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# Letter Report: Stable Hydrogen and Oxygen Isotope Analysis of B-Complex Perched Water Samples

## April 2017

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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# 1.0 Executive Summary

Fine-grained sediments associated with the Cold Creek Unit at Hanford have caused the formation of a perched water aquifer in the deep vadose zone at the B Complex area, which includes waste sites in the 200-DV-1 Operable Unit and the single-shell tank farms in Waste Management Area B-BX-BY. High levels of contaminants, such as uranium, technetium-99, and nitrate, make this aquifer a continuing source of contamination for the groundwater located a few meters below the perched zone. Analysis of deuterium ($^{2}H$) and 18-oxygen ($^{18}O$) of nine perched water samples from three different wells was performed. Samples represent time points from hydraulic tests performed on the perched aquifer using the three wells. The isotope analyses showed that the perched water had $\delta^{2}H$ and $\delta^{18}O$ ratios consistent with the regional meteoric water line, indicating that local precipitation events at the Hanford site likely account for recharge of the perched water aquifer. Data from the isotope analysis can be used along with pumping and recovery data to help understand the perched water dynamics related to aquifer size and hydraulic control of the aquifer in the future.

# 2.0 Background

Plutonium production operations that occurred at the U.S. Department of Energy Hanford Site produced waste streams containing radionuclides such as technetium-99 (Tc-99) and uranium (U) that were discharged to waste sites and B, BX, and BY tank farms in the B Complex area. As a result of a BX tank overfill event that released liquid waste to the subsurface and the waste site discharges to the subsurface, the vadose zone and groundwater beneath the B-Complex have become contaminated. Fine-grained zones made up of Cold Creek Unit sediments, have caused the formation of a perched water aquifer approximately 4.6 meters above the B-Complex water table. The perched-water, which is high in contaminants such as U, represents a future source of groundwater contamination which heightens the need to understand the major water sources for the perched aquifer.

The study described in this report used analysis of $\delta^{2}H$ and $\delta^{18}O$ of samples resulting from two hydraulic tests (FY16) of the perched aquifer to help understand the source of the perched water.

# 3.0 Approach and Methods

Ten perched water samples taken during a perched water single-well and multi-well pumping tests were received in March, April and June of 2016 (Table 1). Locations of the wells used for both pumping tests is shown in Figure 1. Of the 10 samples received, only 9 were analyzed. Sample B33CH7 from well 299-E33-344, from the single-well pumping test, 24 hour time interval showed elevated radioactivity that would have contaminated the instrument, so the sample was not analyzed.

Measurement of $\delta^{2}H$ and $\delta^{18}O$ content of water samples was performed using a Los Gatos Research water analyzer spectroscopy-based isotope measurement platform. Samples were filtered (0.45 µm syringe filter) and dispensed into glass autosampler vials. Each sample was analyzed on two separate days. Triplicate analyses on multiple sample replicates were used for the samples which resulted in a total of 15-18 replicates per sample (Table 1) with one sample (B35JT7) having only 15 replicates due to

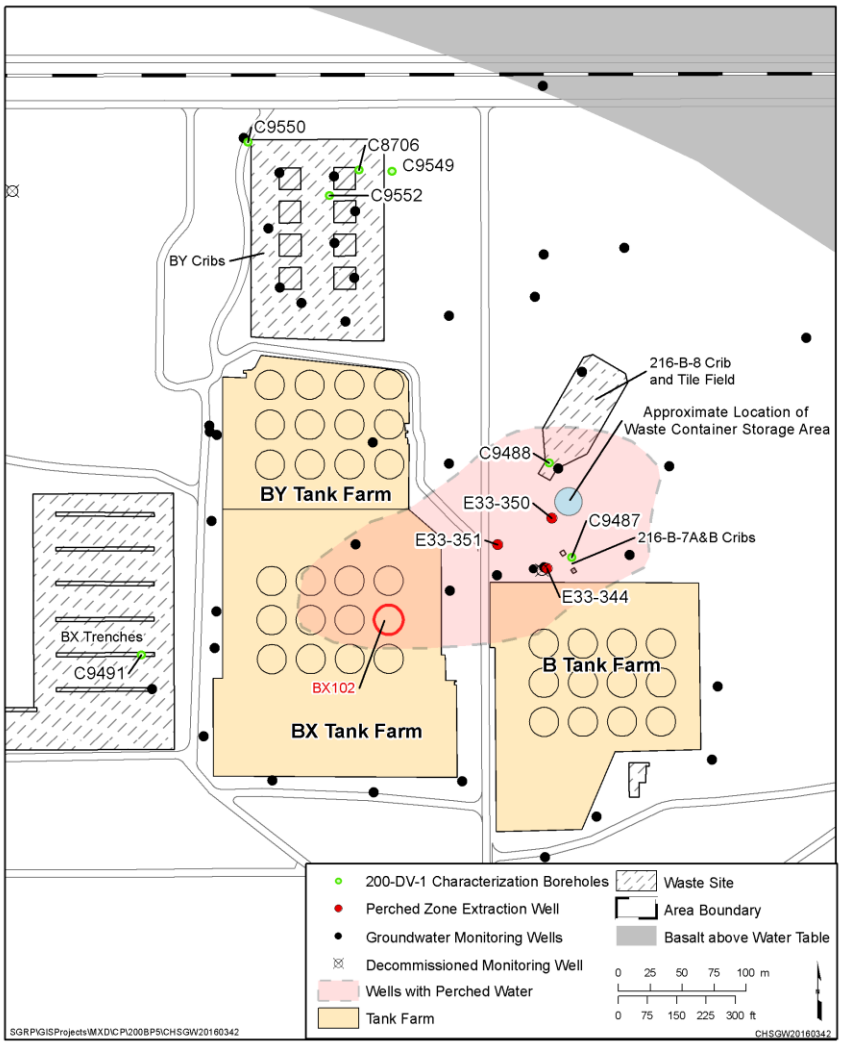


Figure 1. Schematic of B-BX-BY Tank Farms, and the proposed outline of the perched water aquifer. Well locations used for the single- and multi-well pump tests are shown by the red dots.

an autosampler failure. The instrument was calibrated using in-house standards, for which values were confirmed during this project using Vienna Standard Mean Ocean Water ($\delta^2H$ = 0‰ and $\delta^{18}O$ = 0‰) and Standard Light Antarctic Precipitation 2 ($\delta^2H$ = -427.5 ‰ and $\delta^{18}O$ = -55.50‰).

**Table 1. Perched water samples analyzed for deuterium ($^{2}H$) and 18-oxygen ($^{18}O$) content.**

| Sample ID | Well ID | Sample Description |
|---|---|---|
| B33CH7 | 299-E33-344 | 24 hr |
| B33CJ5 | 299-E33-344 | 4 day |
| B35JT7 | 299-E33-344 | 4 wk |
| B35JV5 | 299-E33-344 | 6 wk |
| B34TV9 | 299-E33-350 | 24 hr |
| B34TX3 | 299-E33-350 | 4 day |
| B35K11 | 299-E33-350 | 4 wk |
| B35K19 | 299-E33-350 | 6 wk |
| B34V01 | 299-E33-351 | 24 hr |
| B34V09 | 299-E33-351 | 4 day |

Note: Samples from 24 hr and 4 days were taken during single-well pumping test. Samples from 4 and 6 wks were taken during multi-well pump test.

# 4.0 Results

Isotopic analysis for oxygen and hydrogen are developed and applied for multiple purposes (Prudic et al. 1997). For instance, the stable isotopes of water ($\delta^{2}H$ and $\delta^{18}O$) can be used to assist with tracking of underground contaminant plumes or linking a source to a measured water sample. Isotopic data was collected to assess possible water sources for the perched water. Isotopic ratios for $\delta^{2}H$ and $\delta^{18}O$ are reported in delta ($\delta$) notation, defined as

$$\delta = \left(\frac{\mathrm{Rsa}}{\mathrm{R}std} - 1\right) \mathrm{x}\, 1000$$

where R is the ratio of the abundance of the heavy to light isotope (i.e. $^{2}H/^{1}H$, $^{18}O/^{16}O$), *sa* denotes the sample, and *std* indicates the standard (McKinney et al. 1950). Delta values are reported in per mil (‰), with $\delta^{2}H$ and $\delta^{18}O$ values relative to Vienna Standard Mean Ocean Water ($\delta^{2}H$ = 0‰, $\delta^{18}O$ = 0‰).

Isotopic analysis for $\delta^{2}H$ and $\delta^{18}O$ of the perched water samples are shown in Table 2. Comparison of the perched water $\delta^{2}H$ and $\delta^{18}O$ results to the global meteoric water line (Craig 1961), and an assembled regional meteoric water line (Graham 1983) show fairly good agreement between the samples and the local meteoric water line (Figure 2) and the isotope data therefore is consistent with local precipitation being the primary recharge source for the perched water table. The positioning of the samples from 299-E33-351 slightly to the right of this line is consistent with evaporitic enrichment that may occur within the upper reaches of the vadose zone due to the prevailing dry conditions and relatively

short duration of precipitation events in this location (DePaolo et al., 2004). An interesting observation from the data is the spread of data along the local meteoric water line. There is seasonal variability in the $\delta^2H$ and $\delta^{18}O$ of local precipitation with winter precipitation generally falling on the more isotopically

**Table 2. Perched water samples analyzed for deuterium ($\delta^2H$) and 18-oxygen ($\delta^{18}O$) content**

| Sample ID | Well ID | Pumping | $\delta^{18}O$ (‰) | | $\delta^2H$ (‰) | | n |
|---|---|---|---|---|---|---|---|
| | | | Ave. (‰) | Stan. Dev. (‰) | Ave. (‰) | Stan. Dev. (‰) | |
| B33CJ5 | 299-E33-344 | 4 day | -15.6 | 0.2 | -123.5 | 0.9 | 18 |
| B35JT7 | 299-E33-344 | 4 wk | -15.6 | 0.2 | -123.8 | 0.5 | 15 |
| B35JV5 | 299-E33-344 | 6 wk | -15.7 | 0.2 | -124.0 | 0.8 | 18 |
| B34TV9 | 299-E33-350 | 24 hr | -14.9 | 0.2 | -119.9 | 0.6 | 18 |
| B34TX3 | 299-E33-350 | 4 day | -14.8 | 0.2 | -120.4 | 0.9 | 18 |
| B35K11 | 299-E33-350 | 4 wk | -15.0 | 0.2 | -120.4 | 0.6 | 18 |
| B35K19 | 299-E33-350 | 6 wk | -14.7 | 0.2 | -119.4 | 0.5 | 18 |
| B34V01 | 299-E33-351 | 24 hr | -14.4 | 0.1 | -118.1 | 0.3 | 18 |
| B34V09 | 299-E33-351 | 4 day | -13.7 | 0.3 | -116.1 | 1.2 | 18 |

depleted sections of the meteoric water line. However, DePaolo et al. (2004) used $\delta^2H$ of -138‰ and $\delta^{18}O$ of -18‰ as a typical winter precipitation endmember for this area and all of the data reported here are isotopically enriched from this value. This isotopic shift may be a further indication of evaporitic enrichment at the surface or within the vadose zone prior to the water being trapped within the perched aquifer. Results show that water samples taken from well 299-E33-344 were depleted in both deuterium ($^2H$) and 18-oxygen ($^{18}O$), when compared to water samples taken from the newer wells (299-E33-350 and 299-E33-351).

# 5.0 Conclusions

Nine perched water samples were analyzed to determine stable $\delta^2H$ and $\delta^{18}O$ isotope distribution in the samples. Samples collected on days 1 and 4 during a single-well pumping test and weeks 4 and 6 during a multi-well pumping test were analyzed. Results from the analyses indicate that the perched water has similar $\delta^2H$ and $\delta^{18}O$ ratios to regional precipitation with isotopic enrichment above typical winter precipitation values being likely attributed to evaporative enrichment previously described for this location. Samples from well 299-E33-344 showed depletion of both isotopes compared to wells 299-E33-350 and 299-E33-351. Overall these results show strong evidence that the perched water aquifer is recharged by local precipitation.

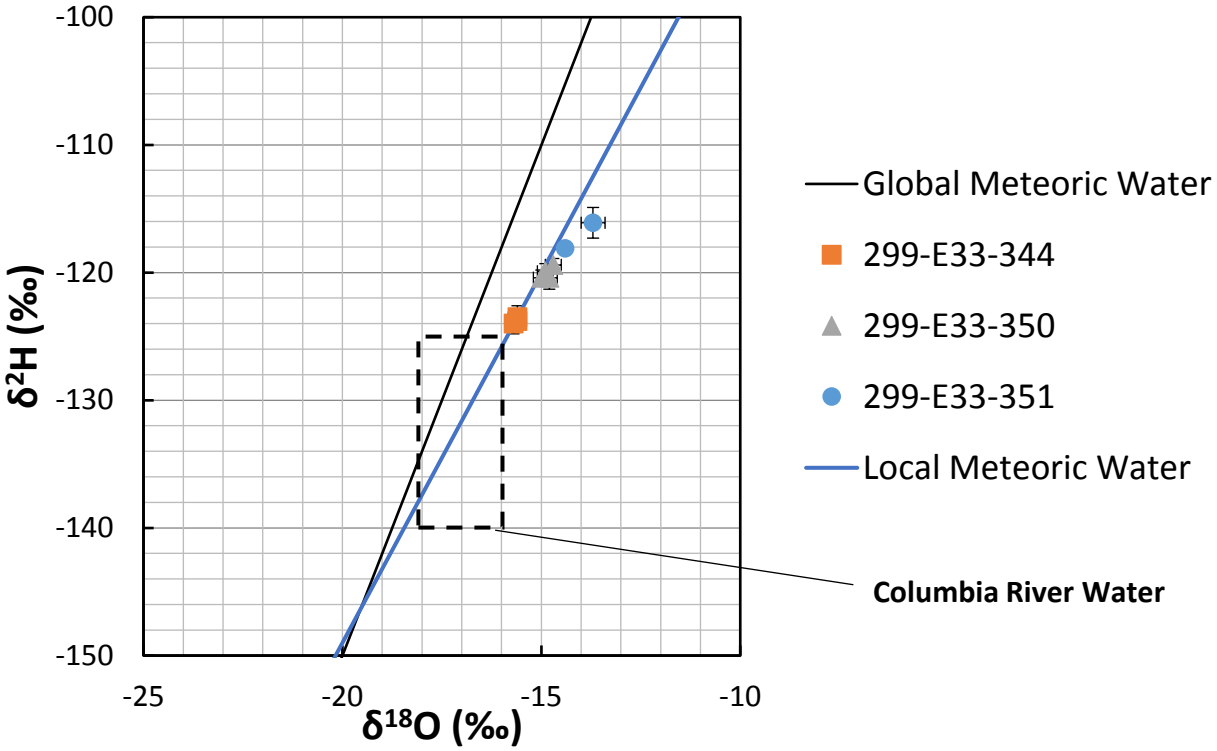


**Figure 2.** Isotope data for perched water sample analyses. Trend lines for isotope values for global and local meteoric waster are included for comparison. Error bars correlate to the standard deviation between replicate analyses. Dashed box shows area comprising measured values of isotopes ratios for Columbia River surface water at this location (Spane and Webber 1995).

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