. One issue that has been discussed at length in research literature is differences between soil temperature near the water table and mean air temperature (e.g., Stute and Sonntag, 1992). Diurnal, as well as seasonal changes in air temperatures, do not influence water table temperature that occurs at depth where the noble gas recharge temperature is set. However, this temperature at depth is typically higher than the mean air temperature, between 2 and 4°C. If we assume that it is 3°C for the recharge area of DWP-7/T910, then the mean air temperature above that recharge zone would be 13.9°C, instead of 16.9°C. The 13.9°C temperature is similar to 14.5°C temperature measured in LADWP Cottonwood Plant Well, which had the youngest groundwater age. The 13.9°C temperature places the calculated recharge elevation for DWP-7/T910 at approximately 4,150 fmsl using the regression in **Figure 8**.

Recharge along the west side of the OLGEP area is dominated by stream recharge. Infiltration is maximized in the springtime during intense snow melting. The infiltration occurs as streams emerge from exposed bedrock surfaces at elevation and begin to cross the porous alluvial fan deposits at lower elevations. The 4,150-foot elevation just west of DWP-7/T910 correlates well with the upper end of the alluvial fan systems and stream flow emerging from the higher bedrock elevations. Consequently, the calculated recharge temperature and recharge elevation correlate with a plausible recharge are for DWP-7/T910. Furthermore, the δD-$\delta^{18}O$ values for DWP-7/T910 correlate to the west side recharge as shown in **Figure 2**.

7.2 Groundwater Age Interpretation

The ^{3}H, ^{14}C, and $\delta^{13}C$ results are most applicable to the west side groundwater. As shown is **Figure 5**, this groundwater has the highest ^{14}C abundance, with three samples having measurable ^{3}H. All of the west side samples, except for the two lower levels of OLGEP wells at site DWP-7, line up on a straight line in **Figure 6** that extrapolates between modern recharge (^{14}C = 89-106 pmc) and a ^{14}C-absent source with $\delta^{13}C$ between 0 and 1 per mil. This strongly suggests that this groundwater uniformly undergoes a fairly rapid reaction with a ^{14}C-absent source. The reaction is rapid because there is no indication that this groundwater has experienced any radiometric decay of its ^{14}C, which would plot data below the straight line in **Figure 6**. As further evidence that a single source is contributing to the decrease in ^{14}C and increase in $\delta^{13}C$, the alkalinity as milli-equivalents (meq) is plotted against the ^{14}C and $\delta^{13}C$ separately in **Figures 9a and 9b**. Milliequivalent is calculated by dividing each constituent contributing to the alkalinity (HCO_3 and CO_3) by its molecular weight and multiplying by its charge state (times 2 in the case of CO_3). This provides a better measure of the dissolved carbon reactivity progress.

First of all, both plots show a linear array of data that have been extrapolated to end member values. In **Figure 9a**, the ^{14}C extrapolates to an alkalinity between 4 and 5 meq at 0 pmc. At the other end at 0 meq, the ^{14}C is between 100 and 120 pmc, consistent with atmospheric carbon dioxide values in the past 20 years. In **Figure 9b**, the extrapolation to an alkalinity between 4 and 5 meq results in a $\delta^{13}C$ values of approximately 0 per mil, a value consistent with marine carbonates. The other end of the extrapolation intersects a $\delta^{13}C$ value of -18 per mil at 0 meq. The -18 per mil value is consistent with a soil zone bicarbonate species in isotopic equilibrium with carbon dioxide of approximately -27 per mil at presumed soil temperatures in this area. The -27 per mil value is consistent with a respired carbon dioxide by plants utilizing a Calvin cycle metabolic pathway. The Calvin cycle is a type of biochemical reaction series that occurs in many common types of plants during photosynthesis. During this cycle, the plant will preferentially take up carbon dioxide with a low ^{13}C content and respire excess carbon dioxide with the same low ^{13}C abundance. The $\delta^{13}C$ value of this respired carbon dioxide ranges between -25 and -30 per mil. Dissolved bicarbonate in open exchange with a carbon dioxide of this isotopic range will subsequently take up a proportionally higher amount of ^{13}C over ^{12}C, and the difference in $\delta^{13}C$ between the bicarbonate and the carbon dioxide is generally between 8 and 10 per mil. This is why the -18 per mil extrapolated end-member in **Figure 9b** is consistent with bicarbonate in isotopic equilibrium with soil zone carbon dioxide. In summary then, the commonality between **Figures 9a** and **9b** supports a uniform reaction process for west side samples.

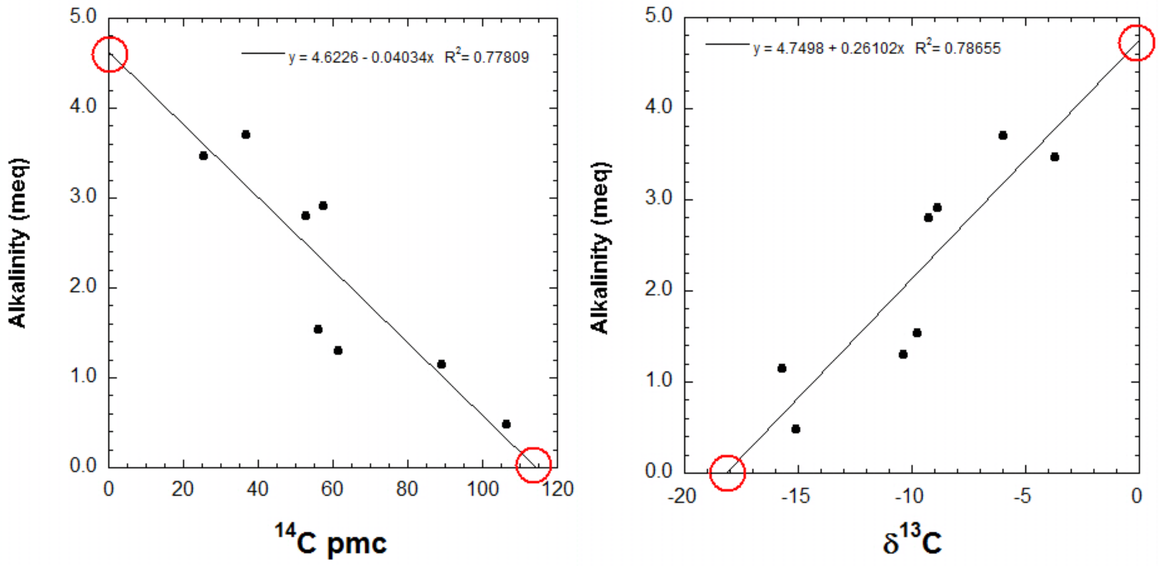

Figure 9
Comparison of Alkalinity with ^{14}C and δ^{13}C Values in West Side Wells

Note: Alkalinity in milli-equivalents for west side samples plotted against (a) ^{14}C and (b) δ^{13}C show linear arrays that when fitted with a best fit line extrapolate to end-member values consistent with those end-members defined for west side samples in Figure 5. This supports the conclusion that a uniform ^{14}C-absent source contributes to decreasing ^{14}C and increasing δ^{13}C of west side groundwater.

The fact that there appears to be no radiometric decay of the ^{14}C in the west side samples likely limits the age of these groundwater to <300 years. The 300-year limit is determined by the measurement precision (approximately ±1 pmc) compared to ^{14}C decay is this timeframe. In the case of Cottonwood Spring NW, LADWP Cottonwood Plant Well, and Cartago-CSD samples, there is measureable ^{3}H, which would limit these groundwaters to ages of <50 years old. It is further likely that these youngest groundwaters are less than 10 years old, since their ^{3}H concentrations are too low to represent 1960s recharge.

The groundwater age determination for the OLGEP wells and east side samples is not as straightforward as the west side samples. This is due largely to the fact that:

1) No ^{3}H is detected in the OLGEP wells or east side samples,
2) The ^{14}C abundance is low, and
3) The δ^{13}C values tend to be enriched.

There also appears to be no systematic change in the ^{14}C and δ^{13}C values as observed in the west side samples. Consequently, determining how much radiometric decay has occurred versus reaction with a ^{14}C-absent source is very difficult, particularly since recharge sources and flow paths are not clearly delineated, and aquifer geochemistry is still poorly understood. Nevertheless, it is possible to calculate minimum and maximum ages for those samples that have detectable ^{14}C and δ^{13}C values less than 0 per mil. This will exclude samples from OLGEP wells at site DWP-9 and the shallow levels at sites DWP-3 and DWP-6. The remaining samples can be treated by two different approaches. The first assumes that all the reaction with a ^{14}C-absent source occurred prior to radiometric decay. This duplicates what has been interpreted to be controlling the west side groundwater ^{14}C values and uses the correlation line in **Figure 6**. It also will calculate the youngest possible ages for the OLGEP wells and east side samples. The second approach assumes all the radiometric decay occurred prior to $\delta^{13}C$ enrichment. This simply ignores the effect of subsurface reaction with a ^{14}C-absent source. This is also known as an apparent age. Age calculations are shown below in **Table 5**.

Table 5
Calculated Groundwater Ages in OLGEP Monitoring Wells and East Side Samples Using ^{14}C and $\delta^{13}C$

Sample	$\delta^{13}C$ per mil	^{14}C pmc	Apparent Age (years)	Minimum Age (years)
OLGEP Monitoring Wells				
DWP-9 / T 896	21.7	2.9	29,269	
DWP-9 / T 898	5.0	7.2	21,751	
DWP-3 / T 899	-1.5	3.8	27,034	20,621
DWP-3 / T 901	0.7	1.8	33,212	
DWP-6 / T 912	-0.2	1.7	33,684	28,017
DWP-6 / T 911	-7.7	1.2	36,564	6,759
DWP-6 / T 913	0.9	0.5	43,801	
DWP-7 / T 908	-8.1	4.4	25,823	6,958
DWP-7 / T 910	-6.0	36.7	8,287	0
East Side				
Dolomite	-7.6	5.6	23,829	7,739
Agr-2	-5.8	3.6	27,481	9,538
KCSD-PW	-5.5	4.4	25,823	10,195
Horse Pasture	-5.1	1.9	32,765	10,096

The calculated age range shows differences between minimum and maximum ages that are small, such as in DWP-3/T899, and large, such as seen DWP-6/T908. This approach to bounding groundwater ages makes relatively simple assumptions about the history of inorganic carbon chemistry in groundwater leading to observed isotopic values. Its history may be far more complex and requires more extensive correction, but at this time there is no supporting data to take this approach. For example, the abnormally high $\delta^{13}C$ values for DWP-9 imply that the inorganic carbon is greatly influenced by active methane generation in the subsurface. This production is likely biological and follows an acetate fermentation pathway. Acetate fermentation is the commonly observed process of complex sugar breakdown to carbon dioxide and methane by micro-organisms in oxygen-limited environments. Examples would include processes that generate carbon dioxide and methane within sanitary landfills, or the well-known fermentation process that leads to alcoholic beverages. This co-production of carbon dioxide and methane will result in an isotopic equilibrium being established between these two species. The partitioning or difference between these two species will be approximately 70 per mil $\delta^{13}C$, with carbon dioxide being high and the methane low. Biogenic methane is typically less than -50 per mil, which will make the carbon dioxide as high as approximately +20 per mil, similar to that observed in DWP-9/T896. Consequently, the ^{14}C abundance of the dissolved inorganic carbon in this groundwater will be controlled mostly by the decaying organic matter and not the recharge source or other inorganic carbon sources.

The ^{4}He results from the noble gas data unfortunately do not provide any additional insight into potential groundwater ages in the OLGEP wells. This is due to the excessive amounts of ^{4}He observed above what is naturally diffused upward from the earth's crust. State-state accumulation of crustal ^{4}He in groundwater averages around 5.0e-7 ccSTP/g for every 10,000 years. Comparison of this rate to the ^{4}He concentrations in **Table 4** would indicate groundwater ages ranging from approximately 10,000 to 1.6 million years old. These ages are entirely inconsistent with both the hydrologic and isotopic evidence collected for OLGEP groundwater. We know little about the actual source area or the rate of high He discharge. Although it is likely related to both recent volcanic activity to the south in the Coso area, as well, as active faulting beneath Owens Lake, it is not known if it is uniformly diffuse through the basin, or discharges in concentrated areas.

8.0 Implications of Isotopic Sample Results on Estimated Aquifer Parameters

The results of isotopic analyses can be used to provide yet another method to estimate hydraulic conductivity based on estimated travel time (groundwater age) and generalized hydrogeologic assumptions. These estimations can then be compared to the current conceptual hydrogeologic model (MWH, 2011).

Using the west side ^{3}H and ^{14}C results, it is possible to produce a general estimate of aquifer hydraulic conductivity using a simple average linear groundwater velocity equation:

$$v = \frac{K}{n}\frac{dh}{dl}$$

where *V* is the average linear velocity, *K* is the hydraulic conductivity, *n* is the effective porosity, and *dh/dl* is the hydraulic gradient.

The linear velocity can be calculated for sample sites on the west side by taking the estimated age and dividing it by the distance to an assumed recharge area. If it is assumed that most of the west side recharge is primarily derived from the apex of the alluvial fans, then the furthest point of recharge would be the apex of the closest alluvial fan. This distance would provide the greatest length of groundwater travel. The hydraulic gradient then is estimated using the linear velocity equation coupled with the following generalized assumptions:

- Assign groundwater ages to be the youngest plausible (5 years for water with ^{3}H, and 60 years for others),
- Assume that the hydraulic gradient is half that of the surface topography, and
- Assume an effective porosity of 0.2.

Results of this exercise are tabulated in **Table 6**. The estimated range in hydraulic conductivity is comparable to previous conceptual models, as reported in MWH (2011).

Table 6
Estimate of Aquifer Hydraulic Conductivities on the West Side of Owens Lake Using Age Determinations from ^{3}H and ^{14}C

Sample Location	Distance (miles)	Age (years)	dh/dl (-)	Estimated K (ft/day)
Cartago-CSD	1	5	0.025	23.15
Northwest Seep	3	60	0.025	5.79
Bartlett Well	3	60	0.025	5.79
Cottonwood Spring NW	2	5	0.025	46.29
LADWP Cottonwood Plant Well	0.5	5	0.025	11.57
Rio Tinto	0.75	60	0.025	1.45
S3(1)	3	60	0.025	5.79
DWP-7/T910	2	60	0.025	3.86

9.0 Conclusions and Recommendations

Water quality data and isotope results are both useful in elucidating sources of recharge and for groundwater age-dating in the OLGEP study area. Major cations and ions provide a simple measure of mixing between dilute and saline water sources. Stable isotopes of deuterium (D) and oxygen-18 (^{18}O) provide a simple approach for delineating specific recharge areas, and tritium (^{3}H) establishes whether a groundwater was recharged within the past 50 years. Radiocarbon (^{14}C) proves less useful for age-dating because of a ubiquitous occurrence of ^{14}C-absent minerals in the OLGEP study area that readily interact with dissolved inorganic carbon in groundwater. Active methane generation at depth below Owens Lake also interferes with ^{14}C age-dating. Likewise, age-dating and recharge temperature calculation from measured dissolved noble gases (He, Ne, Ar, Kr, Xe) proved elusive for OLGEP wells because of an unusually high gas emission rate beneath the lake, in particular helium, that apparently disrupts the relative abundance of noble gases. However, in one well location (DWP-7/T910), a recharge temperature was successfully calculated and correlated well with the most plausible recharge area.

Specific conclusions from the data generated in this study are listed below:

1) The total dissolved solids concentrations are low in groundwater and springs on the west side of Owens Lake, which contrasts with the more saline groundwater beneath Owens Lake at depth, as well as springs and shallow wells on the east side. The dilute concentration observed in west side samples implies that they are not under the immediate influence of the more saline water to the east.

2) The δD-δ^{18}O results demonstrate that the dilute west side waters are recharged by stream channel infiltration originating from the higher elevations of the eastern Sierra Nevada. This is further supported by the similarity in isotope abundances between measured creek samples and local groundwater and springs.

4) The δD-$\delta^{18}O$ of sampled OLGEP monitoring wells (except site DWP-7) demonstrates that they are not recharged locally, but rather their lower isotopic values are consistent with isotopic values of recharge sources further north. In other words, water in OLGEP monitoring wells is consistent with a down-valley flow source.

5) Based on the δD-$\delta^{18}O$ results, it can be concluded that groundwater at OLGEP well site DWP-6 located in the southeastern portion of Owens Lake was recharged by significantly evaporated surface water. This suggests that historically, ponded water may have recharged groundwater aquifers locally in the southern portion of the Owens Lake area.

6) The δD-$\delta^{18}O$ values in groundwater at OLGEP well site DWP-7 indicates recharge from the west side.

7) Based on the geographic distribution of groundwater $\delta^{18}O$ values in the OLGEP study area, mapped faults beneath the western side of Owens Lake are likely limiting groundwater movement between west side recharge and down-valley flow sources.

8) The δD-$\delta^{18}O$ values for springs and shallow wells located on the east side of Owens Lake are generally the same as those for OLGEP monitoring wells recharged by down-valley flow, which indicate a similar isotopic and geochemical character. However, there are some differences observed in the isotopic values, such as in DWP-3/T899, that suggest locally-recharged groundwater does contribute to some recharge on the east side.

9) Groundwater ages measured for springs and shallow wells on the west side of Owens Lake were found to be less than 300 years old.

10) Groundwater from three sites (Cottonwood Spring NW, LADWP Cottonwood Plant Well, and Cartago-CSD) was found to be less than 50 years old.

11) Hydraulic conductivities calculated using isotopic results are comparable to previous conceptual models, as reported in MWH (2011), and appear reasonable.

12) Calculated ^{14}C groundwater ages ranged from approximately 6,800 years to greater than 40,000 years in OLGEP monitoring wells that are recharged by down-valley flow, as well as sample sites on the east side of Owens Lake.

13) The ^{14}C measured in OLGEP well site DWP-9 was heavily influenced by active methane production at depth, and age-dating is highly uncertain.

14) Uncertainties remain for groundwater ages in OLGEP wells and east side sample sites. The uncertainty results from:

    - a poor control on reaction mechanisms that cause ^{14}C-absent minerals to contribute carbon to the dissolved inorganic carbon in groundwater.
    - an usually high helium gas emission occurs below Owens Lake that obscures the steady-state accumulation of ^{4}He commonly used in semi-quantitative age-dating of groundwater.

15) The unusually high helium gas emission is also accompanied by a high discharge of other gas presumed to be methane and was observed in several of the OLGEP wells.

16) This high gas emission rate disrupts the relative abundance of the dissolved noble gases in the aquifer and the wells by preferentially stripping out neon and argon over krypton and xenon. This disruption has made the measured noble gas abundance inadequate for calculating ages and recharge temperatures.

17) Only in the case of OLGEP well DWP-7/T910 was it possible to calculate recharge temperature. The recharge temperature of groundwater in DWP-7/T910 was calculated at 16.9°C, which correlates with a recharge elevation of approximately 4,100 feet above sea level. This elevation is consistent with the upper end of alluvial fans west of DWP-7/T910, where stream channel infiltration takes place.

This limited isotopic study was successful in meeting the goals outlined in the SAP and improved the hydrogeologic conceptual model in several ways. Future isotopic and general water quality sampling and analysis may prove useful for shedding light in key areas:

1) Previous sampling by GBUAPCD, LADWP, and others utilized varying sample suites for cations and anions. A uniform sampling and analysis plan for general minerals (cations and anions) across the study area could provide a useful baseline of water quality. General minerals could also be used as a simple monitoring tool for potential migration of saline water into less saline groundwater following a change in groundwater use patterns.
2) Better resolution for recharge sources of down-valley could be provided by additional measurements of δD and $\delta^{18}O$ conducted on a number of surface and groundwater sites in suspected recharge areas and along flow-paths leading to the OLGEP study area.
3) Better age-dating of down-valley flow may be provided by sampling for ^{14}C and noble gases at OLGEP monitoring well sites DWP-1 and DWP-11 (or similarly accessible wells with well-known depths) and/or down-valley flow sites east of the Owens River where there is well construction data and control on the depth of sampling. However, the sampled wells should be absent of free gas of the type that was observed in site DWP-9.
4) Faulting in the eastern side of Owens Lake that influences groundwater migration could be further defined by additional samples collected for δD and $\delta^{18}O$, particularly for any wells that might be upgradient of the lake level or adjacent wells with distinctly different depths. This will help establish the influence of any locally recharged groundwater flowing towards Owens Lake, and whether this locally-recharged groundwater comingles with down-valley flow.
5) Because δD-$\delta^{18}O$ measurements are diverse enough among the different recharge sources, additional measurements could be used as a simple and inexpensive groundwater recharge mapping tool.

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APPENDIX A

Site Summary Sheets

OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas		
Site Name:	De La Cour Ranch (Carroll Creek)	**Field Label:**	Carroll Crk
Description of Site:	Surface Water from Carroll Creek	**Date Sampled:**	7/23/2012

Coordinates:	**Northing:**	4,040,470.76	**Well Depth (ft):**	N/A
	Easting:	401,272.19	**Screened Intervals (fbgs):**	N/A
	Elevation (fmsl):	5,497		

Field Parameters:	**Temperature (°C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	15.60	8.35	-65	121	0.13	0.0	9.05	91.9

Samples Submitted to Laboratory:	**Cations/ Anions**	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and $\delta^{18}O$	$\delta^{13}C$			
	x	x				

Air Photo Showing Sample Site Location

Location of Sample: Ponded Water on Carroll Creek Upstream of Culvert West of Horseshoe Meadows Road

Measurement of Field Parameters at Culvert on Carroll Creek

OWENS LAKE GROUNDWATER EVALUATION PROJECT

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Water Quality Sample Location Summary Sheet For:

De La Cour Ranch - Carroll Creek

Los Angeles Department of Water & Power

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This sheet is designed to print 11" by 17".

OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas			
Site Name:	Northwest Seep		**Field Label:**	NW Seep
Description of Site:	Spring Water from NW Seep Area		**Date Sampled:**	7/24/2012
Coordinates:	**Northing:**	4,040,533.86	**Well Depth (ft):**	N/A
	Easting:	407,810.09	**Screened Intervals (fbgs):**	N/A
	Elevation (fmsl):	3,575		

Field Parameters:	**Temperature (°C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	20.87	6.36	31	-9	0.88	280.0	0.46	4.7

Samples Submitted to Laboratory:	**Cations/ Anions**	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and δ^{18}O	δ^{13}C			
	x	x	x	x	x	

Air Photo Showing Sample Site Location

View to Southeast Showing Northwest Seep

Sample Preparations at Northwest Seep

OWENS LAKE GROUNDWATER EVALUATION PROJECT

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Water Quality Sample Location Summary Sheet For:

Northwest Seep

Los Angeles Department of Water & Power

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OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas				
Site Name:	Bartlett Well		**Field Label:**	Bartlett-CW	
Description of Site:	Groundwater from Bartlett Flowing Well		**Date Sampled:**	7/24/2012	
Coordinates:	**Northing:**	4,037,918.27	**Well Depth (ft):**	575	(based on 2008 video log and associated interpretation)
	Easting:	408,049.05	**Screened Intervals (fbgs):**	161 - 284 500 - 575	
	Elevation (fmsl):	3,582			

	Temperature (^oC)	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
Field Parameters:	22.15	8.35	-74	-78	0.52	0.0	3.66	41.9

	Cations/ Anions	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and $\delta^{18}O$	$\delta^{13}C$			
Samples Submitted to Laboratory:		x	x	x	x	

Air Photo Showing Sample Site Location

View to the South of the Barlett Well Sample Location

Close-Up Photo of Barlett Well Showing Flowing Water

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

Bartlett Well (BRTLTPW)

Los Angeles Department of Water & Power

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OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas		
Site Name:	Cottonwood Spring NW	**Field Label:**	Cottonwood Spring
Description of Site:	Spring Water from Cottonwood Spring NW	**Date Sampled:**	7/24/2012

Coordinates:	**Northing:**	4,032,155.63	**Well Depth (ft):**	N/A
	Easting:	408,943.32	**Screened Intervals (fbgs):**	N/A
	Elevation (fmsl):	3,563		

	Temperature (°C)	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
Field Parameters:	21.52	7.33	-19	-72	0.47	371.0	0.00	0

	Cations/ Anions	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and $\delta^{18}O$	$\delta^{13}C$			
Samples Submitted to Laboratory:	x	x	x	x	x	

Air Photo Showing Sample Site Location

Photograph Showing Location of Cottonwood Well and Spring

Cottonwood Spring Dug Hole

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Water Quality Sample Location Summary Sheet For:

Cottonwood Spring NW

LA DWP Los Angeles Department of Water & Power

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OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas							
Site Name:	Groundwater from Cottonwood Spring Well				**Field Label:**	Cottonwood-Well		
Description of Site:	Well located near Cottonwood Spring				**Date Sampled:**	7/24/2012		
Coordinates:	**Northing:**	4,032,155.63			**Well Depth (ft):**	Unknown		
	Easting:	408,943.32			**Screened Intervals (fbgs):**	Unknown		
	Elevation (fmsl):	3,566						
Field Parameters:	**Temperature (°C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	23.53	9.05	-115	34	6.03	0.0	0.38	4.7
Samples Submitted to Laboratory:	**Cations/ Anions**		**Stable Isotopes**			**Radiocarbon**	**Tritium**	**Noble Gas**
			δD and δ^{18}O		δ^{13}C			
			x					

Air Photo Showing Sample Site Location

Cottonwood Spring Well

Photograph Showing Location of Cottonwood Well and Spring

OWENS LAKE GROUNDWATER EVALUATION PROJECT

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Water Quality Sample Location Summary Sheet For:

Cottonwood Spring Well

Los Angeles Department of Water & Power

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OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas			
Site Name:	Cottonwood Flume		**Field Label:**	N/A
Description of Site:	Surface Water at Cottonwood Flume (field data only)		**Date Sampled:**	7/24/2012
Coordinates:	**Northing:**	4,032,230.56	**Well Depth (ft):**	N/A
	Easting:	409,446.16	**Screened Intervals (fbgs):**	N/A
	Elevation (fmsl):	3,563		

Field Parameters:	**Temperature (°C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	19.89	7.83	-48	-16	2.63	0.0	6.22	69.3

Samples Submitted to Laboratory:	**Cations/ Anions**	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and $\delta^{18}O$	$\delta^{13}C$			
	x					

Air Photo Showing Sample Site Location

Collection of Field Data at Cottonwood Flume

View to the West of Cottonwood Flume
(Note that the concrete structure is the flume used to gauge flow)

OWENS LAKE GROUNDWATER EVALUATION PROJECT

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Water Quality Sample Location Summary Sheet For:

Cottonwood Flume

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OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas							
Site Name:	LADWP Cottonwood Plant Well				**Field Label:**	Aqueduct Well		
Description of Site:	Groundwater from LADWP Cottonwood Plant Well				**Date Sampled:**	7/24/2012		
Coordinates:	**Northing:**	4,030,667.92			**Well Depth (ft):**	260		
	Easting:	406,827.80			**Screened Intervals (fbgs):**	206 - 260		
	Elevation (fmsl):	3,777						
Field Parameters:	**Temperature (°C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	14.56	5.97	52	107	0.10	0.0	6.77	68.8
Samples Submitted to Laboratory:	**Cations/ Anions**		**Stable Isotopes**			**Radiocarbon**	**Tritium**	**Noble Gas**
			δD and $\delta^{18}O$		$\delta^{13}C$			
	x		x		x	x	x	

Air Photo Showing Sample Site Location

View of the Los Angeles Aqueduct Looking East from the Well Site

OWENS LAKE GROUNDWATER EVALUATION PROJECT

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Water Quality Sample Location Summary Sheet For:

LADWP Cottonwood Plant Well

Los Angeles Department of Water & Power

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OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas			
Site Name:	Ash Creek		**Field Label:**	Ash Crk
Description of Site:	Surface Water from Ash Creek		**Date Sampled:**	7/24/2012
Coordinates:	**Northing:**	4,027,549.90	**Well Depth (ft):**	N/A
	Easting:	407,286.65	**Screened Intervals (fbgs):**	N/A
	Elevation (fmsl):	3,872		

Field Parameters:	**Temperature (^{o}C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	19.59	7.96	-54	62	0.26	0.0	8.13	92

Samples Submitted to Laboratory:	**Cations/ Anions**	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and δ^{18}O	δ^{13}C			
	x	x				

Air Photo Showing Sample Site Location

Ash Creek Sampling Location

Collection of Field Data at Ash Creek Sampling Location

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Water Quality Sample Location Summary Sheet For:

Ash Creek

Los Angeles Department of Water & Power

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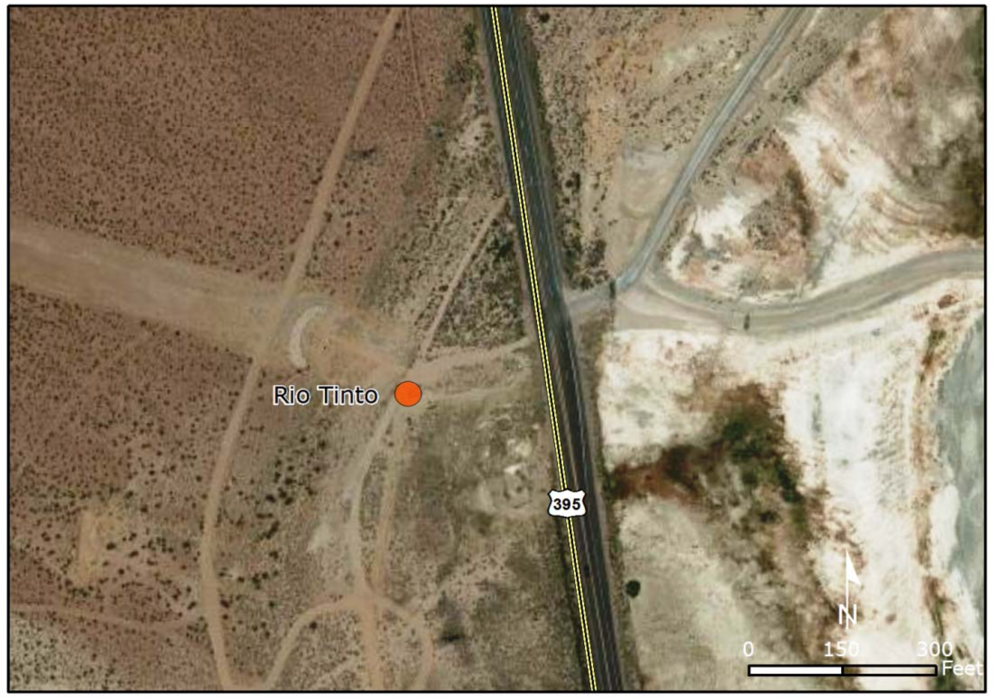
OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas			
Site Name:	Rio Tinto Well		**Field Label:**	Rio Tinto-SW
Description of Site:	Groundwater from Rio Tinto Well		**Date Sampled:**	7/24/2012
Coordinates:	**Northing:**	4,022,932.00	**Well Depth (ft):**	65
	Easting:	408,038.07	**Screened Intervals (fbgs):**	34 - 62
	Elevation (fmsl):	3,616		

	Temperature (°C)	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
Field Parameters:	19.46	7.73	-40	-159	0.30	0.0	0.00	0

	Cations/ Anions	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and $\delta^{18}O$	$\delta^{13}C$			
Samples Submitted to Laboratory:	x	x	x	x	x	



Air Photo Showing Sample Site Location

Rio Tinto Well

View to the Southwest of Rio Tinto Well

OWENS LAKE GROUNDWATER EVALUATION PROJECT

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Water Quality Sample Location Summary Sheet For:

Rio Tinto Well

Los Angeles Department of Water & Power

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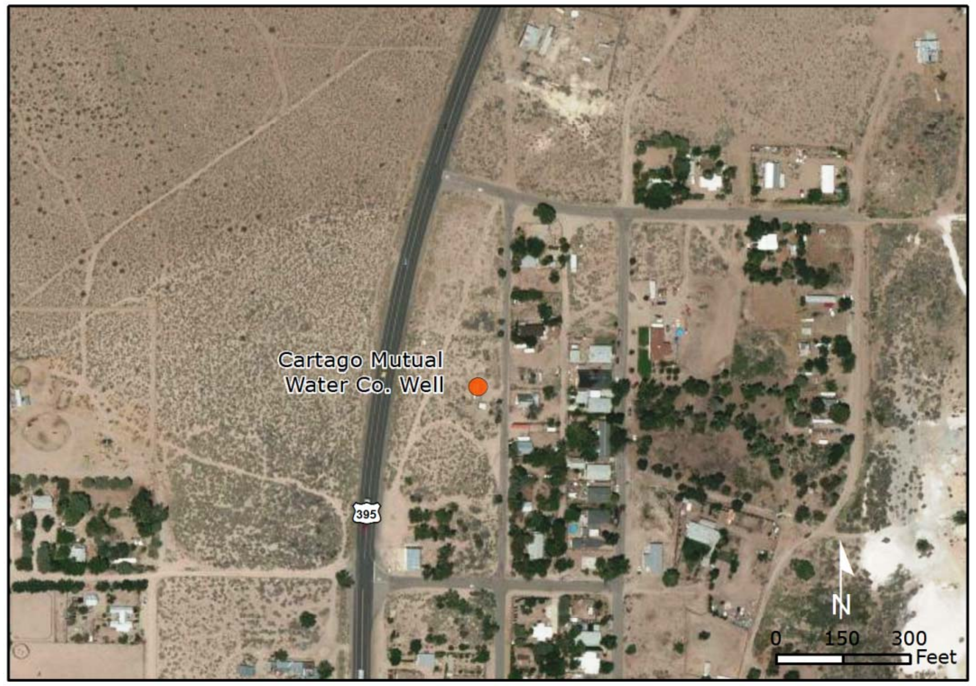
OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas		
Site Name:	Cartago Mutual Water Co. Well	**Field Label:**	Cartago-COM
Description of Site:	Groundwater from Cartago Mutual Water Co. Well	**Date Sampled:**	7/23/2012
Coordinates:	**Northing:** 4020088.13	**Well Depth (ft):**	Unknown
	Easting: 407,887.52	**Screened Intervals (fbgs):**	Unknown
	Elevation (fmsl): 3,655		

Field Parameters:

Temperature (°C)	pH	pH (mV)	Oxidation Reduction Potential (mV)	Electrical Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (%)
18.00	8.33	-65.00	89.00	0.25	0.0	6.26	67.2

Samples Submitted to Laboratory:

Cations/ Anions	Stable Isotopes		Radiocarbon	Tritium	Noble Gas
	δD and δ^{18}O	δ^{13}C			
x	x	x	x	x	



Air Photo Showing Sample Site Location

Sample Collection at Cartago Community Well

Cartago Community Well

OWENS LAKE GROUNDWATER EVALUATION PROJECT

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Water Quality Sample Location Summary Sheet For:

Cartago Mutual Water Co. Well

LADWP Los Angeles Department of Water & Power

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OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas			
Site Name:	DWP - 9 T896		**Field Label:**	DWP - 9 T896
Description of Site:	Groundwater from DWP - 9 T896 - New OLGEP Monitoring Well (Aquifer 5)		**Date Sampled:**	7/23/2012
Coordinates:	**Northing:**	4,041,347.6	**Well Depth (ft):**	1,601
	Easting:	412,453.5	**Screened Intervals (fbgs):**	1,280 - 1,360
	Elevation (fmsl):	3,572.10		

	Temperature (^{o}C)	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
Field Parameters:	19.15	9.15	-110	-349	1.46	237.0	0.00	0

	Cations/ Anions	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and δ^{18}O	δ^{13}C			
Samples Submitted to Laboratory:		x	x	x	x	x

Air Photo Showing Sample Site Location

Sampling at T896

Noble Gas Collection at T896

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

DWP-9 T896

Los Angeles Department of Water & Power

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OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas							
Site Name:	DWP - 9 T897				**Field Label:**	DWP - 9 T897		
Description of Site:	Groundwater from DWP - 9 T897 - New OLGEP Monitoring Well (Aquifer 3)				**Date Sampled:**	7/23/2012		
Coordinates:	**Northing:**	4,041,340.1			**Well Depth (ft):**	880		
	Easting:	412,453.6			**Screened Intervals (fbgs):**	780 - 860		
	Elevation (fmsl):	3,572.39						
Field Parameters:	**Temperature (^{o}C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	19.25	9.33	-119	-412	1.77	164.0	0.00	0
Samples Submitted to Laboratory:	**Cations/ Anions**		**Stable Isotopes**			**Radiocarbon**	**Tritium**	**Noble Gas**
			δD and δ^{18}O		δ^{13}C			
			x					

Air Photo Showing Sample Site Location

Sample Collection at T897

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

DWP-9 T897

LA DWP Los Angeles Department of Water & Power

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This sheet is designed to print 11" by 17".

OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas			
Site Name:	DWP - 9 T898		**Field Label:**	DWP - 9 T898
Description of Site:	Groundwater from DWP - 9 T897 - New OLGEP Monitoring Well (Aquifer 1)		**Date Sampled:**	7/23/2012
Coordinates:	**Northing:**	4,041,332.4	**Well Depth (ft):**	340
	Easting:	412,453.3	**Screened Intervals (fbgs):**	240 - 320
	Elevation (fmsl):	3,572.22		

	Temperature (°C)	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
Field Parameters:	19.77	9.28	-117	-349	1.35	108.0	0.00	0

	Cations/ Anions	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and $\delta^{18}O$	$\delta^{13}C$			
Samples Submitted to Laboratory:		x	x	x	x	x

Air Photo Showing Sample Site Location

Sample Collection at T898

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

DWP-9 T898

Los Angeles Department of Water & Power

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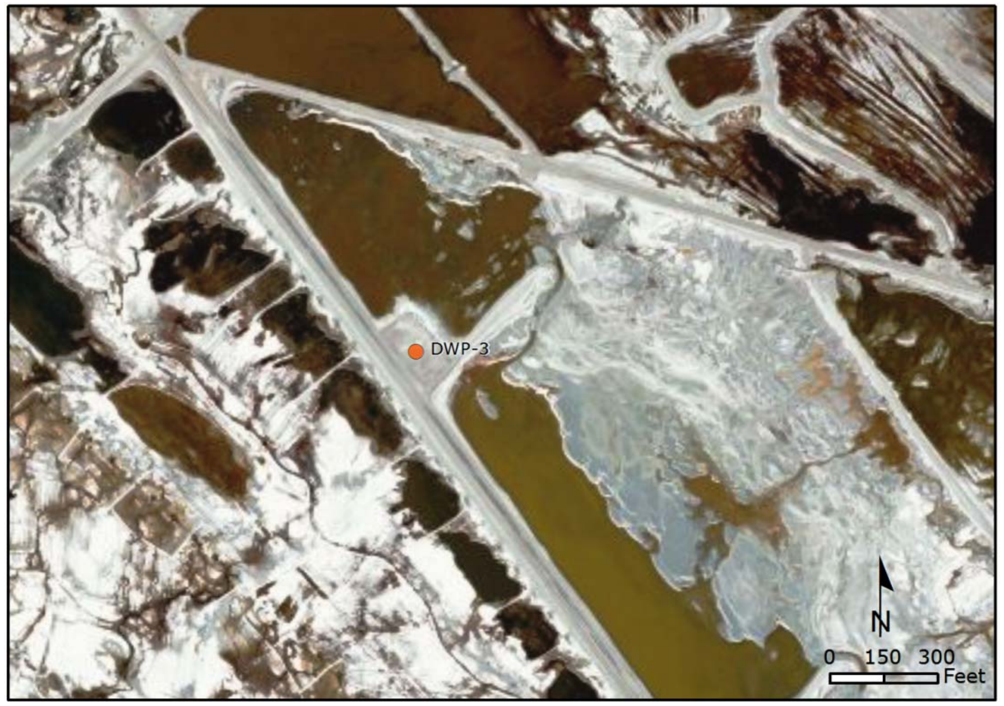
This sheet is designed to print 11" by 17".

OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas			
Site Name:	DWP - 3 T899		**Field Label:**	DWP - 9 T899
Description of Site:	Groundwater from DWP - 3 T899 - New OLGEP Monitoring Well (Aquifer 5)		**Date Sampled:**	7/23/2012
Coordinates:	**Northing:**	4,038,643.9	**Well Depth (ft):**	1,003
	Easting:	418,254.5	**Screened Intervals (fbgs):**	920 - 960
	Elevation (fmsl):	3,572.98		

	Temperature (°C)	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
Field Parameters:	19.40	8.99	-101	-394	1.25	0.0	0.00	0

	Cations/ Anions	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and δ^{18}O	δ^{13}C			
Samples Submitted to Laboratory:		x	x	x	x	x



Air Photo Showing Sample Site Location

Sample Collection at T899

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

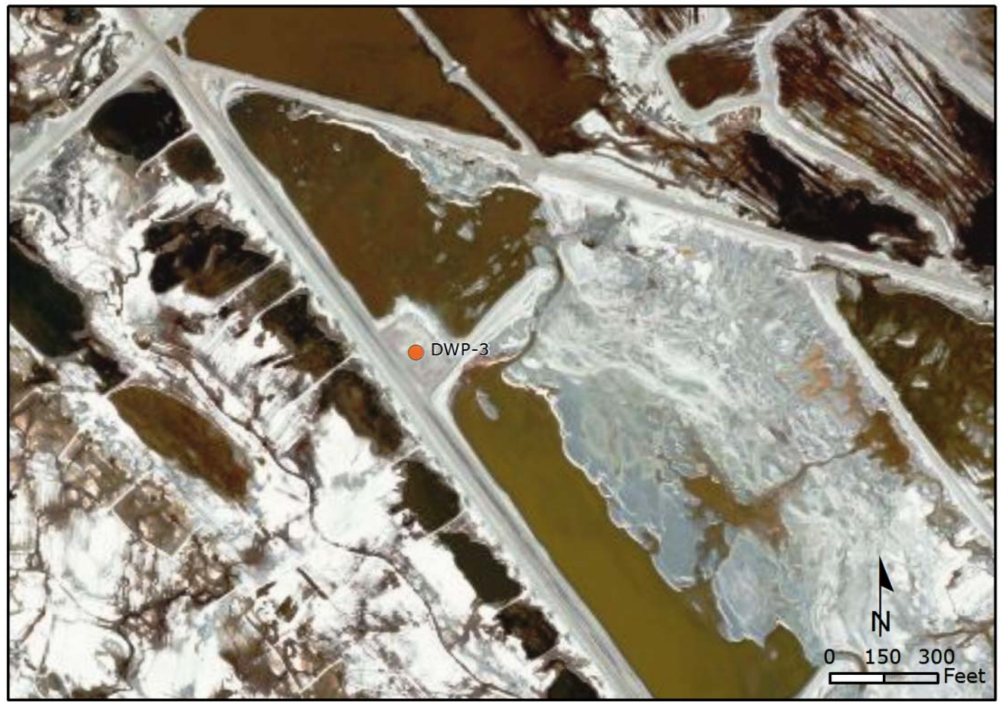
DWP-3 T899

Los Angeles Department of Water & Power

MWH

This sheet is designed to print 11" by 17".

OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas							
Site Name:	DWP - 3 T901				**Field Label:**	DWP - 3 T901		
Description of Site:	Groundwater from DWP - 3 T901 - New OLGEP Monitoring Well (Aquifer 1)				**Date Sampled:**	7/23/2012		
Coordinates:	**Northing:**	4,038,651.50			**Well Depth (ft):**	190		
	Easting:	418,265.10			**Screened Intervals (fbgs):**	150 - 170		
	Elevation (fmsl):	3,572.87						
Field Parameters:	**Temperature (°C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	19.78	9.26	-115	-256	3.57	406.0	0.00	0
Samples Submitted to Laboratory:	**Cations/ Anions**		**Stable Isotopes**			**Radiocarbon**	**Tritium**	**Noble Gas**
			δD and $\delta^{18}O$		$\delta^{13}C$			
			x		x	x	x	x



Air Photo Showing Sample Site Location

Sample Collection at T901

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

DWP-3 T901

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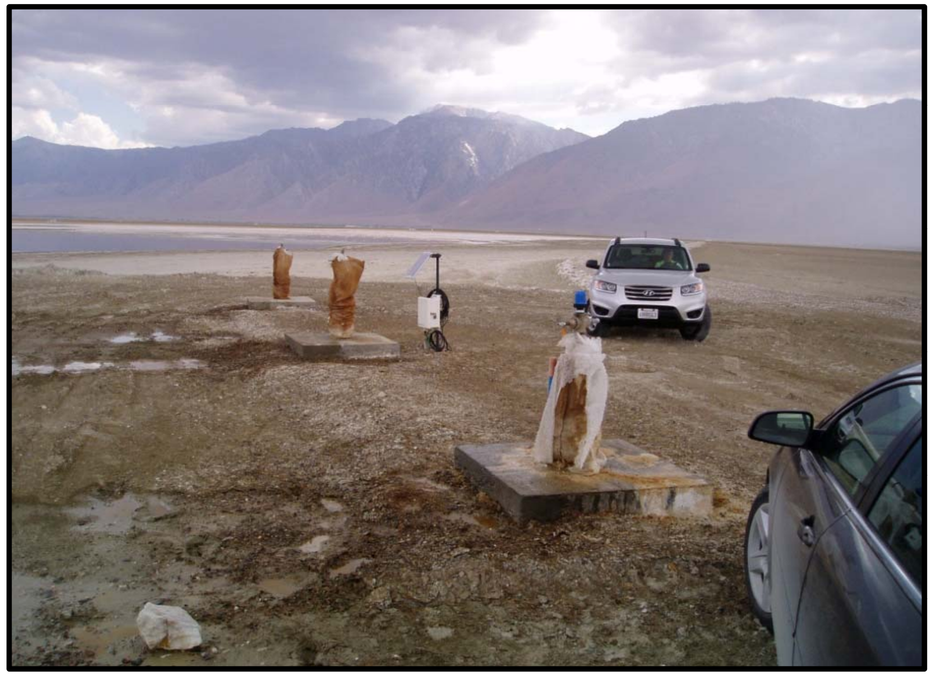
OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas							
Site Name:	DWP - 6 T912				**Field Label:**	DWP - 6 T912		
Description of Site:	Groundwater from DWP - 6 T912 - New OLGEP Monitoring Well (Aquifer 5)				**Date Sampled:**	7/24/2012		
Coordinates:	**Northing:**	4,025,249.3			**Well Depth (ft):**	1,080		
	Easting:	414,248.3			**Screened Intervals (fbgs):**	1,020 - 1,060		
	Elevation (fmsl):	3,564.42						
Field Parameters:	**Temperature (^{o}C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	20.01	9.23	-114	-316	5.58	533.0	0.00	0
Samples Submitted to Laboratory:	**Cations/ Anions**		**Stable Isotopes**			**Radiocarbon**	**Tritium**	**Noble Gas**
			δD and δ^{18}O		δ^{13}C			
			x		x	x	x	

Air Photo Showing Sample Site Location



Sample Collection at T912

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

DWP-6 T912

Los Angeles Department of Water & Power

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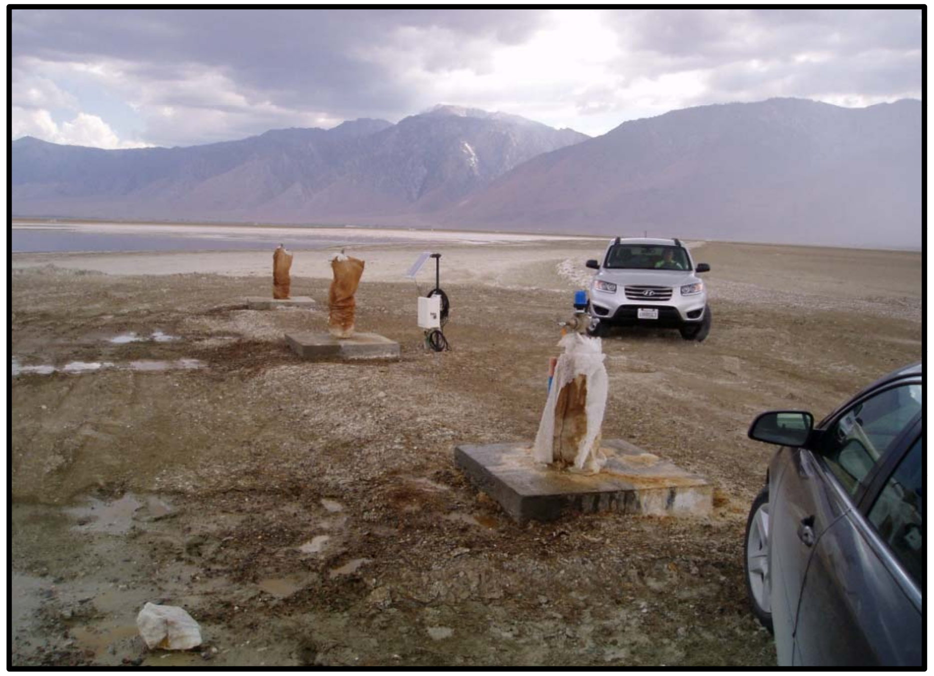
OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas			
Site Name:	DWP - 6 T911		**Field Label:**	DWP - 6 T 911
Description of Site:	Groundwater from DWP - 6 T911 - New OLGEP Monitoring Well (Aquifer 5)		**Date Sampled:**	7/23/2012
Coordinates:	**Northing:**	4,025,254.3	**Well Depth (ft):**	1,500
	Easting:	414,252.0	**Screened Intervals (fbgs):**	1,420 - 1,460
	Elevation (fmsl):	3,564.44		

Field Parameters:	**Temperature (°C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	19.00	8.77	-89	-303	9.82	86.7	0.00	0

Samples Submitted to Laboratory:	**Cations/ Anions**	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and δ^{18}O	δ^{13}C			
		x	x	x	x	x

Air Photo Showing Sample Site Location



DWP-6 Well Site

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

DWP-6 T911

Los Angeles Department of Water & Power

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OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas							
Site Name:	DWP - 6 T913				**Field Label:**	DWP - 6 T 913		
Description of Site:	Groundwater from DWP - 6 T913 - New OLGEP Monitoring Well (Aquifer 1)				**Date Sampled:**	7/23/2012		
Coordinates:	**Northing:**	4,025,259.6			**Well Depth (ft):**	312		
	Easting:	414,255.5			**Screened Intervals (fbgs):**	260 - 300		
	Elevation (fmsl):	3,564.51						
Field Parameters:	**Temperature (°C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	20.39	9.24	-115	-302	38.90	1.7	0.00	0
Samples Submitted to Laboratory:	**Cations/ Anions**		**Stable Isotopes**			**Radiocarbon**	**Tritium**	**Noble Gas**
			δD and δ^{18}O		δ^{13}C			
			x		x	x	x	

Air Photo Showing Sample Site Location

Sample Collection at T913

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

DWP-6 T913

Los Angeles Department of Water & Power

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OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas							
Site Name:	DWP - 7 T908				**Field Label:**	DWP - 7 T908		
Description of Site:	Groundwater from DWP - 7 T908 - New OLGEP Monitoring Well (Aquifer 5)				**Date Sampled:**	7/23/2012		
Coordinates:	**Northing:**	4,020,292.7			**Well Depth (ft):**	1,470		
	Easting:	410,017.4			**Screened Intervals (fbgs):**	1,360 - 1,400		
	Elevation (fmsl):	3,581.90						
Field Parameters:	**Temperature (°C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	18.95	9.22	-113	-301	1.68	3.4	0.00	0
Samples Submitted to Laboratory:	**Cations/ Anions**		**Stable Isotopes**			**Radiocarbon**	**Tritium**	**Noble Gas**
			δD and $\delta^{18}O$		$\delta^{13}C$			
			x		x	x	x	

Air Photo Showing Sample Site Location

Installation of Monitoring Well at DWP-7

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

DWP-7 T908

Los Angeles Department of Water & Power

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This sheet is designed to print 11" by 17".

OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas							
Site Name:	DWP - 7 T909				**Field Label:**	DWP - 7 T909		
Description of Site:	Groundwater from DWP - 7 T909 - New OLGEP Monitoring Well (Aquifer 3)				**Date Sampled:**	7/23/2012		
Coordinates:	**Northing:**	4,020,298.7			**Well Depth (ft):**	800		
	Easting:	410,017.4			**Screened Intervals (fbgs):**	740 - 780		
	Elevation (fmsl):	3,581.91						
Field Parameters:	**Temperature (°C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	19.12	9.29	-117	-315	0.75	0.0	0.00	0
Samples Submitted to Laboratory:	**Cations/ Anions**		**Stable Isotopes**			**Radiocarbon**	**Tritium**	**Noble Gas**
			δD and δ^{18}O		δ^{13}C			
			x					

Air Photo Showing Sample Site Location

Installation of Monitoring Well at DWP-7

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

DWP-7 T909

This sheet is designed to print 11" by 17".

OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas			
Site Name:	DWP - 7 T910		**Field Label:**	DWP - 7 T910
Description of Site:	Groundwater from DWP - 7 T910 - New OLGEP Monitoring Well (Aquifer 1)		**Date Sampled:**	7/23/2012
Coordinates:	**Northing:**	4,020,304.8	**Well Depth (ft):**	260
	Easting:	410,018.6	**Screened Intervals (fbgs):**	200 - 240
	Elevation (fmsl):	3,581.50		

Field Parameters:	**Temperature (^{o}C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	18.76	9.03	-103	-322	0.40	0.0	0.00	0

Samples Submitted to Laboratory:	**Cations/ Anions**	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and δ^{18}O	δ^{13}C			
		x	x	x	x	x

Air Photo Showing Sample Site Location

Installation of Monitoring Well at DWP-7

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

DWP-7 T910

Los Angeles Department of Water & Power

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OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas		
Site Name:	Dolomite Well	**Field Label:**	Dolomite
Description of Site:	Groundwater from Dolomite Well	**Date Sampled:**	7/23/2012

Coordinates:	**Northing:**	4,046,162.64	**Well Depth (ft):**	127
	Easting:	415,578.77	**Screened Intervals (fbgs):**	Unknown
	Elevation (fmsl):	3,673		

	Temperature (°C)	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
Field Parameters:	25.10	7.58	-26	-122	1.40	10.3	0.00	0

	Cations/ Anions	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
Samples Submitted to Laboratory:		δD and δ^{18}O	δ^{13}C			
		x	x	x	x	

Air Photo Showing Sample Site Location

Dolomite Well House

Dolomite Well Inside Well House

OWENS LAKE GROUNDWATER EVALUATION PROJECT

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Water Quality Sample Location Summary Sheet For:

Dolomite Well

Los Angeles Department of Water & Power

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This sheet is designed to print 11" by 17".

OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas							
Site Name:	AGRP-2				**Field Label:**	Agr-2		
Description of Site:	Groundwater from Agrarian Well No. 2 (owned by Frank Stradling)				**Date Sampled:**	7/23/2012		
Coordinates:	**Northing:**	4,042,586.35			**Well Depth (ft):**	140		
	Easting:	418,138.20			**Screened Intervals (fbgs):**	100 - 140		
	Elevation (fmsl):	3,604						
Field Parameters:	**Temperature (°C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	20.33	7.64	-28	-98	1.65	60.6	5.60	60
Samples Submitted to Laboratory:	**Cations/ Anions**		**Stable Isotopes**			**Radiocarbon**	**Tritium**	**Noble Gas**
			δD and δ^{18}O		δ^{13}C			
			x		x	x	x	

Air Photo Showing Sample Site Location

View to the West of AGRP-2 Well

View to the North of AGRP-2 Well

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

AGRP-2

Los Angeles Department of Water & Power

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OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas			
Site Name:	Keeler CSD Well		**Field Label:**	KCSD-PW
Description of Site:	Groundwater from Keller CSD Well		**Date Sampled:**	7/23/2012
Coordinates:	**Northing:**	4,039,398.93	**Well Depth (ft):**	125
	Easting:	421,351.49	**Screened Intervals (fbgs):**	51 - 109
	Elevation (fmsl):	3,651		

	Temperature (°C)	pH	pH (mV)	Oxidation Reduction Potential (mV)	Electrical Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (%)
Field Parameters:	22.32	7.56	-24	22	1.59	0.0	0.00	0

	Cations/ Anions	Stable Isotopes		Radiocarbon	Tritium	Noble Gas
		δD and δ^{18}O	δ^{13}C			
Samples Submitted to Laboratory:		x	x	x	x	

Air Photo Showing Sample Site Location

Sample Collection at Keeler CSD Well

Keeler CSD Well

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

Keeler CSD Well

Los Angeles Department of Water & Power

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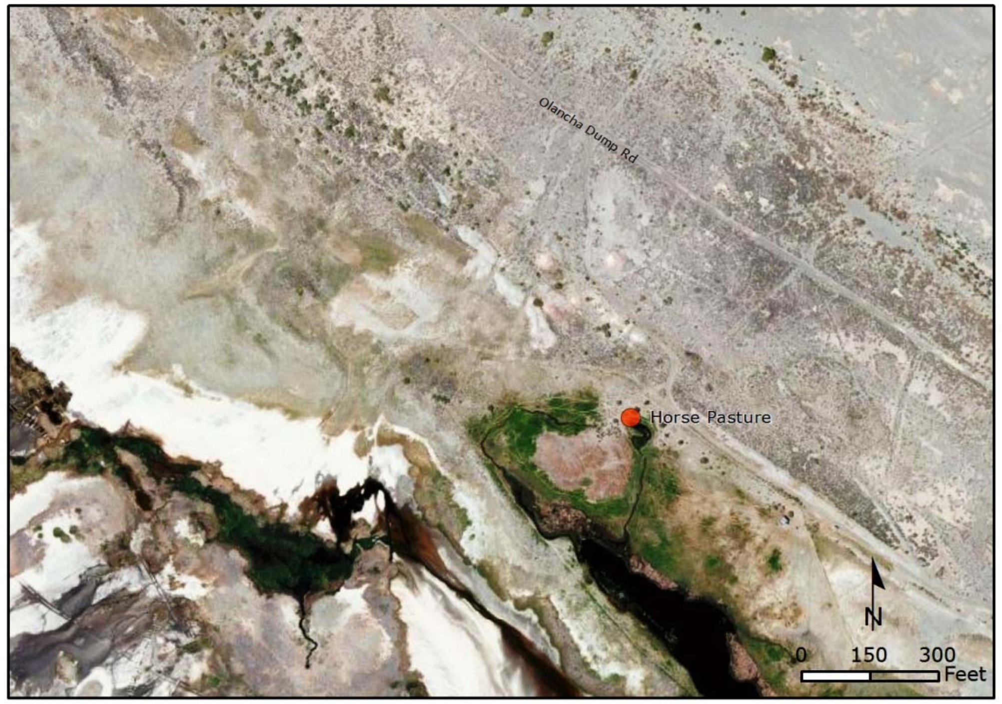
OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas			
Site Name:	Horse Pasture Well		**Field Label:**	Horse Pasture
Description of Site:	Groundwater from Horse Pasture Abandoned Flowing Well		**Date Sampled:**	7/23/2012
Coordinates:	**Northing:**	4,039,288.62	**Well Depth (ft):**	Unknown
	Easting:	419,995.19	**Screened Intervals (fbgs):**	Unknown
	Elevation (fmsl):	3,602		

Field Parameters:	**Temperature (°C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	22.22	7.75	-35	-127	2.91	0.0	0.00	0

Samples Submitted to Laboratory:	**Cations/ Anions**	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and $\delta^{18}O$	$\delta^{13}C$			
		x	x	x	x	



Air Photo Showing Sample Site Location

View to the West of Horse Pasture Well

Collection of Field Data at Horse Pasture Well

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

Horse Pasture Well

This sheet is designed to print 11" by 17".

OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas			
Site Name:	S3(1) (SE Piezomter)		**Field Label:**	S31
Description of Site:	Groundwater from Shallow Piezometer in SE Portion of Study Area		**Date Sampled:**	7/24/2012
Coordinates:	**Northing:**	4,018,930.25	**Well Depth (ft):**	10
	Easting:	411,798.53	**Screened Intervals (fbgs):**	9 - 10
	Elevation (fmsl):	3,596		

Field Parameters:	**Temperature (^{o}C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	20.00	9.43	135	-206	1.10	0.0	0.59	6.1

Samples Submitted to Laboratory:	**Cations/ Anions**	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
		δD and δ^{18}O	δ^{13}C			
	x	x	x	x	x	

Air Photo Showing Sample Site Location

View to the North of S3(1) Piezometer

View to the Southeast of S3(1) Piezometer

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

S3 (1) (SE Piezometer)

LA DWP Los Angeles Department of Water & Power

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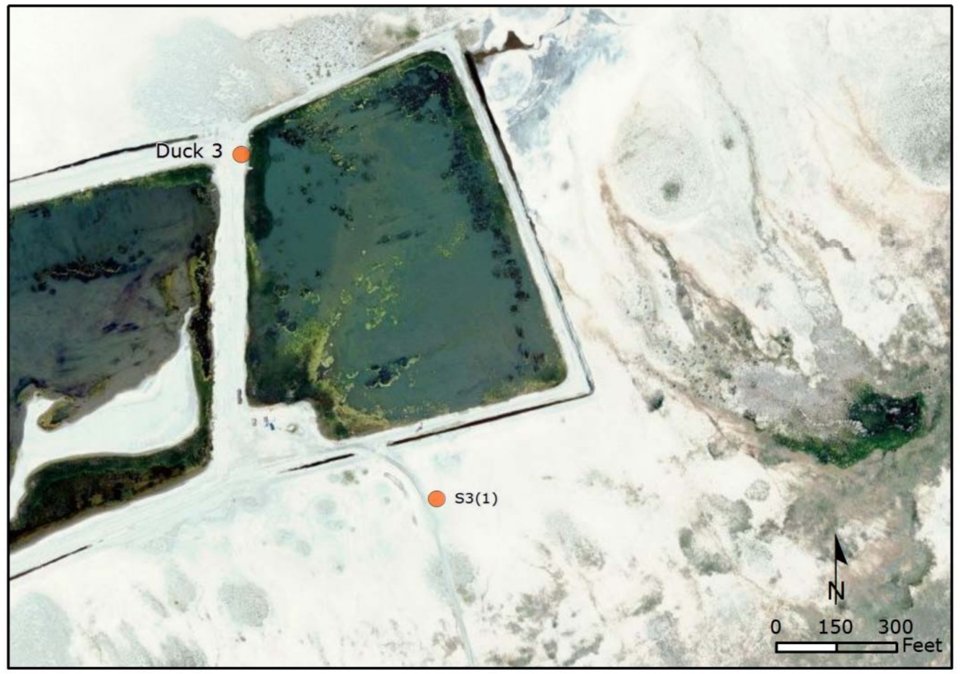
OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas			
Site Name:	Duck 3		**Field Label:**	Duck-CN
Description of Site:	Groundwater from Duck 3 Flowing Well		**Date Sampled:**	7/24/2012
Coordinates:	**Northing:**	4,019,201.93	**Well Depth (ft):**	165
	Easting:	411,650.52	**Screened Intervals (fbgs):**	40 - 140
	Elevation (fmsl):	3,598		

	Temperature (°C)	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
Field Parameters:	21.08	9.22	-123	-209	0.90	0.0	1.64	18.8

	Cations/ Anions	**Stable Isotopes**		**Radiocarbon**	**Tritium**	**Noble Gas**
Samples Submitted to Laboratory:		δD and $\delta^{18}O$	$\delta^{13}C$			
		x				



Air Photo Showing Sample Site Location

Duck Pond Panorama View to the North

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

Duck 3

Los Angeles Department of Water & Power

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OLGEP Task:	401.1.9.2 - Perform Isotope Sampling and Analysis of Groundwater and Surface Discharge Areas							
Site Name:	Tubman Cement Pond				**Field Label:**	Tubman-CP		
Description of Site:	Spring Water from Tubman Cement Pond				**Date Sampled:**	7/24/2012		
Coordinates:	**Northing:**	4,024,798.25			**Well Depth (ft):**	N/A		
	Easting:	418,778.81			**Screened Intervals (fbgs):**	N/A		
	Elevation (fmsl):	3,596						
Field Parameters:	**Temperature (°C)**	**pH**	**pH (mV)**	**Oxidation Reduction Potential (mV)**	**Electrical Conductivity (mS/cm)**	**Turbidity (NTU)**	**Dissolved Oxygen (mg/l)**	**Dissolved Oxygen (%)**
	26.43	7.94	-54	-165	8.76	893.0	2.82	36.5
Samples Submitted to Laboratory:	**Cations/ Anions**		**Stable Isotopes**			**Radiocarbon**	**Tritium**	**Noble Gas**
			δD and $\delta^{18}O$		$\delta^{13}C$			
			x					

Air Photo Showing Sample Site Location

View to the North Showing Tubman Area in Background

OWENS LAKE GROUNDWATER EVALUATION PROJECT

OLGEP

Water Quality Sample Location Summary Sheet For:

Tubman Cement Pond

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APPENDIX B

Laboratory Analytical Data

APPENDIX B-1

Laboratory Analytical Data - General Mineral Data from LADWP Laboratory

DEPARTMENT OF WATER & POWER
OF THE CITY OF LOS ANGELES
Power System
Integrated Support Services

Report No. C11913
COC 12-2032
Page 1 of 1

ENVIRONMENTAL LABORATORY DATA REPORT

Owens Lake – Dela Car Ranch
Water Sample

Five water samples were collected on July 23, 2012 from the Owens Valley Dela Car Ranch.

Sample identification, tests requested, test methods, test date, and test results are listed below

All quality assurance data indicate that the results for these samples are of acceptable quality. If you have any questions, or, if further information is required, please contact Mrs. Nina Perez at (213) 367-7481 or Mr. Kevin Han at (213) 367-7267.

Sample ID	Analysis Requested	Method	Analysis Date	Results	Analysis By
LM09765	Total Dissolved Solids (TDS)	SM 2540C	7/30/2012	**69 mg/L**	Env Lab
LM09766	Sodium (Na)	EPA 6010B	7/31/2012	**4.87 mg/L**	Env Lab
	Calcium (Ca)	EPA 6010B	7/31/2012	**12.8 mg/L**	Env Lab
	Magnesium (Mg)	EPA 6010B	7/31/2012	**1.49 mg/L**	Env Lab
	Potassium (K)	EPA 6010B	7/31/2012	**0.623 mg/L**	Env Lab
LM09767	Chloride (Cl)	EPA 300.0	7/30/2012	**7.22 mg/L**	Env Lab
	Sulfate (SO_4^{-2})	EPA 300.0	7/30/2012	**10.7 mg/L**	Env Lab
LM09768	Alkalinity	SM 2320B	8/1/2012	**42 mg/L**	Env Lab
	Bicarbonate Alkalinity (HCO_3)	SM 2320B	8/1/2012	**42 mg/L**	Env Lab
	Carbonate Alkalinity (CO_3)	SM 2320B	8/1/2012	**ND**	Env Lab
LM09769	Specific Conductivity	EPA 120.1	7/30/2012	**100 us/cm**	Env Lab

ND: None Detected

Date Completed: 8/20/12
Work Order No.: UAE32
Job Card No. : J96745
Copies to: M.Busatto
N.Liu
K. Han
N. Perez
Filenet

Tests Made by: Environmental Lab

Report by: NP Date: 8/20/12
Checked by: Date: 8/21/1
Approved: Kevin Han 8/21/2012
K. Han **Date**
Acting Manager of Environmental Laboratory

Environmental Laboratory
1630 N. Main Street, Bldg 7
Los Angeles , CA. 90012
(213) 367-7248/7399
(213) 367-7285 FAX
Address

Department of Water and Power
City of Los Angeles

Chain of Custody Record

COC # : 12-2032

Page _1_ of _1_

Report C# 11913 JC# J96745 WO# UAE32
Refrig#. Ref 1 Shelf 53 Bin#.____
Initial of Field Personnel: ☐
No. of Field Test: ☐

Sample Location: OWENS LAKE #4

	Chem Lab use only CHEMISTRY LOG NUMBERS (For sample duplicates use .1 or .X)	Sample Date	(24 Hr) Sample Time	Sample Location and Description	Preservatives	Container No.	Container Type	Container Size	Sample Matrix	Analysis Required	Test Result	Analyst(s) Assigned
1	LM09765	7/23/12	19:25	Dela Cor Ranch	None	1	P	250 mL	water	TDS		Env Lab
2	9766	〃	〃	〃	HNO_3	1	P	250 mL	water	Na,Ca,Mg,K		Env Lab
3	9767	〃	〃	〃	None	1	P	250 mL	water	Chloride, Sulfate		Env Lab
4	9768	〃	〃	〃	None	1	P	250 mL	water	Alkalinity ($CaCO_3$)/HCO3/CO3		Env Lab
5	9769	〃	〃	〃	None	1	P	250 mL	water	Sp. Cond		Env Lab
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15												
16												

Date & Time Stamp

DWP
2012 JUL 25 AM 8:20
RECD BY ENV CHEM LAB

Requested by . Marina Busatto Organization / Div. WQC
Address. JFB RM 1213 Tele 70731 Fax. 73297

Analyst________ date________
Approved by________ date________

Priority
2-4 Hrs
1Day
2 Wks
4Wks
Specify

KH
KG
RK
KC
BE
NP

	Printed Name	Signature	Time	Date
Sampled by:	Saeed Jorat	Sampled by:	17:25	7/23/12
Relinquished by:	Saeed Jorat	Relinquished by:	8:17	7/25
Received by	D Wong	Received by	8:17	7/25/12

Chem Lab COC Form #1
Revision: 10/2/2001

COC12- 2032

DEPARTMENT OF WATER & POWER
OF THE CITY OF LOS ANGELES
Power System
Integrated Support Services

Report No. C11912
COC 12-2031
Page 1 of 1

ENVIRONMENTAL LABORATORY DATA REPORT

Owens Lake – Cartego Community Well
Water Sample

Five water samples were collected on July 23, 2012 from the Owens Valley Cartego Community Well.

Sample identification, tests requested, test methods, test date, and test results are listed below

All quality assurance data indicate that the results for these samples are of acceptable quality. If you have any questions, or, if further information is required, please contact Mrs. Nina Perez at (213) 367-7481 or Mr. Kevin Han at (213) 367-7267.

Sample ID	Analysis Requested	Method	Analysis Date	Results	Analysis By
LM09760	Total Dissolved Solids (TDS)	SM 2540C	7/30/2012	**138 mg/L**	Env Lab
LM09761	Sodium (Na)	EPA 6010B	7/31/2012	**12.1 mg/L**	Env Lab
	Calcium (Ca)	EPA 6010B	7/31/2012	**24.4 mg/L**	Env Lab
	Magnesium (Mg)	EPA 6010B	7/31/2012	**2.07 mg/L**	Env Lab
	Potassium (K)	EPA 6010B	7/31/2012	**2.02 mg/L**	Env Lab
LM09762	Chloride (Cl)	EPA 300.0	7/30/2012	**7.37 mg/L**	Env Lab
	Sulfate (SO_4^{-2})	EPA 300.0	7/30/2012	**14.6 mg/L**	Env Lab
LM09763	Alkalinity	SM 2320B	8/1/2012	**80 mg/L**	Env Lab
	Bicarbonate Alkalinity (HCO_3)	SM 2320B	8/1/2012	**80 mg/L**	Env Lab
	Carbonate Alkalinity (CO_3)	SM 2320B	8/1/2012	**ND**	Env Lab
LM09764	Specific Conductivity	EPA 120.1	7/30/2012	**196 us/cm**	Env Lab

ND: None Detected

Date Completed: 8/20/12
Work Order No.: UAE32
Job Card No. : J96745
Copies to: M.Busatto
N.Liu
K. Han
N. Perez
Filenet

Tests Made by: Environmental Lab

Report by: NP Date: 8/20/12
Checked by: Date: 8/21/12.

Approved: Kevin Han 8/21/2012
K. Han **Date**
Acting Manager of Environmental Laboratory

Environmental Laboratory
1630 N. Main Street, Bldg 7
Los Angeles , CA. 90012
(213) 367-7248/7399
(213) 367-7285 FAX

Department of Water and Power
City of Los Angeles
Chain of Custody Record

COC # : 12 - 2031

Page _1_ of _1_

Report C# 11912 JC# J96745 WO# UAE32
Refrig#. R4 Shelf 53 Bin#.
Initial of Field Personnel: SJ
No. of Field Test:

Address
Sample Location: OWENS LAKE #3

Chem Lab use only CHEMISTRY LOG NUMBERS (For sample duplicates use .1 or .X)	Sample Date	(24 Hr) Sample Time	Sample Location and Description	Preservatives	Container No.	Container Type	Container Size	Sample Matrix	Analysis Required	Test Result	Analyst(s) Assigned
1 LM09760	7/23/12	18:17	Cartago Community Well	None	1	P	250 mL	water	TDS		Env Lab
2 9761	"	18:17	"	HNO_3	1	P	250 mL	water	Na,Ca,Mg,K		Env Lab
3 9762	"	18:18	"	None	1	P	250 mL	water	Chloride, Sulfate		Env Lab
4 9763	"	18:18	"	None	1	P	250 mL	water	Alkalinity ($CaCO_3$)/HCO3/CO3		Env Lab
5 9764	"	18:18	"	None	1	P	250 mL	water	Sp. Cond		Env Lab
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Date & Time Stamp

LADWP
2012 JUL 25 AM 8:20
REC'D BY: ENV. CHEM LAB

Requested by . Marina Busatto Organization / Div. WQC
Address. JFB RM 1213 Tel 70731 Fax. 73297

Analyst ____________ date ____________
Approved by ____________ date ____________

Priority
2-4 Hrs
1Day
2 Wks
4Wks
Specify

KH
RG
RK
KC
BE
NP

Printed Name	Signature	Time	Date
Sampled by: Saeed Jorat	*Sampled by:*		
Relinquished by: Saeed Jorat	*Relinquished by:*	8:17	7/25
Received by D. Wong	*Received by*	8:17	7/25/12

Chem Lab COC Form #1
Revision: 10/2/2001

COC12- 2031

DEPARTMENT OF WATER & POWER
OF THE CITY OF LOS ANGELES
Power System
Integrated Support Services

Report No. C11911
COC 12-2030
Page 1 of 1

ENVIRONMENTAL LABORATORY DATA REPORT

Owens Lake – Northwest Spring
Water Sample

Five water samples were collected on July 24, 2012 from the Owens Valley Northwest Spring.

Sample identification, tests requested, test methods, test date, and test results are listed below

All quality assurance data indicate that the results for these samples are of acceptable quality. If you have any questions, or, if further information is required, please contact Mrs. Nina Perez at (213) 367-7481 or Mr. Kevin Han at (213) 367-7267.

Sample ID	Analysis Requested	Method	Analysis Date	Results	Analysis By
LM09755	Total Dissolved Solids (TDS)	SM 2540C	7/30/2012	**409 mg/L**	Env Lab
LM09756	Sodium (Na)	EPA 6010B	7/31/2012	**116 mg/L**	Env Lab
	Calcium (Ca)	EPA 6010B	7/31/2012	**28.2 mg/L**	Env Lab
	Magnesium (Mg)	EPA 6010B	7/31/2012	**5.52 mg/L**	Env Lab
	Potassium (K)	EPA 6010B	7/31/2012	**5.37 mg/L**	Env Lab
LM09757	Chloride (Cl)	EPA 300.0	7/30/2012	**49.2 mg/L**	Env Lab
	Sulfate (SO_4^{-2})	EPA 300.0	7/30/2012	**48.1 mg/L**	Env Lab
LM09758	Alkalinity	SM 2320B	8/1/2012	**178 mg/L**	Env Lab
	Bicarbonate Alkalinity (HCO_3)	SM 2320B	8/1/2012	**178 mg/L**	Env Lab
	Carbonate Alkalinity (CO_3)	SM 2320B	8/1/2012	**ND**	Env Lab
LM09759	Specific Conductivity	EPA 120.1	7/30/2012	**672 us/cm**	Env Lab

ND: None Detected

Date Completed: 8/20/12
Work Order No.: UAE32
Job Card No. : J96745
Copies to: M.Busatto
N.Liu
K. Han
N. Perez
Filenet

Tests Made by: Environmental Lab

Report by: NP Date: 8/20/12
Checked by: Date: 8/21/12

Approved: Kevin Han 8/21/2012
K. Han **Date**
Acting Manager of Environmental Laboratory

Environmental Laboratory
1630 N. Main Street, Bldg 7
Los Angeles , CA. 90012
(213) 367-7248/7399
(213) 367-7285 FAX

Department of Water and Power
City of Los Angeles
Chain of Custody Record

COC # : 12-2030

Page _1_ of _1_

Report C# 11911 JC# JQ6745 WO# UAE32
Refrig#. R4 Shelf S3 Bin#.
Initial of Field Personnel: No. of Field Test:

Address
Sample Location: OWENS LAKE #2

Chem Lab use only CHEMISTRY LOG NUMBERS (For sample duplicates use .1 or .X)	Sample Date	(24 Hr) Sample Time	Sample Location and Description	Preservatives	Container No.	Container Type	Container Size	Sample Matrix	Analysis Required	Test Result	Analyst(s) Assigned
1 LM09755	7/24/02	7:05	Northwest Spring	None	1	P	250 mL	water	TDS		Env Lab
2 9756				HNO_3	1	P	250 mL	water	Na,Ca,Mg,K		Env Lab
3 9757				None	1	P	250 mL	water	Chloride, Sulfate		Env Lab
4 9758				None	1	P	250 mL	water	Alkalinity ($CaCO_3$)/HCO3/CO3		Env Lab
5 9759				None	1	P	250 mL	water	Sp. Cond		Env Lab
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Date & Time Stamp
2002 JUL 25 AM 8:19
DWP CHEM LAB

Requested by . Marina Busatto Organization / Div. WQC
Address. JFB RM 1213 Tel 70731 Fax. 73297

Analyst ________ date ________
Approved by ________ date ________

Priority	
2-4 Hrs	KH
1Day	RG
2 Wks	RR
4Wks	KC
Specify	BE
	NP

	Printed Name	Signature	Time	Date
Sampled by:	Saeed Jorat	Sampled by: Saeed Jorat	7:15	7/24/02
Relinquished by:	Saeed Jorat	Relinquished by: Saeed	8:17	7/25
Received by	D. Wong	Received by	8:17	7/25/

COC12- 2030

hem Lab COC Form #1
Revision: 10/2/2001

DEPARTMENT OF WATER & POWER
OF THE CITY OF LOS ANGELES
Power System
Integrated Support Services

Report No. C11910
COC 12-2029
Page 1 of 1

ENVIRONMENTAL LABORATORY DATA REPORT

Owens Lake – Cottonwood Treatment Plant Well
Water Sample

Five water samples were collected on July 24, 2012 from the Owens Valley Cottonwood Treatment Plant Well.

Sample identification, tests requested, test methods, test date, and test results are listed below

All quality assurance data indicate that the results for these samples are of acceptable quality. If you have any questions, or, if further information is required, please contact Mrs. Nina Perez at (213) 367-7481 or Mr. Kevin Han at (213) 367-7267.

Sample ID	Analysis Requested	Method	Analysis Date	Results	Analysis By
LM09750	Total Dissolved Solids (TDS)	SM 2540C	7/30/2012	**56 mg/L**	Env Lab
LM09751	Sodium (Na)	EPA 6010B	7/31/2012	**4.16 mg/L**	Env Lab
	Calcium (Ca)	EPA 6010B	7/31/2012	**7.19 mg/L**	Env Lab
	Magnesium (Mg)	EPA 6010B	7/31/2012	**1.75 mg/L**	Env Lab
	Potassium (K)	EPA 6010B	7/31/2012	**1.43 mg/L**	Env Lab
LM09752	Chloride (Cl)	EPA 300.0	7/30/2012	**7.07 mg/L**	Env Lab
	Sulfate (SO_4^{-2})	EPA 300.0	7/30/2012	**9.87 mg/L**	Env Lab
LM09753	Alkalinity	SM 2320B	8/1/2012	**30 mg/L**	Env Lab
	Bicarbonate Alkalinity (HCO_3)	SM 2320B	8/1/2012	**30 mg/L**	Env Lab
	Carbonate Alkalinity (CO_3)	SM 2320B	8/1/2012	**ND**	Env Lab
LM09754	Specific Conductivity	EPA 120.1	7/30/2012	**73 us/cm**	Env Lab

ND: None Detected

Date Completed: 8/20/12
Work Order No.: UAE32
Job Card No. : J96745
Copies to: M.Busatto
N.Liu
K. Han
N. Perez
Filenet

Tests Made by: Environmental Lab

Report by: NP Date: 8/20/12
Checked by: Date: 8/21/12
Approved: Kevin Han 8/21/2012
K. Han **Date**
Acting Manager of Environmental Laboratory

Environmental Laboratory
1630 N. Main Street, Bldg 7
Los Angeles , CA. 90012
(213) 367-7248/7399
(213) 367-7285 FAX
Address

Department of Water and Power
City of Los Angeles

Chain of Custody Record

COC # : 12-2029 Page _1_ of _1_

Report C# 11910 JC# J96745 WO# WAE32
Refrig#. R4 Shelf 53 Bin#.
Initial of Field Personnel:
No. of Field Test:

Sample Location: OWENS LAKE #1

	Chem Lab use only CHEMISTRY LOG NUMBERS (For sample duplicates use .1 or .X)	Sample Date	(24 Hr) Sample Time	Sample Location and Description	Preservatives	Container No.	Container Type	Container Size	Sample Matrix	Analysis Required	Test Result	Analyst(s) Assigned
1	LM 09750	7/24/12	10:40	Cottonwood Treatment Plant Well	None	1	P	250 mL	water	TDS		Env Lab
2	9751	"	"	Cottonwood Treatment Plant Well	HNO_3	1	P	250 mL	water	Na,Ca,Mg,K		Env Lab
3	9752	"	"	"	None	1	P	250 mL	water	Chloride, Sulfate		Env Lab
4	9753	"	"	"	None	1	P	250 mL	water	Alkalinity ($CaCO_3$)/HCO3/CO3		Env Lab
5	9754	"	"	"	None	1	P	250 mL	water	Sp. Cond		Env Lab
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16												

Date & Time Stamp

RECD BY CHEM LAB
2012 JUL 25 AM 8:19
LADWP

Requested by . Marina Busatto Organization / Div. WQC
Address. JFB RM 1213 Tel 70731 Fax. 73297

Analyst ____ date ____
Approved by ____ date ____

Priority
2-4 Hrs
1Day
2 Wks
4Wks
Specify

KH
RG
RR
KE
BE
NP

Printed Name	Signature	Time	Date
Sampled by: Saeed Jorat	Sampled by:	16:45	6/24/12
Relinquished by: Saeed Jorat	Relinquished by:	8:17	7/25
Received by RWn	Received by	8:17	7/25/12

COC12- 2029

n Lab COC Form #1
vision: 10/2/2001

DEPARTMENT OF WATER & POWER
OF THE CITY OF LOS ANGELES
Power System
Integrated Support Services

Report No. C11914
COC 12-2033
Page 1 of 1

ENVIRONMENTAL LABORATORY DATA REPORT

Owens Lake – Cottonwood Spring Northwest
Water Sample

Five water samples were collected on July 24, 2012 from the Owens Valley Cottonwood Spring Northwest.

Sample identification, tests requested, test methods, test date, and test results are listed below

All quality assurance data indicate that the results for these samples are of acceptable quality. If you have any questions, or, if further information is required, please contact Mrs. Nina Perez at (213) 367-7481 or Mr. Kevin Han at (213) 367-7267.

Sample ID	Analysis Requested	Method	Analysis Date	Results	Analysis By
LM09770	Total Dissolved Solids (TDS)	SM 2540C	7/30/2012	**230 mg/L**	Env Lab
LM09771	Sodium (Na)	EPA 6010B	7/31/2012	**29.0 mg/L**	Env Lab
	Calcium (Ca)	EPA 6010B	7/31/2012	**26.5 mg/L**	Env Lab
	Magnesium (Mg)	EPA 6010B	7/31/2012	**7.21 mg/L**	Env Lab
	Potassium (K)	EPA 6010B	7/31/2012	**3.55 mg/L**	Env Lab
LM09772	Chloride (Cl)	EPA 300.0	7/30/2012	**42.3 mg/L**	Env Lab
	Sulfate (SO_4^{-2})	EPA 300.0	7/30/2012	**23.9 mg/L**	Env Lab
LM09773	Alkalinity	SM 2320B	8/1/2012	**70 mg/L**	Env Lab
	Bicarbonate Alkalinity (HCO_3)	SM 2320B	8/1/2012	**70 mg/L**	Env Lab
	Carbonate Alkalinity (CO_3)	SM 2320B	8/1/2012	**ND**	Env Lab
LM09774	Specific Conductivity	EPA 120.1	7/30/2012	**347 us/cm**	Env Lab

ND: None Detected

Date Completed: 8/20/12
Work Order No.: UAE32
Job Card No. : J96745
Copies to: M.Busatto
N.Liu
K. Han
N. Perez
Filenet

Tests Made by: Environmental Lab

Report by: NP Date: 8/20/12
Checked by: JH Date: 8/21/12

Approved: Kevin Han 8/21/2012
K. Han **Date**
Acting Manager of Environmental Laboratory

Environmental Laboratory
1630 N. Main Street, Bldg 7
Los Angeles , CA. 90012
(213) 367-7248/7399
(213) 367-7285 FAX

Department of Water and Power
City of Los Angeles

Chain of Custody Record

COC # : 12-2033

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Report C# 11914 JC# J96745 WO# UAE32
Refrig#. R4 Shelf S3 Bin#.
Initial of Field Personnel:
No. of Field Test:

Address
Sample Location: OWENS LAKE #5

Chem Lab use only CHEMISTRY LOG NUMBERS (For sample duplicates use .1 or .X)	Sample Date	(24 Hr) Sample Time	Sample Location and Description	Preservatives	Container No.	Container Type	Container Size	Sample Matrix	Analysis Required	Test Result	Analyst(s) Assigned
1 LM09770	7/24/12	9:05	Cottonwood Spring N.West	None	1	P	250 mL	water	TDS		Env Lab
2 9771	"	"	" , northwest	HNO_3	1	P	250 mL	water	Na,Ca,Mg,K		Env Lab
3 9772	"	"	" , Northwest	None	1	P	250 mL	water	Chloride, Sulfate		Env Lab
4 9773	"	"	"	None	1	P	250 mL	water	Alkalinity ($CaCO_3$)/HCO3/CO3		Env Lab
5 9774	"	"		None	1	P	250 mL	water	Sp. Cond		Env Lab
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Date & Time Stamp
2012 JUL 25 AM 8 20
LA

Requested by . Marina Busatto Organization / Div. WQC
Address. JFB RM 1213 Tel 70731 Fax. 73297

Analyst ______ date ______
Approved by ______ date ______

Priority
2-4 Hrs
1Day
2 Wks
4Wks
Specify

KH
RG
KR
KC
BE
NP

	Printed Name	Signature	Time	Date
Sampled by:	Saeed Jorat	Sampled by:	9:15	7/24/12
Relinquished by:	Saeed Jorat	Relinquished by:	8:17	7/25
Received by	D. Wong	Received by	8:17	7/25/12

Chem Lab COC Form #1
Revision: 10/2/2001

COC12- 2033

DEPARTMENT OF WATER & POWER
OF THE CITY OF LOS ANGELES
Power System
Integrated Support Services

Report No. C11915
COC 12-2034
Page 1 of 1

ENVIRONMENTAL LABORATORY DATA REPORT

Owens Lake – S(3)1 Pizometer
Water Sample

Five water samples were collected on July 24, 2012 from the Owens Valley S(3)1 Pizometer.

Sample identification, tests requested, test methods, test date, and test results are listed below

All quality assurance data indicate that the results for these samples are of acceptable quality. If you have any questions, or, if further information is required, please contact Mrs. Nina Perez at (213) 367-7481 or Mr. Kevin Han at (213) 367-7267.

Sample ID	Analysis Requested	Method	Analysis Date	Results	Analysis By
LM09775	Total Dissolved Solids (TDS)	SM 2540C	7/30/2012	**555 mg/L**	Env Lab
LM09776	Sodium (Na)	EPA 6010B	7/31/2012	**179 mg/L**	Env Lab
	Calcium (Ca)	EPA 6010B	7/31/2012	**1.71 mg/L**	Env Lab
	Magnesium (Mg)	EPA 6010B	7/31/2012	**0.051 mg/L**	Env Lab
	Potassium (K)	EPA 6010B	7/31/2012	**15.8 mg/L**	Env Lab
LM09777	Chloride (Cl)	EPA 300.0	7/30/2012	**92.8 mg/L**	Env Lab
	Sulfate (SO_4^{-2})	EPA 300.0	7/30/2012	**79.5 mg/L**	Env Lab
LM09778	Alkalinity	SM 2320B	8/1/2012	**150 mg/L**	Env Lab
	Bicarbonate Alkalinity (HCO_3)	SM 2320B	8/1/2012	**90 mg/L**	Env Lab
	Carbonate Alkalinity (CO_3)	SM 2320B	8/1/2012	**60 mg/L**	Env Lab
LM09779	Specific Conductivity	EPA 120.1	7/30/2012	**886 us/cm**	Env Lab

ND: None Detected

Date Completed: 8/20/12
Work Order No.: UAE32
Job Card No. : J96745
Copies to: M.Busatto
N.Liu
K. Han
N. Perez
Filenet

Tests Made by: Environmental Lab

Report by: NP Date: 8/20/12
Checked by: Date: 8/21/12

Approved: Kevin Han 8/21/2012
K. Han **Date**
Acting Manager of Environmental Laboratory

Environmental Laboratory
1630 N. Main Street, Bldg 7
Los Angeles , CA. 90012
(213) 367-7248/7399
(213) 367-7285 FAX
Address

Department of Water and Power
City of Los Angeles
Chain of Custody Record

COC # : 12 - 2034
Page _1_ of _1_

Report C# 11915 JC# J90745 WO# UAE32
Refrig#. R4 Shelf 53 Bin#.
Initial of Field Personnel:
No. of Field Test:

Sample Location: OWENS LAKE #6

Chem Lab use only CHEMISTRY LOG NUMBERS (For sample duplicates use .1 or .X)	Sample Date	(24 Hr) Sample Time	Sample Location and Description	Preservatives	Container No.	Container Type	Container Size	Sample Matrix	Analysis Required	Test Result	Analyst(s) Assigned
1 LM09775	7/24/12	1:15	S(3)1 Pizomater	None	1	P	250 mL	water	TDS		Env Lab
2 9776	"	"	"	HNO$_3$	1	P	250 mL	water	Na,Ca,Mg,K		Env Lab
3 9777	"	"	"	None	1	P	250 mL	water	Chloride, Sulfate		Env Lab
4 9778	"	"	"	None	1	P	250 mL	water	Alkalinity (CaCO$_3$)/HCO3/CO3		Env Lab
5 9779	"	"	"	None	1	P	250 mL	water	Sp. Cond		Env Lab
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Date & Time Stamp

RECD BY: ENV. CHEM LAB
2012 JUL 25 AM 8:20
LADWP

Requested by . Marina Busatto Organization / Div. WQC
Address. JFB RM 1213 Tel 70731 Fax. 73297

Analyst______ date______
Approved by______ date______

Priority
2-4 Hrs
1Day
2 Wks
4Wks
Specify

KH
RG
RR
KC
BE
NP

Printed Name	Signature	Time	Date
Sampled by: Saeed Jorat	Sampled by: Saeed Jorat		
Relinquished by: Saeed Jorat	Relinquished by: Saeed Jorat	8:17	7/25
Received by D. Wong	Received by	8:17	7/25/12

Chem Lab COC Form #1
Revision: 10/2/2001

COC12- 2034

DEPARTMENT OF WATER & POWER
OF THE CITY OF LOS ANGELES
Power System
Integrated Support Services

Report No. C11916
COC 12-2035
Page 1 of 1

ENVIRONMENTAL LABORATORY DATA REPORT

Owens Lake – Ash Creek
Water Sample

Five water samples were collected on July 24, 2012 from the Owens Valley Ash Creek.

Sample identification, tests requested, test methods, test date, and test results are listed below

All quality assurance data indicate that the results for these samples are of acceptable quality. If you have any questions, or, if further information is required, please contact Mrs. Nina Perez at (213) 367-7481 or Mr. Kevin Han at (213) 367-7267.

Sample ID	Analysis Requested	Method	Analysis Date	Results	Analysis By
LM09780	Total Dissolved Solids (TDS)	SM 2540C	7/30/2012	**122 mg/L**	Env Lab
LM09781	Sodium (Na)	EPA 6010B	7/31/2012	**7.95 mg/L**	Env Lab
	Calcium (Ca)	EPA 6010B	7/31/2012	**23.7 mg/L**	Env Lab
	Magnesium (Mg)	EPA 6010B	7/31/2012	**3.67 mg/L**	Env Lab
	Potassium (K)	EPA 6010B	7/31/2012	**1.87 mg/L**	Env Lab
LM09782	Chloride (Cl)	EPA 300.0	7/30/2012	**7.37 mg/L**	Env Lab
	Sulfate (SO_4^{-2})	EPA 300.0	7/30/2012	**29.0 mg/L**	Env Lab
LM09783	Alkalinity	SM 2320B	8/1/2012	**60 mg/L**	Env Lab
	Bicarbonate Alkalinity (HCO_3)	SM 2320B	8/1/2012	**60 mg/L**	Env Lab
	Carbonate Alkalinity (CO_3)	SM 2320B	8/1/2012	**ND**	Env Lab
LM09784	Specific Conductivity	EPA 120.1	7/30/2012	**198 mg/L**	Env Lab

ND: None Detected

Date Completed: 8/20/12
Work Order No.: UAE32
Job Card No. : J96745
Copies to: M.Busatto
N.Liu
K. Han
N. Perez
Filenet

Tests Made by: Environmental Lab

Report by: NP Date: 8/20/12
Checked by: JHL Date: 8/21/12
Approved: Kevin Han 8/21/2012
K. Han **Date**
Acting Manager of Environmental Laboratory

Environmental Laboratory
1630 N. Main Street, Bldg 7
Los Angeles , CA. 90012
(213) 367-7248/7399
(213) 367-7285 FAX

Department of Water and Power
City of Los Angeles
Chain of Custody Record

COC # : 12 - 2035

Page _1_ of _1_

Report C# 11916 JC# JA0745 WO# UAE32

Refrig#. R4 Shelf S3 Bin#.

Initial of Field Personnel: ☐

No. of Field Test: ☐

Address
Sample Location: OWENS LAKE #7

Chem Lab use only CHEMISTRY LOG NUMBERS (For sample duplicates use .1 or .X)	Sample Date	(24 Hr) Sample Time	Sample Location and Description	Preservatives	Container No.	Container Type	Container Size	Sample Matrix	Analysis Required	Test Result	Analyst(s) Assigned
1 LM09780	7/24/12	11:20	Ash Creek	None	1	P	250 mL	water	TDS		Env Lab
2 9781	〃	〃	〃	HNO_3	1	P	250 mL	water	Na,Ca,Mg,K		Env Lab
3 9782	〃	〃	〃	None	1	P	250 mL	water	Chloride, Sulfate		Env Lab
4 9783	〃	〃	〃	None	1	P	250 mL	water	Alkalinity ($CaCO_3$)/HCO3/CO3		Env Lab
5 9784	〃		〃	None	1	P	250 mL	water	Sp. Cond		Env Lab
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											

Date & Time Stamp

2012 JUL 25 8:20
LADWP

Requested by . Marina Busatto
Organization / Div. WQC
Address. JFB RM 1213
Tele 70731
Fax. 73297

Analyst__________ date__________
Approved by__________ date__________

Priority
2-4 Hrs
1Day
2 Wks
4Wks
Specify

KH
RG
KE
KG
BE
MP

Printed Name	Signature	Time	Date
Sampled by: Saeed Jorat	Sampled by: Saeed Jorat		
Relinquished by: Saeed Jorat	Relinquished by:	8:17	7/25
Received by D. Wong	Received by D. Wong	8:17	7/25/1

COC12- 2035

Lab COC Form #1
vision: 10/2/2001

DEPARTMENT OF WATER & POWER
OF THE CITY OF LOS ANGELES
Power System
Integrated Support Services

Report No. C11917
COC 12-2036
Page 1 of 1

ENVIRONMENTAL LABORATORY DATA REPORT

Owens Lake – Rio Tinto Supply Well
Water Sample

Five water samples were collected on July 24, 2012 from the Owens Valley Rio Tinto Supply Well.

Sample identification, tests requested, test methods, test date, and test results are listed below

All quality assurance data indicate that the results for these samples are of acceptable quality. If you have any questions, or, if further information is required, please contact Mrs. Nina Perez at (213) 367-7481 or Mr. Kevin Han at (213) 367-7267.

Sample ID	Analysis Requested	Method	Analysis Date	Results	Analysis By
LM09785	Total Dissolved Solids (TDS)	SM 2540C	7/30/2012	**158 mg/L**	Env Lab
LM09786	Sodium (Na)	EPA 6010B	7/31/2012	**25.9 mg/L**	Env Lab
	Calcium (Ca)	EPA 6010B	7/31/2012	**17.0 mg/L**	Env Lab
	Magnesium (Mg)	EPA 6010B	7/31/2012	**2.14 mg/L**	Env Lab
	Potassium (K)	EPA 6010B	7/31/2012	**3.28 mg/L**	Env Lab
LM09787	Chloride (Cl)	EPA 300.0	7/30/2012	**7.87 mg/L**	Env Lab
	Sulfate (SO_4^{-2})	EPA 300.0	7/30/2012	**15.7 mg/L**	Env Lab
LM09788	Alkalinity	SM 2320B	8/1/2012	**94 mg/L**	Env Lab
	Bicarbonate Alkalinity (HCO_3)	SM 2320B	8/1/2012	**94 mg/L**	Env Lab
	Carbonate Alkalinity (CO_3)	SM 2320B	8/1/2012	**ND**	Env Lab
LM09789	Specific Conductivity	EPA 120.1	7/30/2012	**226 mg/L**	Env Lab

ND: None Detected

Date Completed: 8/20/12
Work Order No.: UAE32
Job Card No. : J96745
Copies to: M.Busatto
N.Liu
K. Han
N. Perez
Filenet

Tests Made by: Environmental Lab

Report by: NP Date: 8/20/12
Checked by: Date: 8/21/12
Approved: 8/21/2012
K. Han **Date**
Acting Manager of Environmental Laboratory

Environmental Laboratory
1630 N. Main Street, Bldg 7
Los Angeles , CA. 90012
(213) 367-7248/7399
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Department of Water and Power
City of Los Angeles

Chain of Custody Record

COC # : 12-2036

Page _1_ of _1_

Report C# 11917 JC# JA674J WO# UAE32
Refrig#. R4 Shelf S3 Bin#.
Initial of Field Personnel:
No. of Field Test:

Address
Sample Location: OWENS LAKE #8

	Chem Lab use only CHEMISTRY LOG NUMBERS (For sample duplicates use .1 or .X)	Sample Date	(24 Hr) Sample Time	Sample Location and Description	Preservatives	Container No.	Container Type	Container Size	Sample Matrix	Analysis Required	Test Result	Analyst(s) Assigned
1	LM09785	7/24/12	12:45	Rio Tinto Supply Well	None	1	P	250 mL	water	TDS		Env Lab
2	9786	7/24/12	12:45	Rio Tinto Supply Well	HNO$_3$	1	P	250 mL	water	Na,Ca,Mg,K		Env Lab
3	9787	"	"	"	None	1	P	250 mL	water	Chloride, Sulfate		Env Lab
4	9788	"	"	"	None	1	P	250 mL	water	Alkalinity (CaCO$_3$)/HCO3/CO3		Env Lab
5	9789	"	"	"	None	1	P	250 mL	water	Sp. Cond		Env Lab
6		"	"									
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												

Date & Time Stamp
LA
2012 JUL 25 AM 8 20
CHEM LAB

Requested by . Marina Busatto Organization / Div. WQC
Address. JFB RM 1213 Tel 70731 Fax. 73297

Analyst ________ date ________
Approved by ________ date ________

Priority
☐ 2-4 Hrs
1Day
2 Wks
4Wks
Specify

KH
RG
RR
KC
BE
NP

	Printed Name	Signature	Time	Date
Sampled by:	Saeed Jorat	Sampled by:		
Relinquished by:	Saeed Jorat	Relinquished by:	8:17	7/25
Received by	D. Wong	Received by	~~8:17~~	7/25/12

Chem Lab COC Form #1
Revision: 10/2/2001

COC12- 2036

APPENDIX B-2

Laboratory Analytical Data - Isotope Data from Isotech Laboratories

Project Name:
OLGEP TASK: 401.1.9.2

Project Contact:
Name: Victor Harris, MWH Americas, Inc.
Phone: 626-568-6024
Email: Victor.E.Harris@us.mwhglobal.com

MWH®

Laboratory Name
Isotech Laboratories

Lab Contact
Name: Christy Legner
Phone: 877-632 4190
Email: legner@isotechlabs.com

SAMPLE I.D.	NUMBER OF CONTAINERS	SAMPLE LOCATION		SAMPLE COLLECTION DATE	SAMPLE COLLECTION TIME	ANALYSIS TYPE				
		Northing	Easting			δD	$\delta^{18}O$	^{3}H	^{14}C	$\delta^{13}C$
Carroll Crk	1			7/23/2012		x	x			
NW Seep	3			7/24/2012		x	x	x	x	x
Bartlett-CW	3			7/24/2012		x	x	x	x	x
Cottonwood Spr	3			7/24/2012		x	x	x	x	x
Cottonwood-Well	1			7/24/2012		x	x			
Aqueduct Well	3			7/24/2012		x	x	x	x	x
Ash Crk	1			7/24/2012		x	x			
Rio Tinto-SW	3			7/24/2012		x	x	x	x	x
Cartago-COM	3			7/23/2012		x	x	x	x	x
DWP - 9 T 896	3			7/23/2012		x	x	x	x	x
DWP - 9 T 897	1			7/23/2012		x	x			
DWP - 9 T 898	3			7/23/2012		x	x	x	x	x
DWP - 3 T 899	3			7/23/2012		x	x	x	x	x
DWP - 3 T 901	3			7/23/2012		x	x	x	x	x
DWP - 6 T912	3			7/23/2012		x	x	x	x	x
DWP - 6 T 911	3			7/23/2012		x	x	x	x	x
DWP - 6 T 913	3			7/23/2012		x	x	x	x	x
DWP- 7 T908	3			7/23/2012		x	x	x	x	x
DWP- 7 T909	1			7/23/2012		x	x			
DWP -7 T 910	3			7/23/2012		x	x	x	x	x
Dolomite	3			7/23/2012		x	x	x	x	x
Agr-2	3			7/23/2012		x	x	x	x	x
KCSD-PW	3			7/23/2012		x	x	x	x	x
Horse Pasture	3			7/23/2012		x	x	x	x	x
S31	3			7/24/2012		x	x	x	x	x
Duck-CN	1			7/24/2012		x	x			
Tubman-CP	1			7/24/2012		x	x			

Relinquished by:	M. Lee Davisson	Date/Time:	7/25/12 6pm
Received by:	- Isotech Labs	Date/Time:	7/27/12 @ 1000
Relinquished by:		Date/Time:	
Received by:		Date/Time:	
Relinquished by:		Date/Time:	
Received by:		Date/Time:	
Relinquished by:		Date/Time:	
Received by:		Date/Time:	

ISOTECH
ISOTECH LABORATORIES INC
www.isotechlabs.com

Isotech Water Data

Job 18823

Isotech Lab No.	Sample Name	Sample Date	Field Name	Analysis Date	δD H_2O ‰	δ^{18}O H_2O ‰	Tritium TU	Std. Dev.	δ^{13}C DIC ‰	^{14}C DIC pMC	Std. Dev.
258207	Carroll Crk	7/23/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-120.5	-15.94					
258208	NW Seep	7/24/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-121.4	-15.80	< 1.00		-8.9	57.5	0.2
258209	Bartlett-CW	7/24/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-123.3	-16.16	< 1.00		-9.3	52.8	0.2
258210	Cottonwood Spr	7/24/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-120.4	-15.47	7.46	0.20	-15.7	88.9	0.3
258211	Cottonwood-Well	7/24/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-103.5	-12.01					
258212	Aqueduct Well	7/24/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-119.3	-15.40	3.82	0.17	-15.1	106.5	0.4
258213	Ash Crk	7/24/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-111.2	-14.56					
258214	Rio Tinto-SW	7/24/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-114.5	-14.88	< 1.00		-9.8	56.1	0.2
258215	Cartago-COM	7/23/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-112.1	-14.71	1.76	0.15	-10.4	61.3	0.3
258216	DWP-9 / T 896	7/23/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-129.5	-16.55	< 1.00		21.7	2.9	0.1
258217	DWP-9 / T 897	7/23/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-131.8	-16.96					
258218	DWP-9 / T 898	7/23/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-129.4	-16.74	< 1.00		5.0	7.2	0.1
258219	DWP-3 / T 899	7/23/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-123.3	-15.68	< 1.00		-1.5	3.8	0.1
258220	DWP-3 / T 901	7/23/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-125.8	-16.11	< 1.00		0.7	1.8	0.1
258221	DWP-6 / T 912	7/23/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-132.7	-16.59	< 1.00		-0.2	1.7	0.1
258222	DWP-6 / T 911	7/23/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-114.2	-13.25	< 1.00		-7.7	1.2	0.1
258223	DWP-6 / T 913	7/23/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-88.0	-8.28	< 1.00		0.9	0.5	0.1
258224	DWP-7 / T 908	7/23/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-108.9	-14.34	< 1.00		-8.1	4.4	0.1
258225	DWP-7 / T 909	7/23/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-109.0	-14.38					
258226	DWP-7 / T 910	7/23/2012	OLGEP TASK: 401.1.9.2	8/5/2012	-110.1	-14.62	< 1.00		-6.0	36.7	0.2
258227	Dolomite	7/23/2012	OLGEP TASK: 401.1.9.2	8/6/2012	-127.6	-16.29	< 1.00		-7.6	5.6	0.1
258228	Agr-2	7/23/2012	OLGEP TASK: 401.1.9.2	8/6/2012	-125.0	-16.13	< 1.00		-5.8	3.6	0.1
258229	KCSD-PW	7/23/2012	OLGEP TASK: 401.1.9.2	8/6/2012	-124.5	-16.09	< 1.00		-5.5	4.4	0.1
258230	Horse Pasture	7/23/2012	OLGEP TASK: 401.1.9.2	8/6/2012	-130.9	-16.70	< 1.00		-5.1	1.9	0.1
258231	S31	7/24/2012	OLGEP TASK: 401.1.9.2	8/6/2012	-110.2	-14.28	< 1.00		-3.7	25.5	0.2
258232	Duck-CN	7/24/2012	OLGEP TASK: 401.1.9.2	8/6/2012	-111.7	-14.82					
258233	Tubman-CP	7/24/2012	OLGEP TASK: 401.1.9.2	8/6/2012	-128.8	-15.66					

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ANALYSIS REPORT

Water Analysis

Lab Number: 258207 Job Number: 18823

Submitter Sample Name: Carroll Crk

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water	----------------	-120.5 ‰ relative to VSMOW
δ^{18}O of water	----------------	-15.94 ‰ relative to VSMOW
Tritium content of water	----------------	na
δ^{13}C of DIC	----------------	na
^{14}C content of DIC	----------------	na
δ^{15}N of nitrate	----------------	na
δ^{18}O of nitrate	----------------	na
δ^{34}S of sulfate	----------------	na
δ^{18}O of sulfate	----------------	na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258208 Job Number: 18823

Submitter Sample Name: NW Seep

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/24/2012 Results Reported: 8/31/2012

δD of water ---------------- -121.4 ‰ relative to VSMOW

$\delta^{18}O$ of water ---------------- -15.80 ‰ relative to VSMOW

Tritium content of water ---------------- < 1.00 TU

$\delta^{13}C$ of DIC ---------------- -8.9 ‰ relative to VPDB

^{14}C content of DIC ---------------- 57.5 ± 0.2 percent modern carbon

$\delta^{15}N$ of nitrate ---------------- na

$\delta^{18}O$ of nitrate ---------------- na

$\delta^{34}S$ of sulfate ---------------- na

$\delta^{18}O$ of sulfate ---------------- na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258209 Job Number: 18823

Submitter Sample Name: Bartlett-CW

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/24/2012 Results Reported: 8/31/2012

δD of water ---------------- -123.3 ‰ relative to VSMOW

$\delta^{18}O$ of water ---------------- -16.16 ‰ relative to VSMOW

Tritium content of water ---------------- < 1.00 TU

$\delta^{13}C$ of DIC ---------------- -9.3 ‰ relative to VPDB

^{14}C content of DIC ---------------- 52.8 ± 0.2 percent modern carbon

$\delta^{15}N$ of nitrate ---------------- na

$\delta^{18}O$ of nitrate ---------------- na

$\delta^{34}S$ of sulfate ---------------- na

$\delta^{18}O$ of sulfate ---------------- na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258210 Job Number: 18823

Submitter Sample Name: Cottonwood Spr

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/24/2012 Results Reported: 8/31/2012

δD of water	-120.4 ‰ relative to VSMOW
$\delta^{18}O$ of water	-15.47 ‰ relative to VSMOW
Tritium content of water	7.46 ± 0.20 TU
$\delta^{13}C$ of DIC	-15.7 ‰ relative to VPDB
^{14}C content of DIC	88.9 ± 0.3 percent modern carbon
$\delta^{15}N$ of nitrate	na
$\delta^{18}O$ of nitrate	na
$\delta^{34}S$ of sulfate	na
$\delta^{18}O$ of sulfate	na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number:	258211	Job Number:	18823
Submitter Sample Name:	Cottonwood-Well		
Submitter Sample ID:			
Submitter Job #:			
Company:	MWH Laboratories		
Field or Site:	OLGEP TASK: 401.1.9.2		
Location:			
Depth/Formation:			
Container Type:	Amber Bottle		
Sample Collected:	7/24/2012	Results Reported:	8/31/2012

δD of water	----------------	-103.5 ‰ relative to VSMOW
$\delta^{18}O$ of water	----------------	-12.01 ‰ relative to VSMOW
Tritium content of water	----------------	na
$\delta^{13}C$ of DIC	----------------	na
^{14}C content of DIC	----------------	na
$\delta^{15}N$ of nitrate	----------------	na
$\delta^{18}O$ of nitrate	----------------	na
$\delta^{34}S$ of sulfate	----------------	na
$\delta^{18}O$ of sulfate	----------------	na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258212 Job Number: 18823

Submitter Sample Name: Aqueduct Well

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/24/2012 Results Reported: 8/31/2012

δD of water	-119.3 ‰ relative to VSMOW
δ^{18}O of water	-15.40 ‰ relative to VSMOW
Tritium content of water	3.82 ± 0.17 TU
δ^{13}C of DIC	-15.1 ‰ relative to VPDB
^{14}C content of DIC	106.5 ± 0.4 percent modern carbon
δ^{15}N of nitrate	na
δ^{18}O of nitrate	na
δ^{34}S of sulfate	na
δ^{18}O of sulfate	na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number:	258213	Job Number:	18823
Submitter Sample Name:	Ash Crk		
Submitter Sample ID:			
Submitter Job #:			
Company:	MWH Laboratories		
Field or Site:	OLGEP TASK: 401.1.9.2		
Location:			
Depth/Formation:			
Container Type:	Amber Bottle		
Sample Collected:	7/24/2012	Results Reported:	8/31/2012

δD of water ----------------	-111.2 ‰ relative to VSMOW
$\delta^{18}O$ of water ----------------	-14.56 ‰ relative to VSMOW
Tritium content of water ----------------	na
$\delta^{13}C$ of DIC ----------------	na
^{14}C content of DIC ----------------	na
$\delta^{15}N$ of nitrate ----------------	na
$\delta^{18}O$ of nitrate ----------------	na
$\delta^{34}S$ of sulfate ----------------	na
$\delta^{18}O$ of sulfate ----------------	na

Remarks:

ISOTECH®
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ANALYSIS REPORT

Water Analysis

Lab Number: 258214 Job Number: 18823

Submitter Sample Name: Rio Tinto-SW

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/24/2012 Results Reported: 8/31/2012

δD of water ---------------- -114.5 ‰ relative to VSMOW

δ^{18}O of water ---------------- -14.88 ‰ relative to VSMOW

Tritium content of water ---------------- < 1.00 TU

δ^{13}C of DIC ---------------- -9.8 ‰ relative to VPDB

^{14}C content of DIC ---------------- 56.1 ± 0.2 percent modern carbon

δ^{15}N of nitrate ---------------- na

δ^{18}O of nitrate ---------------- na

δ^{34}S of sulfate ---------------- na

δ^{18}O of sulfate ---------------- na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258215 Job Number: 18823

Submitter Sample Name: Cartago-COM

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water ---------------- -112.1 ‰ relative to VSMOW

δ^{18}O of water ---------------- -14.71 ‰ relative to VSMOW

Tritium content of water ---------------- 1.76 ± 0.15 TU

δ^{13}C of DIC ---------------- -10.4 ‰ relative to VPDB

^{14}C content of DIC ---------------- 61.3 ± 0.3 percent modern carbon

δ^{15}N of nitrate ---------------- na

δ^{18}O of nitrate ---------------- na

δ^{34}S of sulfate ---------------- na

δ^{18}O of sulfate ---------------- na

Remarks:

ISOTECH®
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ANALYSIS REPORT

Water Analysis

Lab Number: 258216 Job Number: 18823

Submitter Sample Name: DWP-9 / T 896

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water	----------------	-129.5 ‰ relative to VSMOW
$\delta^{18}O$ of water	----------------	-16.55 ‰ relative to VSMOW
Tritium content of water	----------------	< 1.00 TU
$\delta^{13}C$ of DIC	----------------	21.7 ‰ relative to VPDB
^{14}C content of DIC	----------------	2.9 ± 0.1 percent modern carbon
$\delta^{15}N$ of nitrate	----------------	na
$\delta^{18}O$ of nitrate	----------------	na
$\delta^{34}S$ of sulfate	----------------	na
$\delta^{18}O$ of sulfate	----------------	na

Remarks:

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ISOTECH LABORATORIES INC
ANALYSIS REPORT

Water Analysis

Lab Number: 258217 Job Number: 18823

Submitter Sample Name: DWP-9 / T 897

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water	----------------	-131.8 ‰ relative to VSMOW
δ^{18}O of water	----------------	-16.96 ‰ relative to VSMOW
Tritium content of water	----------------	na
δ^{13}C of DIC	----------------	na
^{14}C content of DIC	----------------	na
δ^{15}N of nitrate	----------------	na
δ^{18}O of nitrate	----------------	na
δ^{34}S of sulfate	----------------	na
δ^{18}O of sulfate	----------------	na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258218 Job Number: 18823

Submitter Sample Name: DWP-9 / T 898

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water ---------------- -129.4 ‰ relative to VSMOW

$\delta^{18}O$ of water ---------------- -16.74 ‰ relative to VSMOW

Tritium content of water ---------------- < 1.00 TU

$\delta^{13}C$ of DIC ---------------- 5.0 ‰ relative to VPDB

^{14}C content of DIC ---------------- 7.2 ± 0.1 percent modern carbon

$\delta^{15}N$ of nitrate ---------------- na

$\delta^{18}O$ of nitrate ---------------- na

$\delta^{34}S$ of sulfate ---------------- na

$\delta^{18}O$ of sulfate ---------------- na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258219 Job Number: 18823

Submitter Sample Name: DWP-3 / T 899

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water	----------------	-123.3 ‰ relative to VSMOW
δ^{18}O of water	----------------	-15.68 ‰ relative to VSMOW
Tritium content of water	----------------	< 1.00 TU
δ^{13}C of DIC	----------------	-1.5 ‰ relative to VPDB
^{14}C content of DIC	----------------	3.8 ± 0.1 percent modern carbon
δ^{15}N of nitrate	----------------	na
δ^{18}O of nitrate	----------------	na
δ^{34}S of sulfate	----------------	na
δ^{18}O of sulfate	----------------	na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258220 Job Number: 18823

Submitter Sample Name: DWP-3 / T 901

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water	----------------	-125.8 ‰ relative to VSMOW
δ^{18}O of water	----------------	-16.11 ‰ relative to VSMOW
Tritium content of water	----------------	< 1.00 TU
δ^{13}C of DIC	----------------	0.7 ‰ relative to VPDB
^{14}C content of DIC	----------------	1.8 ± 0.1 percent modern carbon
δ^{15}N of nitrate	----------------	na
δ^{18}O of nitrate	----------------	na
δ^{34}S of sulfate	----------------	na
δ^{18}O of sulfate	----------------	na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258221 Job Number: 18823

Submitter Sample Name: DWP-6 / T 912

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water ---------------- -132.7 ‰ relative to VSMOW

δ^{18}O of water ---------------- -16.59 ‰ relative to VSMOW

Tritium content of water ---------------- < 1.00 TU

δ^{13}C of DIC ---------------- -0.2 ‰ relative to VPDB

^{14}C content of DIC ---------------- 1.7 ± 0.1 percent modern carbon

δ^{15}N of nitrate ---------------- na

δ^{18}O of nitrate ---------------- na

δ^{34}S of sulfate ---------------- na

δ^{18}O of sulfate ---------------- na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258222 Job Number: 18823

Submitter Sample Name: DWP-6 / T 911

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water	----------------	-114.2 ‰ relative to VSMOW
$\delta^{18}O$ of water	----------------	-13.25 ‰ relative to VSMOW
Tritium content of water	----------------	< 1.00 TU
$\delta^{13}C$ of DIC	----------------	-7.7 ‰ relative to VPDB
^{14}C content of DIC	----------------	1.2 ± 0.1 percent modern carbon
$\delta^{15}N$ of nitrate	----------------	na
$\delta^{18}O$ of nitrate	----------------	na
$\delta^{34}S$ of sulfate	----------------	na
$\delta^{18}O$ of sulfate	----------------	na

Remarks:

Water Analysis

Lab Number: 258223 Job Number: 18823

Submitter Sample Name: DWP-6 / T 913

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water ---------------- -88.0 ‰ relative to VSMOW

$\delta^{18}O$ of water ---------------- -8.28 ‰ relative to VSMOW

Tritium content of water ---------------- < 1.00 TU

$\delta^{13}C$ of DIC ---------------- 0.9 ‰ relative to VPDB

^{14}C content of DIC ---------------- 0.5 ± 0.1 percent modern carbon

$\delta^{15}N$ of nitrate ---------------- na

$\delta^{18}O$ of nitrate ---------------- na

$\delta^{34}S$ of sulfate ---------------- na

$\delta^{18}O$ of sulfate ---------------- na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258224 Job Number: 18823

Submitter Sample Name: DWP-7 / T 908

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water	----------------	-108.9 ‰ relative to VSMOW
δ^{18}O of water	----------------	-14.34 ‰ relative to VSMOW
Tritium content of water	----------------	< 1.00 TU
δ^{13}C of DIC	----------------	-8.1 ‰ relative to VPDB
^{14}C content of DIC	----------------	4.4 ± 0.1 percent modern carbon
δ^{15}N of nitrate	----------------	na
δ^{18}O of nitrate	----------------	na
δ^{34}S of sulfate	----------------	na
δ^{18}O of sulfate	----------------	na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258225 Job Number: 18823

Submitter Sample Name: DWP-7 / T 909

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water ---------------- -109.0 ‰ relative to VSMOW

δ^{18}O of water ---------------- -14.38 ‰ relative to VSMOW

Tritium content of water ---------------- na

δ^{13}C of DIC ---------------- na

^{14}C content of DIC ---------------- na

δ^{15}N of nitrate ---------------- na

δ^{18}O of nitrate ---------------- na

δ^{34}S of sulfate ---------------- na

δ^{18}O of sulfate ---------------- na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number:	258226	Job Number:	18823
Submitter Sample Name:	DWP-7 / T 910		
Submitter Sample ID:			
Submitter Job #:			
Company:	MWH Laboratories		
Field or Site:	OLGEP TASK: 401.1.9.2		
Location:			
Depth/Formation:			
Container Type:	Amber Bottle		
Sample Collected:	7/23/2012	Results Reported:	8/31/2012

δD of water	----------------	-110.1 ‰ relative to VSMOW
δ^{18}O of water	----------------	-14.62 ‰ relative to VSMOW
Tritium content of water	----------------	< 1.00 TU
δ^{13}C of DIC	----------------	-6.0 ‰ relative to VPDB
^{14}C content of DIC	----------------	36.7 ± 0.2 percent modern carbon
δ^{15}N of nitrate	----------------	na
δ^{18}O of nitrate	----------------	na
δ^{34}S of sulfate	----------------	na
δ^{18}O of sulfate	----------------	na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258227 Job Number: 18823

Submitter Sample Name: Dolomite

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water ---------------- -127.6 ‰ relative to VSMOW

$\delta^{18}O$ of water ---------------- -16.29 ‰ relative to VSMOW

Tritium content of water ---------------- < 1.00 TU

$\delta^{13}C$ of DIC ---------------- -7.6 ‰ relative to VPDB

^{14}C content of DIC ---------------- 5.6 ± 0.1 percent modern carbon

$\delta^{15}N$ of nitrate ---------------- na

$\delta^{18}O$ of nitrate ---------------- na

$\delta^{34}S$ of sulfate ---------------- na

$\delta^{18}O$ of sulfate ---------------- na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258228 Job Number: 18823

Submitter Sample Name: Agr-2

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water	----------------	-125.0 ‰ relative to VSMOW
$\delta^{18}O$ of water	----------------	-16.13 ‰ relative to VSMOW
Tritium content of water	----------------	< 1.00 TU
$\delta^{13}C$ of DIC	----------------	-5.8 ‰ relative to VPDB
^{14}C content of DIC	----------------	3.6 ± 0.1 percent modern carbon
$\delta^{15}N$ of nitrate	----------------	na
$\delta^{18}O$ of nitrate	----------------	na
$\delta^{34}S$ of sulfate	----------------	na
$\delta^{18}O$ of sulfate	----------------	na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258229 Job Number: 18823

Submitter Sample Name: KCSD-PW

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water	----------------	-124.5 ‰ relative to VSMOW
$\delta^{18}O$ of water	----------------	-16.09 ‰ relative to VSMOW
Tritium content of water	----------------	< 1.00 TU
$\delta^{13}C$ of DIC	----------------	-5.5 ‰ relative to VPDB
^{14}C content of DIC	----------------	4.4 ± 0.1 percent modern carbon
$\delta^{15}N$ of nitrate	----------------	na
$\delta^{18}O$ of nitrate	----------------	na
$\delta^{34}S$ of sulfate	----------------	na
$\delta^{18}O$ of sulfate	----------------	na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258230 Job Number: 18823

Submitter Sample Name: Horse Pasture

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/23/2012 Results Reported: 8/31/2012

δD of water ---------------- -130.9 ‰ relative to VSMOW

δ^{18}O of water ---------------- -16.70 ‰ relative to VSMOW

Tritium content of water ---------------- < 1.00 TU

δ^{13}C of DIC ---------------- -5.1 ‰ relative to VPDB

^{14}C content of DIC ---------------- 1.9 ± 0.1 percent modern carbon

δ^{15}N of nitrate ---------------- na

δ^{18}O of nitrate ---------------- na

δ^{34}S of sulfate ---------------- na

δ^{18}O of sulfate ---------------- na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number:	258231	Job Number:	18823
Submitter Sample Name:	S31		
Submitter Sample ID:			
Submitter Job #:			
Company:	MWH Laboratories		
Field or Site:	OLGEP TASK: 401.1.9.2		
Location:			
Depth/Formation:			
Container Type:	Amber Bottle		
Sample Collected:	7/24/2012	Results Reported:	8/31/2012

δD of water	----------------	-110.2 ‰ relative to VSMOW
δ^{18}O of water	----------------	-14.28 ‰ relative to VSMOW
Tritium content of water	----------------	< 1.00 TU
δ^{13}C of DIC	----------------	-3.7 ‰ relative to VPDB
^{14}C content of DIC	----------------	25.5 ± 0.2 percent modern carbon
δ^{15}N of nitrate	----------------	na
δ^{18}O of nitrate	----------------	na
δ^{34}S of sulfate	----------------	na
δ^{18}O of sulfate	----------------	na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258232 Job Number: 18823

Submitter Sample Name: Duck-CN

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/24/2012 Results Reported: 8/31/2012

δD of water ---------------- -111.7 ‰ relative to VSMOW

δ^{18}O of water ---------------- -14.82 ‰ relative to VSMOW

Tritium content of water ---------------- na

δ^{13}C of DIC ---------------- na

^{14}C content of DIC ---------------- na

δ^{15}N of nitrate ---------------- na

δ^{18}O of nitrate ---------------- na

δ^{34}S of sulfate ---------------- na

δ^{18}O of sulfate ---------------- na

Remarks:

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ANALYSIS REPORT

Water Analysis

Lab Number: 258233 Job Number: 18823

Submitter Sample Name: Tubman-CP

Submitter Sample ID:

Submitter Job #:

Company: MWH Laboratories

Field or Site: OLGEP TASK: 401.1.9.2

Location:

Depth/Formation:

Container Type: Amber Bottle

Sample Collected: 7/24/2012 Results Reported: 8/31/2012

δD of water	-128.8 ‰ relative to VSMOW
δ^{18}O of water	-15.66 ‰ relative to VSMOW
Tritium content of water	na
δ^{13}C of DIC	na
^{14}C content of DIC	na
δ^{15}N of nitrate	na
δ^{18}O of nitrate	na
δ^{34}S of sulfate	na
δ^{18}O of sulfate	na

Remarks:

APPENDIX B-3

Laboratory Analytical Data - Noble Gas Data from the University of Utah

Lee Davisson

925- 998-7384

Project Name:
OLGEP TASK: 401.1.9.2

Project Contact:
Name: Victor Harris, MWH Americas, Inc.
Phone: 626-568-6024
Email: Victor.E.Harris@us.mwhglobal.com

MWH®

Laboratory Name
University of Utah Noble Gas Laboratory

Lab Contact

Name:	Alan Rigby
Phone:	801-585-5214
Email:	alan.rigby@utah.edu

SAMPLE I.D.	NUMBER OF CONTAINERS	SAMPLE LOCATION		SAMPLE COLLECTION DATE	SAMPLE COLLECTION TIME	ANALYSIS TYPE (Noble Gases)
		Northing	Easting			
DWP - 9 T 896 ✓	2			7/23/2012		x
DWP - 9 T 898 ✓	2			7/23/2012		x
DWP - 3 T 899 ✓	2			7/23/2012		x
DWP - 3 T 901 ✓	2			7/23/2012		x
DWP - 6 T 911 ✓	2			7/23/2012		x
DWP -7 T 910 ✓	2			7/23/2012		x

Relinquished by:	M. Lee Davisson	Date/Time:	7/25/12 6pm
Received by:	Alan D. Rigby - U of U	Date/Time:	07/28/12
Relinquished by:		Date/Time:	
Received by:		Date/Time:	
Relinquished by:		Date/Time:	
Received by:		Date/Time:	
Relinquished by:		Date/Time:	
Received by:		Date/Time:	

University of Utah - Dissolved and Noble Gas Lab - Sample Report

Sample I.D.	N2 total (ccSTP/g)	Ar total (ccSTP/g)	Ne total (ccSTP/g)	Kr total (ccSTP/g)	Xe total (ccSTP/g)	He4 (ccSTP/g)	R/Ra	Rech. Temp °C	ΔNe(%)	Notes
DWP-3 / T899	1.16E-02	3.17E-04	1.84E-07	4.41E-08	1.17E-08	1.04E-05	0.91	-	5.23	Large amount of excess He; poor gas model fit
DWP-3 / T901	8.60E-02	1.18E-03	3.12E-06	1.26E-07	1.33E-08	3.59E-06	1.17	-	1726.90	Large amount of excess He; poor gas model fit; exces air
DWP-6 / T911	3.78E-02	3.15E-04	1.57E-07	7.00E-08	1.45E-08	7.84E-05	1.26	-	-9.37	Large amount of excess He; poor gas model fit; sampl stripped
DWP-7 / T910	1.21E-02	3.68E-04	2.29E-07	3.12E-08	1.04E-08	5.63E-07	0.81	16.9	36.07	Large amount of excess He; OK gas model fit
DWP-9 / T896	1.05E-02	2.91E-04	1.27E-07	2.84E-08	1.28E-08	1.69E-05	1.52	-	-19.46	Large amount of excess He; poor gas model fit; sampl stripped
DWP-9 / T898	1.10E-02	3.83E-04	2.02E-07	1.12E-07	2.06E-08	4.38E-06	0.88	-	18.30	Large amount of excess He; poor gas model fit

APPENDIX C

Use of Isotope Measurements in Groundwater

Appendix C. Use of Isotope Measurements in Groundwater

C.1 Stable Isotopes

The stable isotope measurements of oxygen-18/oxygen-16 ($^{18}O/^{16}O$) and deuterium/hydrogen (D/H; deuterium is hydrogen-2) ratios in water are used to delineate different water populations in recharged groundwater. The measured $^{18}O/^{16}O$ and D/H ratios are normalized to a recognized standard and the converted results are reported in δ notation (pronounced "del"), where

$$\delta D = \left(\frac{D/H}{D/H_{std}} - 1 \right) 1000$$

$$\delta^{18}O = \left(\frac{^{18}O/^{16}O}{^{18}O/^{16}O_{std}} - 1 \right) 1000$$

The $^{18}O/^{16}O_{std}$ and D/H_{std} are the isotopic ratios of "Standard Mean Ocean Water" (SMOW). A δ value is a per mil (or parts per thousand) deviation from the standard.

The atomic masses differences of these different isotopes in water molecules underlie differences in measured ratios. These differences arise from phase transitions in water (i.e., vapor, water, ice) which favors higher atomic masses in lower energy states of matter. For example, the measured difference in the $\delta^{18}O$ value measured between a water vapor and its condensed liquid form at 25°C is approximately 9.3 per mil. This difference is large compared to the typical measurement precision of 0.1 per mil.

The isotopic ratios of ocean water are remarkably uniform worldwide, owing to global circulation patterns. However, since all continental precipitation originates from the ocean, isotopic partitioning occurs between water phases, and because continental storm fronts are isolated from the ocean and behave as closed systems, the isotopic ratios of measured precipitation varies systematically. This variation is almost exclusively driven by elevation difference and distance inland from the ocean. An example of $\delta^{18}O$ variations in precipitation across British Columbia are illustrated below in Figure C.1a. Figure C.1b shows how shallow groundwater collected on the western slope of the Sierra Nevada record this systematic $\delta^{18}O$ variation in its recharge.

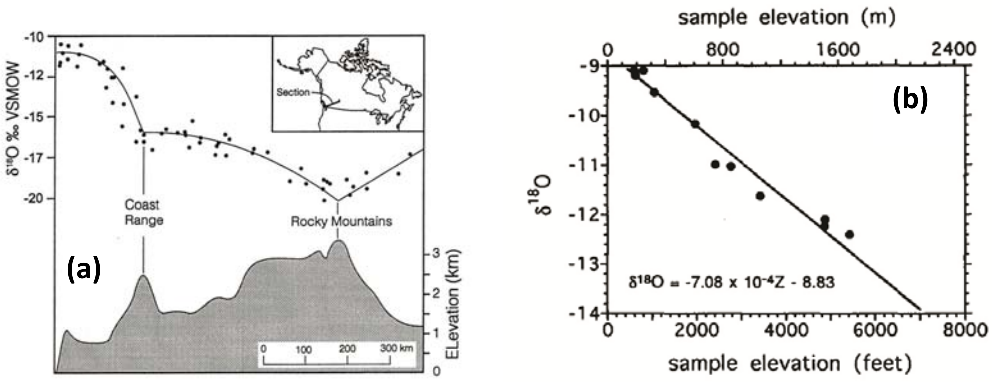

Figure C.1a,b. Figure C-1a shows systematic variation of δ^{18}O values in precipitation across British Columbia (from Yonge et al., 1989). Figure C.1b shows how shallow groundwater records this systematic variation on the western slope of the Sierra Nevada (from Rose et al., 1996).

The method for comparing the isotopic character of different waters lies in the use of a δD- δ^{18}O plot of the isotope ratios. A plot of δD vs. δ^{18}O values provides a graphical means to distinguish various populations of data relating to different water masses of different origins (Fig. C-2).

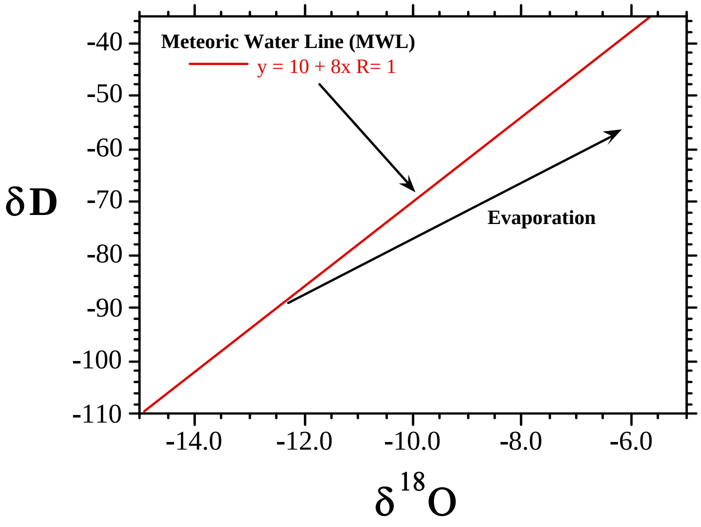

Figure C-2. General δD-δ^{18}O plot showing the Meteoric Water Line (MWL) and the effects of evaporation on natural waters. The slope of the evaporation line can vary between 2 and 6 and depends on the ambient temperature and humidity. The MWL has a constant slope of 8 for global precipitation.

Also on this plot lies what is referred to as the Global Meteoric Water Line (MWL), a linear regression through the values of various unevaporated precipitation collected world-wide, which results in an empirical equation of $\delta D = 8\,\delta^{18}O + 10$. The slope of this line originates from the fact that isotopic partitioning of deuterium between water vapor and liquid is approximately 8 times greater than for ^{18}O. Since global precipitation forms a slope of 8 indicates that cloud water establishes isotopic equilibrium between vapor and liquid.

However, when liquid water evaporates from the surface of water body, a non-equilibrium partitioning develops between the relative deuterium and ^{18}O abundances, causing isotopic enrichment of the remaining liquid water. On a δD- δ^{18}O plot, progressive evaporation causes a shift of the remaining liquid to the right of the MWL along a straight line (see Fig. C-2). The slope of this evaporation line depends on temperature and humidity of the surrounding air. The proximity of an evaporated isotopic value relative to the MWL is proportional to the extent of evaporation or isotopic enrichment.

C.2 Tritium-Helium-3 Age Dating

Attempts have been made in the past to date groundwater with the radioactive (unstable) hydrogen-3 isotope tritium (^{3}H; see Mazor, 1991 and references therein). Because of its radioactive half-life of 12.43 years, it is ideally a good chronometer for young ($\leq$40 years) groundwater flow. Unfortunately from a dating standpoint, ^{3}H concentrations in precipitation have varied considerably over the past 30 years due to ^{3}H production from surface testing of thermonuclear weapons (Fig. C-3).

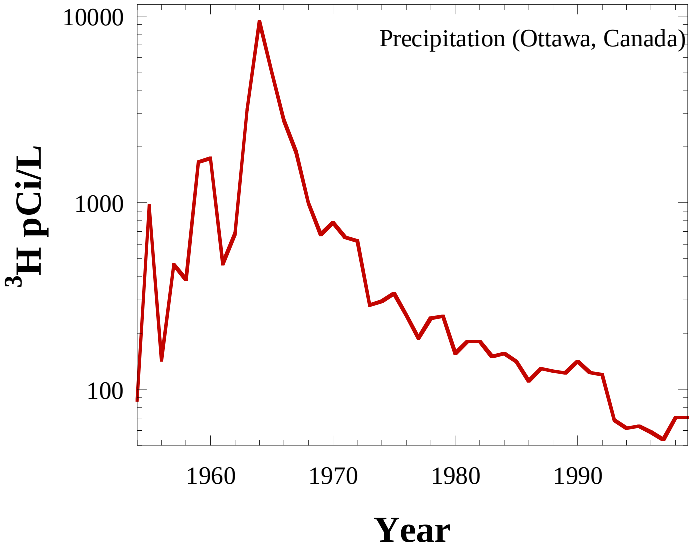

Figure C-3. Changes in the ^{3}H concentration in precipitation have varied over an order of magnitude due to fallout of thermonuclear-produced tritium from surface testing. IAEA/WMO (2001). Global Network of Isotopes in Precipitation. The GNIP Database. Accessible at: http://isohis.iaea.org

Tritium measurements in groundwater 20 years ago were useful from the standpoint of tracing the "bomb-pulse" ^{3}H that had recharged into groundwater in the early 1960s and calculating the groundwater travel time based on the observed depth of the "bomb pulse". Today, however, much of the "bomb-pulse" is not well defined in groundwater due to ^{3}H decay and groundwater dispersion. Tritium measurements alone cannot be used for dating groundwater reliably because of the uncertainty in what the original ^{3}H concentration was at the time of recharge, but it does serve the purpose of defining relatively young groundwater when it is observed.

In more recent years with the development of high-precision noble gas mass spectrometry, the radioactive decay product of ^{3}H, helium-3 (^{3}He), can be measured. The advantage to this lies in the dating equation, where

$$-17.9 \ x \ ln\left(\frac{^3H}{^3H_0}\right) = age \ ,$$

^3H is the concentration of the tritium at any given time, and ^3H_o is the original tritium concentration at the time of recharge. Since the ^3H_o has a large uncertainty due to the spatially and temporally variable "bomb pulse" tritium, the resulting age calculation will have large uncertainties. By simultaneously measuring the ^{3}He produced by tritium decay (known as the tritiogenic ^{3}He or $^3He_{trit}$) we can reconstruct the ^3H_o by adding together the measured tritiogenic $^3He_{trit}$ and the ^3H which leads to

$$-17.9xln\left(\frac{^3H}{^3H+^3H_{trit}}\right) = age,$$

Dissolved ^{3}He measured in a groundwater is actually derived from several sources that include:

$$^3He_{meas} = {}^3He_{trit} + {}^3He_{equil} + {}^3He_{excess} + {}^3He_{rad} \ ,$$

where $^3He_{meas}$ is the total ^{3}He analytically measured, $^3He_{equil}$ is the amount of ^{3}He dissolved in a non-turbulent surface water in equilibrium with the atmosphere and is temperature dependent, $^3He_{excess}$ is the amount of ^{3}He dissolved in water exceeding the equilibrium amount (a common phenomenon in groundwater due to excess dissolved air), and $^3He_{rad}$ is the amount of ^{3}He produced from radioactive decay of isotopes other than tritium. The latter species is very minor and totals only about 0.2% of the total ^{3}He. Separating these different components of the ^{3}He requires additional measurements of the ^{4}He abundance which comprise:

$$^4He_{meas} = {}^4He_{equil} + {}^4He_{excess} + {}^4He_{rad,}$$

where the subscripts are the same as those for ^{3}He. In the case of $^4He_{rad}$, a product of uranium-thorium decay, the abundance can be significant where older waters are involved (e.g. >1000 years old) and has been used numerous times as an independent groundwater age measurement due to its steady state accumulation.

The $^3He_{equil}$, $^4He_{equil}$, and $^4He_{rad}$ terms are either assumed or determined by other noble gas abundance measurements (see below), while the $^3He_{rad}$ term is assumed. The two unknowns left are the excess air terms and the tritiogenic ^{3}He, of which we can formulate two equations to solve for them.

The $^4He_{meas}/^4He_{equil}$ ratios provide a method for determining the excess air contribution to the sample, since a ratio >1.0 is created by incorporation of more dissolved helium than in equilibrium with the atmosphere, assuming an appreciable amount of ^{4}He has not accumulated from radioactive decay (see below). This assumption can be validated with additional noble gas measurements. If radiogenic ^{4}He is a concern, though, the $^3He/^4He$ ratios can be calculated and compared to ratios expected in water at equilibrium concentrations. This comparison is important since if there is any appreciable radiogenic ^{4}He, then the $^3He/^4He$ ratio relative to equilibrium will be <1.0. This is due to the accumulation of ^{4}He from uranium-thorium decay. Where there are indications of radiogenic ^{4}He we can correct for it in the age calculations.

C.3 Noble Gas Abundance

The noble gases of helium, neon, argon, krypton, and xenon naturally occur at trace abundance in the atmosphere. They also dissolve in groundwater during recharge. Their concentration in groundwater is controlled by 1) equilibrium solubility and 2) incorporation of excess air. The solubility of the noble gases in non-turbulent, free-standing water is temperature dependent, with increasing solubility with decreasing temperature. This temperature dependency is most pronounced in the argon, krypton, and xenon concentration (Fig. C-4).

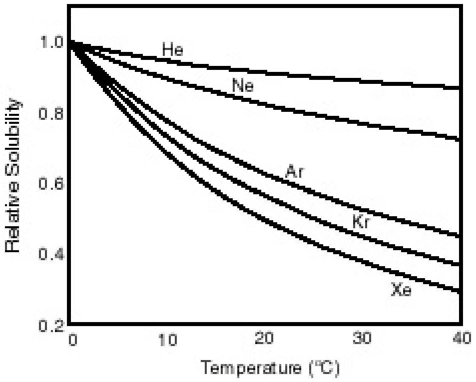

Figure C-4. Solubility of noble gases in water at various temperatures can be used to calculate groundwater recharge temperatures. See Mazor (1991) for examples and further discussion.

The curves in figure C-4 provide a means to calibrate measured dissolved noble gas abundances in groundwater against its recharge temperature. During most groundwater recharge, the mean soil temperature dictates the equilibrium noble gas concentrations dissolved in recharging water, which in most regions is around 2°C greater than the mean annual air temperature.

Dissolved noble gas abundances in groundwater other than helium that exceed an equilibrium amount are due to dissolution of excess air. Incorporation of excess air into recharged groundwater is thought to occur when air in the vadose zone is trapped by a plug of recharge water and is transported to deep enough depths that it is dissolved.

Groundwater recharged through a vadose zone likely has excess dissolved air. In almost all cases the composition of the excess air is the same as the atmosphere (Heaton et al., 1981). Therefore, the amount of noble gases dissolved in groundwater above the equilibrium amount is a simple arithmetic addition of each noble gas from the atmosphere. Therefore, the amount of each dissolved noble gas relative to each other within a single sample should reflect a single equilibrium solubility temperature at the time of groundwater recharge. The amount of excess air dissolved in a groundwater can also provide qualitative information about the type of groundwater recharge. For instance, high excess air content may suggest recharge by a periodic "piston" flow under vadose zone conditions. Little excess air may suggest recharge with a limited vadose zone such as in river or lake infiltration.

The remaining noble gas effect that requires some consideration is the build-up of radiogenic ^{4}He. There is a constant flux toward the ground surface of ^{4}He derived from radioactive decay of uranium and thorium in the Earth's crust that, given enough time, can accumulate in groundwater. Typically groundwater that is thousands of years old will have an appreciable amount of radiogenic ^{4}He, while young groundwater (<100 years old) has little or none except in special conditions such as close proximity to large-scale active faults.

To test for the presence of radiogenic ^{4}He, the other noble gas abundances must be measured and calibrated to a recharge temperature. With this recharge temperature, the ^{4}He content can be predicted based on equilibrium solubility. Any ^{4}He that is above this predicted amount can be attributed to radiogenic ^{4}He, and subsequently subtracted. This will provide a revised ^{3}He/^{4}He ratio that can be used for calculating the groundwater age.

C.5 Radiocarbon and Carbon-13

Radiocarbon, or carbon-14 (^{14}C) is a radioactive isotope of carbon with a half-life of 5730 years. For decades ^{14}C has been used for age-dating of carbon-bearing materials (e.g. archeological artifacts) in the range of 100 to 50,000 years. Groundwater has also been dated, and most commonly by the ^{14}C abundance in dissolved inorganic carbon (DIC). Although many successful studies have been conducted using DIC ^{14}C measurements, much debate still continues about how and to what the extent carbonate minerals in aquifer systems dilute ^{14}C in recharging groundwater. As a result, absolute age determinations of groundwater using ^{14}C are limited to special cases where the absence of carbonate can be demonstrated or ^{14}C correction models can be validated. For the most part, absolute ages ≤1000 years old are usually highly uncertain.

The stable isotope of carbon, carbon-13 (^{13}C), is often measured in DIC and can provide either a source indicator or a relative measure of carbonate mineral reaction. Groundwater acquires DIC during recharge through plant root zones. The partial pressure of CO_2 in the soil root zone is usually higher (i.e. factor of 2 to 1000) than the atmosphere. Recharging groundwater will dissolve this soil zone CO_2, which is chemically neutralized by dissolution of minerals. Soil carbonate is the most common mineral interaction, but in its absence, aluminosilicates can also serve as a reactive substrate. Atmospheric CO_2 has a δ^{13}C value of approximately –7.5 per mil (the del system is the same as used for ^{18}O and deuterium, but carbon isotope ratios are compared to a reference carbonate material instead). Higher plants growing on the surface use this CO_2 for photosynthesis and in the process preferentially use ^{12}C over ^{13}C. As a result, plant $\delta^{13}C$ values tend to either be around –28 per mil, or for many grasses around –13 per mil. These same $\delta^{13}C$ values will occur in the soil zone CO_2 which originates from plant roots. Consequently, the $\delta^{13}C$ of DIC in recharging groundwater will be a mixture of the root zone CO_2 and any carbonate mineral it reacts with. To complicate matters further, for root zones where the partial pressure of CO_2 can be 10 times greater than the atmosphere, and recharging groundwater is relatively slow, isotopic exchange can occur between the DIC and the atmospheric CO_2, causing an enrichment in the $\delta^{13}C$ DIC value (partitioning between DIC and CO2 is approximately 8-10 per mil, depending on temperature). This latter complication is common to desert environments. With all these variables in the recharging groundwater, predicting the final DIC ^{14}C and $\delta^{13}C$ values of groundwater reaching the saturated zone creates many uncertainties. As a result, it is more common to take an empirical approach and compare populations of $\delta^{13}C$ values of groundwater DIC collected in the same general vicinity, and estimate the amount of carbonate interaction and the recharge dynamics.

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APPENDIX D

Elevation-Air Temperature Data for Meteorological Sites within the Owens Valley Region

Station Name	Latitude Longitude	Elevation (feet above sea level)	T°C
Independence	36°48' 118°12'	3,910	15.5
Haiwee	36°08' 117°57'	3,830	15.4
Inyokern	35°39' 117°49'	2,440	17.7
Bishop WSO Airport	37°22' 118°25'	4,150	13.3
Wildrose Ranger Stn	36°16' 117°11'	4,110	14.9
China Lake Armitage	35°41'117°41'	2,240	17.6
Trona	35°47' 117°23'	1,700	19.3
Lodgepole	36°36' 118°44'	6,750	5.4
South Lake	37°10' 118°34'	9,630	4.1
Lake Sabrina	37°13' 118°37'	9,080	5.4
Deep Spring College	37°22' 117°59'	5,230	11.4
Giant Forest	36°34' 118°46'	6,380	8.1
Huntington Lake	37°14' 119°13'	7,020	7.0
White Mt	37°35' 118°14'	12,470	-2.5