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Vertical Characterization of Flow and Contaminant Concentration in New Hanford Extraction Wells

September 2025

Rebecka Iveson
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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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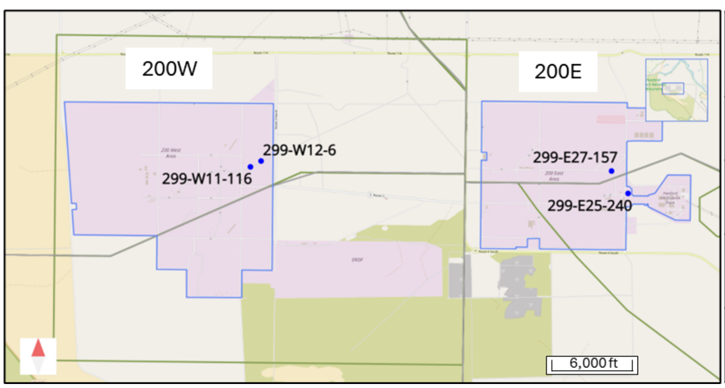
Introduction

Effective groundwater remediation should focus on high-concentration, low-permeability zones within the aquifer, as these areas often present significant challenges to contaminant removal. Characterizing the vertical distribution of contamination in an aquifer is therefore critical for optimizing and monitoring pump-and-treat (P&T) systems to meet target cleanup timelines. Flow patterns driven by hydraulic gradients and variations in permeability are described to provide insight into contaminant mass removal from long-screened wells. The objective of this multi-phase work is to provide actionable recommendations for improving remedy performance monitoring and P&T operations, which ongoing evaluations will address. This report summarizes the preliminary results of vertical flow and contaminant distribution monitoring in new extraction wells at the Hanford Site.

Technical Basis and Study Area

The U.S. Department of Energy Hanford Field Office and their prime cleanup contractor, Central Plateau Cleanup Company (CPCCo), are pursuing optimized remedy performance to accelerate cleanup of groundwater contamination at the Hanford Site. The site's 200 West Area P&T facility primarily uses fully-screened extraction wells designed to treat contaminants of concern throughout the entire thickness of the aquifer. However, performance monitoring of trends in contaminant concentrations poses unique challenges due to complex aquifer-well interactions and vertical flow dynamics.



Well ID	OU	COC	Geology (Saturated Interval)
299-W12-6 (D0473)	ZP-1	CCl_4, TCE	Top: Rwie Bottom: Rwia
299-W11-116 (D0474)	ZP-1	CCl_4, TCE	Top: Rwie Bottom: Rwia
299-E27-157 (D0118)	BP-5	Tc-99	CCUg
299-E25-240 (D0119)	PO-1	Tc-99	Top: CCUg Bottom: Rwia

Figure 1. Map and summary details of study wells. Geology key: Rwie: Ringold Formation - Unit E; Rwia: Ringold Formation – Unit A; CCUg: Cold Creek Unit Gravels

The multilayered sedimentary aquifer system at Hanford can introduce varying vertical hydraulic gradients and permeabilities along the saturated interval of the well screen. This can result in vertical borehole flow and produce flow-weighted sampled concentrations, generally irrespective of pump depth intake. The resulting dilution from low-concentration, high-permeability zones may obscure the presence of high-concentration, low-permeability zones within the aquifer, complicating remedy design. Thus, characterizing well-aquifer dynamics in newly installed extraction wells can provide context for existing datasets (e.g., hydraulic data collected during drilling, post-development samples, nearby hydraulic parameter estimations) and generate new information to better understand potential impediments to achieving remediation objectives.

Vertical flow profiling and depth-discrete sampling were conducted in four new P&T extraction wells at Hanford. Wells were chosen to represent multiple groundwater operable units (OUs), varied geology, and the following contaminants of concern (COCs): carbon tetrachloride (CCl_4), trichloroethene, and technecium-99 (Tc-99) (Figure 1).

Approach

Vertical flow profiling using an electromagnetic borehole flowmeter (EBF) and groundwater sampling under ambient and dynamic (pumped) conditions were conducted over a 4-month period (April–July 2025). Groundwater samples were collected under pumping conditions and passively in depth-discrete intervals. Groundwater quality (pH, temperature, dissolved oxygen, conductivity) during pumping was continuously measured using an AquaTroll 600 multi-parameter sonde. Figure 2 depicts a typical field site (left) and the deployment of the EBF down-well via a wireline cable, pulley, and electric winch.

Figure 2. Field site at 299-W12-6 (left) and the deployment of the EBF (right).

Vertical Flow Measurements

An EBF was used to measure vertical flow within each of the four wells. The EBF is ~1.54 m long and uses a centralizer and rubber baffles (e.g., “skirts”) to reduce bypass around the sensor. The EBF is conveyed within the well using an electric winch. Logging occurred in the upward direction, beginning in the sump. Flow measurements were collected under ambient (i.e., no pumping) and dynamic (i.e., pumping, Figure 3) conditions. The condition of the survey provides unique hydrogeologic information:

- Ambient flow profiles characterize flow due to vertical gradients (e.g., head-weighted flow).
- Dynamic flow profiles characterize flow driven by differences in permeability (e.g., permeability-weighted flow) (Figure 3).
- Ambient and dynamic flow profiles are combined to generate a normalized hydraulic conductivity (K) profile along the well screen, while also indicating the origin of pumped water.

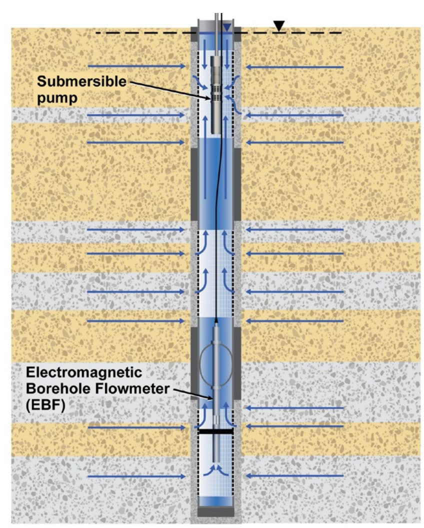


Figure 3. Schematic of a dynamic flow survey

Ambient flow surveys were repeated after a dynamic survey and after ambient snap sampling to verify steady-state conditions. Figure 4 provides a general timeline for field collection of EBF measurements and groundwater sampling in long-screened wells.

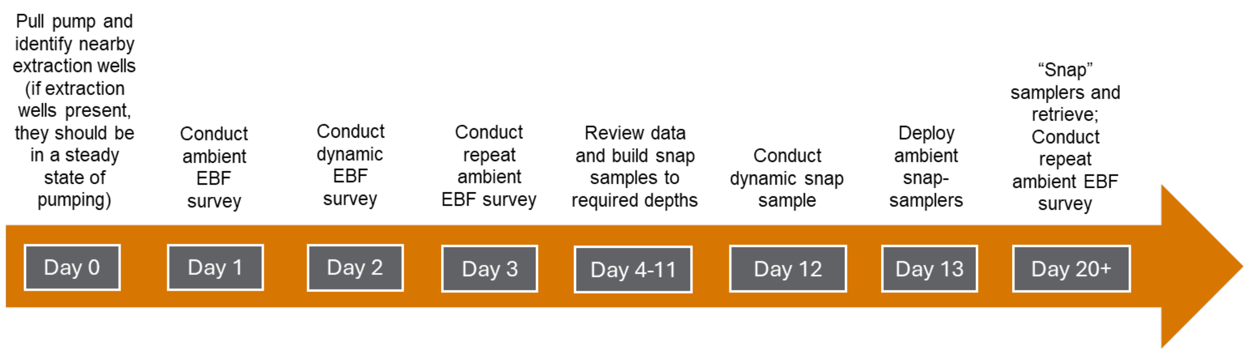


Figure 4. Typical schedule of flow profiling and sampling in a long-screened well.

Depth-Discrete Sampling Methods

Depth-discrete groundwater sampling was conducted using "Snap Samplers" (henceforth snap samplers) (Figure 5), a type of passive sampling system that allows for sample collection without purging. The sample bottles are suspended in a well while open, allowing the water in the bottle and the well to equilibrate (Figure 6).

Figure 5. Snap sample construction (left); snap sample deployment (right).

Snap sample placement (i.e., depth) was informed by the flow profiles generated by EBF surveys. Generally, snap samples were placed at inflow zones to quantify depth-discrete mass entering the well bore. Snap samples were collected under ambient (Figure 6) and dynamic conditions:

- Ambient snap samplers characterize the contaminant composition profile of groundwater under ambient hydraulic conditions.
- Dynamic snap samplers characterize groundwater from inflow zones during pumping and can identify intervals that may contribute more contaminant mass during extraction.

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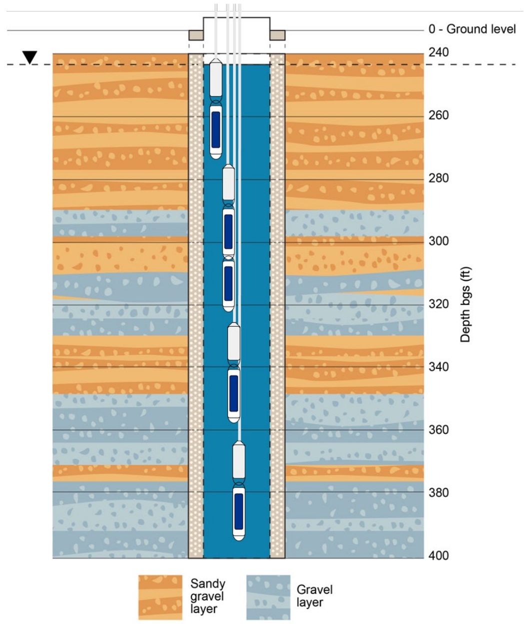

Figure 6. Schematic of snap samplers installed in a well under ambient flow conditions. An example of a duplicate sample (e.g., two bottles at a similar depth) is shown near 300 ft bgs.

Preliminary Results

Evaluation of the results of vertical flow and contaminant profiling to characterize the hydrologic and contaminant conditions in the Hanford Site 200 East and 200 West areas is ongoing. Preliminary results of this study offer valuable insights into important factors influencing aquifer remediation, including ambient vertical flow dynamics, inflow zones during pumping, hydraulic conductivity distributions, and depth-discrete contaminant concentration profiles across newly installed extraction wells.

200 East Area Extraction Wells

The flow and contaminant profiles of well 299-E25-240 are presented in Figure 7 and demonstrate broader trends seen in both extraction wells.

Well and Aquifer Hydraulics

Under ambient conditions, low vertical gradients, indicated by low vertical flow patterns, limit intraborehole flow and contaminant redistribution by reducing inflow and outflow zones within the wells. These low vertical gradients are consistent with a relatively low horizontal hydraulic gradient measured in the 200 East Area (DOE 2025). Slightly higher hydraulic head observed in the deeper portions of the aquifer system drives groundwater upward toward the top of the screened interval, potentially biasing passively sampled water to represent contaminant concentrations at lower depths.

Under dynamic conditions, flow profiles reveal that the upper portion of the screened interval, primarily within the Cold Creek Unit gravel (CCUg), is the most permeable compared to the lower Rwia formation. Negligible flow was detected from the Rwia, even when the pump intake was positioned within this interval, suggesting limited hydraulic contribution from the lower aquifer section (Figure 7, Panel B). Increased flow in the upper CCUg during pumping results in higher normalized hydraulic conductivity (K) values for this zone (Figure 9, Panel C). However, these results may be influenced by bypass flow, which is where groundwater flows around the EBF sensor, either in the filter pack or around the diverter skirt. To address these uncertainties, ongoing evaluations aim to quantify bypass effects and refine the normalized K profiles for improved characterization of aquifer dynamics and well performance monitoring.

Tc-99 Concentration

The ambient snap sample results from the 200-East area did not vary significantly in Tc-99 concentration with depth. The lower-concentration groundwater flowing upward in the well, in addition to the overall low flows and lack of major inflow zones at the depths corresponding to higher-contaminant concentration, may have masked potential variation of concentration with depth under ambient conditions.

Pumped concentrations of Tc-99 most likely originated from the upper portion of the screened aquifer (i.e. the CCUg) based on the dynamic flow results and concentrations sampled during drilling. The relative permeability is lower in the Rwia compared to the CCUg (Figure 9, Panel C); therefore, groundwater pumped from this well will originate from the CCUg. Tc-99 mass in the Rwia will not be extracted from this well while it is fully screened across both units.

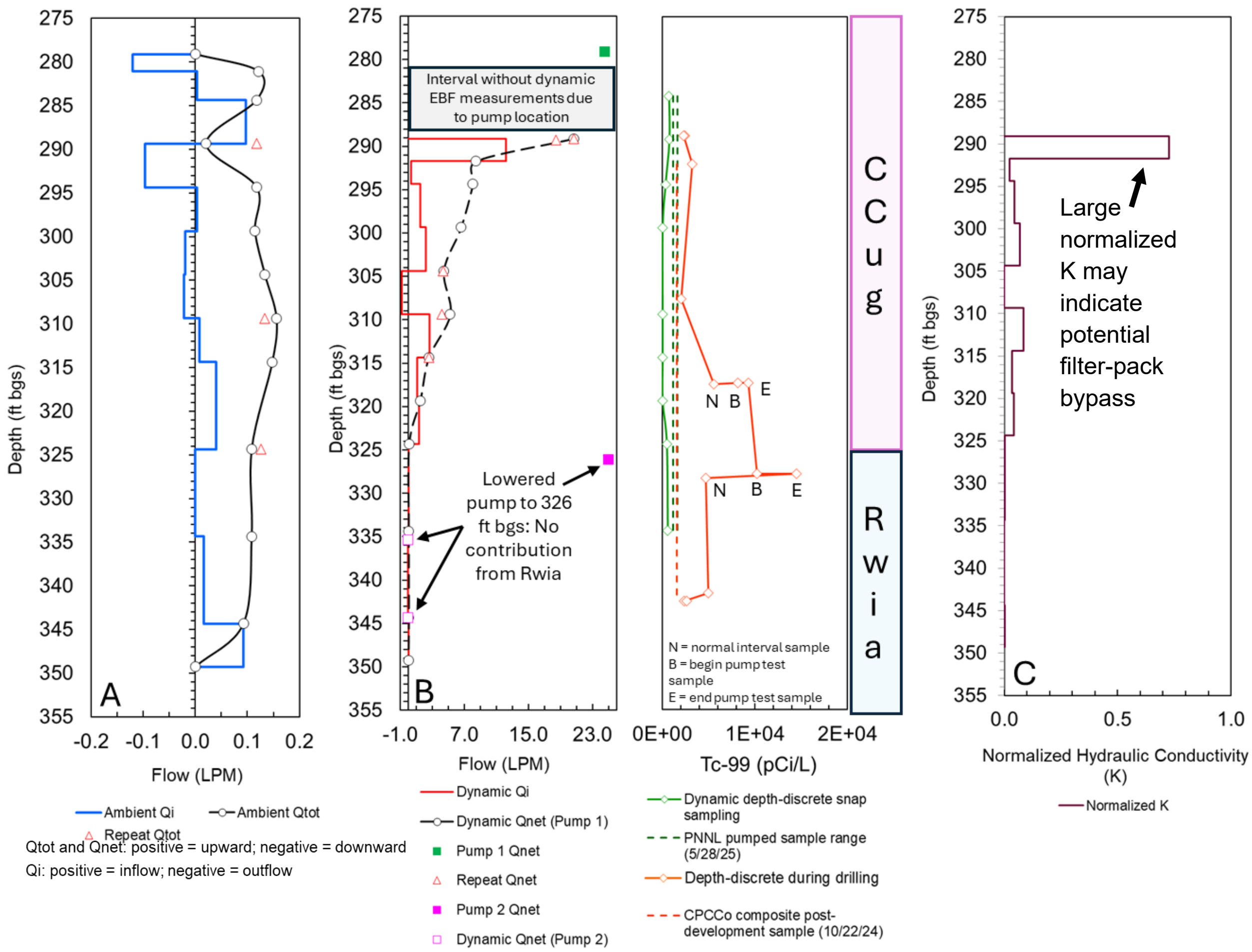

Figure 7. Flow and concentration profiling results, well 299-E25-240: (A) ambient flow profile, (B) dynamic profile – flow (left) and Tc-99 concentration (right). Sampling results from CPCCo are included for comparison. (C) Normalized K profile generated using ambient and dynamic flow survey results.

As indicated above, any bypass of groundwater through the filter pack or unequal mixing within the wellbore can impact the interpretation of pumped sample concentrations by masking high-concentration zones. Ongoing evaluations are therefore necessary to interpret dynamic snap sample results in order to account for this potential bypass through the filter pack and the effects of unequal mixing during pumping (e.g. Martin-Hayden 2000; McMillan et al. 2014).

200-West Area Extraction Wells

The ambient flow profile of well 299-W12-6 is shown in Figure 8, and flow and contaminant profiles of well 299-W11-116 are presented in Figure 9. The broader trends seen in both extraction wells are summarized below.

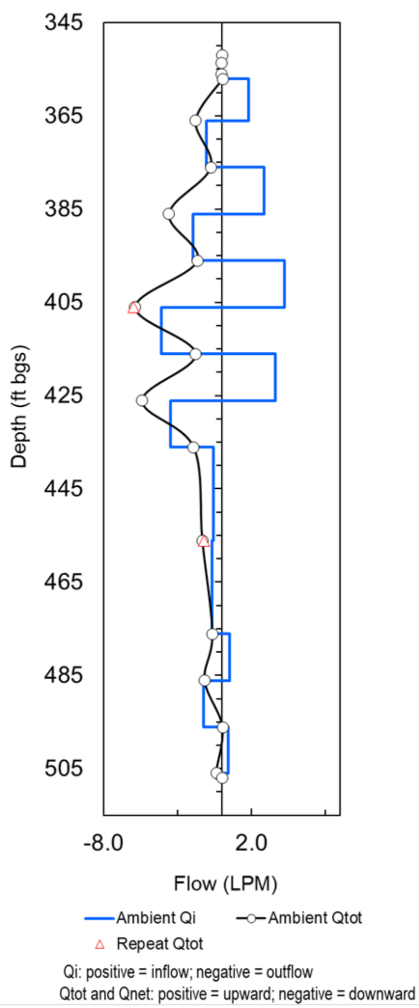

Figure 8. Ambient flow profile of well 299-W12-6.

Well and Aquifer Hydraulics

The 200 West Area wells exhibit significantly greater ambient flow magnitudes and stronger vertical hydraulic gradients compared to the 200 East Area wells. This suggests distinct hydraulic conditions, likely influenced by local-scale heterogeneities and the presence of preferential pathways. These conditions increase intraborehole flow and subsequent contaminant redistribution. The differences in flow profiles between the two extraction wells (Figure 10 vs. Figure 11, Panel A), despite being in similar hydrostratigraphic units, further highlight these localized influences rather than large-scale operational factors. Both of the 200 West Area wells have downward flow from the top of the screened interval in the Rwie, indicating higher hydraulic head in this unit compared to the underlying Rwia.

Pumping from nearby extraction wells may be preferentially lowering the head (drawdown) in portions of the aquifer where there is a stronger lateral hydraulic connection. The alternating inflow and outflow zones observed in the upper portion of the screen in well 299-W12-6 (Figure 8) suggest significant zones of varying head and/or permeability within the Rwie.

Under dynamic conditions, flow measurements indicate groundwater is preferentially drawn from the Rwie, rather than the underlying Rwia, resulting in higher overall normalized K estimations in the upper aquifer.

While the K values of the Rwie are expected to be higher than estimates of the Rwia based on the conceptual site model, similar to the 200 East Area wells, it is likely that bypass flow through the filter pack is occurring. The effect of bypass on the estimated K distribution is currently being evaluated.

CCl_4 Concentrations

Depth-discrete samples during drilling had higher CCl_4 concentrations than those collected with passive snap samplers. The discrepancy between concentrations, potentially exacerbated by the masking effect of ambient outflow zones, suggests that intraborehole flow and external hydraulic influences are significantly altering contaminant distribution near the well. This highlights the critical need to integrate vertical flow data with depth-discrete concentration measurements to accurately characterize the contaminant profile in the formation.

The dynamic survey found that water is preferentially pumped from the upper portion of the aquifer (e.g., the Rwie), and dynamic snap sampled concentrations increased at these higher flow depths. This indicates that P&T operations may be ineffective at treating the entire target aquifer in these wells, particularly the underlying Rwia, without implementing zonal isolation measures. This insight is critical to evaluating the performance of the P&T remediation method over time and can help inform future strategic decisions regarding well design and target cleanup levels.

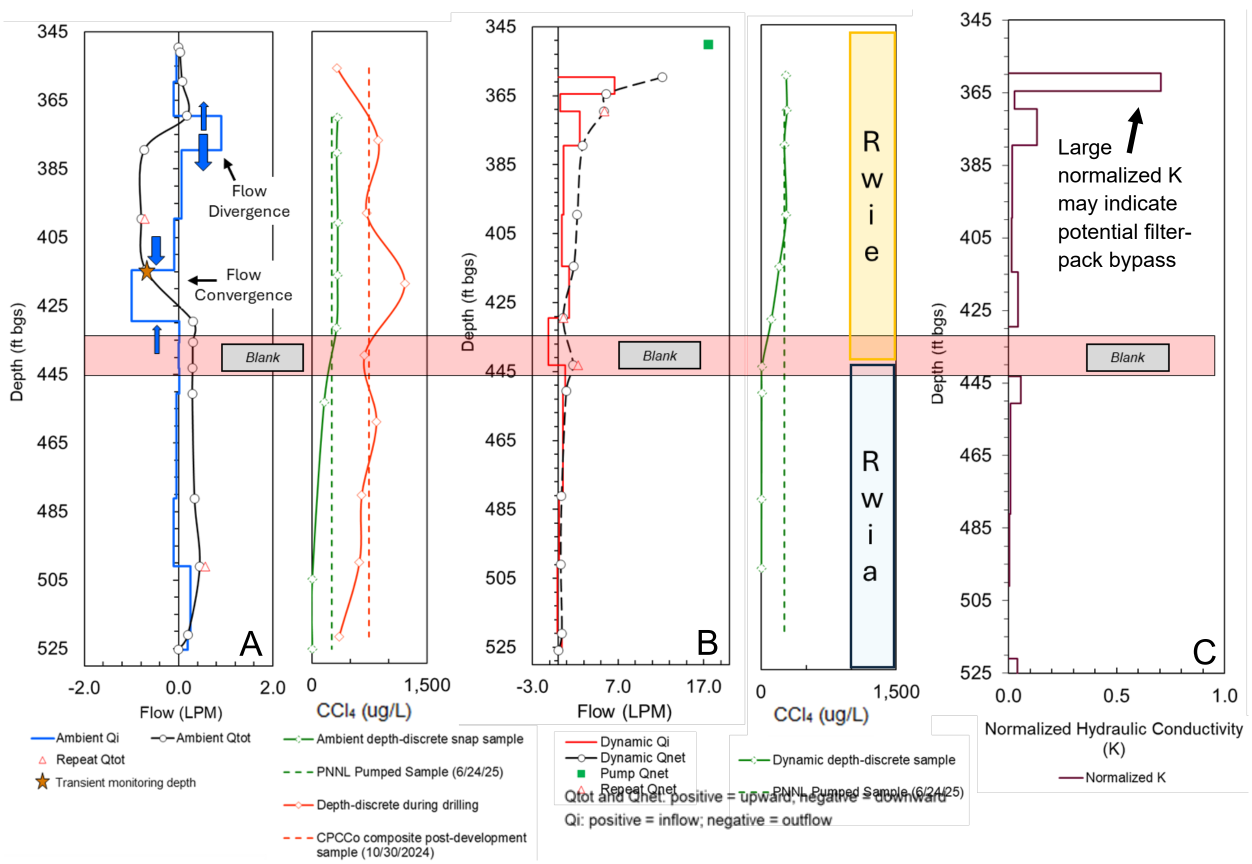

Figure 9. Flow and concentration profiling results, well 299-W11-116. (A) Ambient profile: flow (left) and CT concentration (right). Sampling results from CPCCo are included for comparison. (B) Dynamic profile: flow (left) and CT concentration (right). (C) Normalized K profile generated using ambient and dynamic flow survey results.

Influence of the P&T System on Vertical Flow

Repeat ambient flow surveys in well 299-W11-116 indicated a heavy hydraulic influence and variability related to changes in pumping rates from nearby extraction wells, with flow profiles before and after a planned P&T shutdown event showing very different patterns. To evaluate this further, extended EBF monitoring was performed to measure temporal changes coinciding with another planned P&T system outage and partial restart (Figure 10).

The EBF was stationed at a fixed depth immediately above an active outflow zone that is present while nearby extraction wells are running. Upon shutdown, flow switches to upward past the EBF and significantly increases magnitude (Figure 10). Water-level monitoring in the well indicates a recovery in head in response to the cessation of pumping. Upward flow indicates that an interval below the EBF is responding faster than above – a more rapid head recovery in this interval could be explained by higher hydraulic conductivity or a stronger lateral hydraulic connection to the portions of the aquifer being stressed by pumping. This emphasizes the need to collect EBF measurements and depth-discrete sampling during periods of steady pumping, especially when extraction wells are located near the well of interest. It also confirms the presence of lateral and vertical heterogeneities in the aquifer and vertical intervals where pumping seems to have more effect.

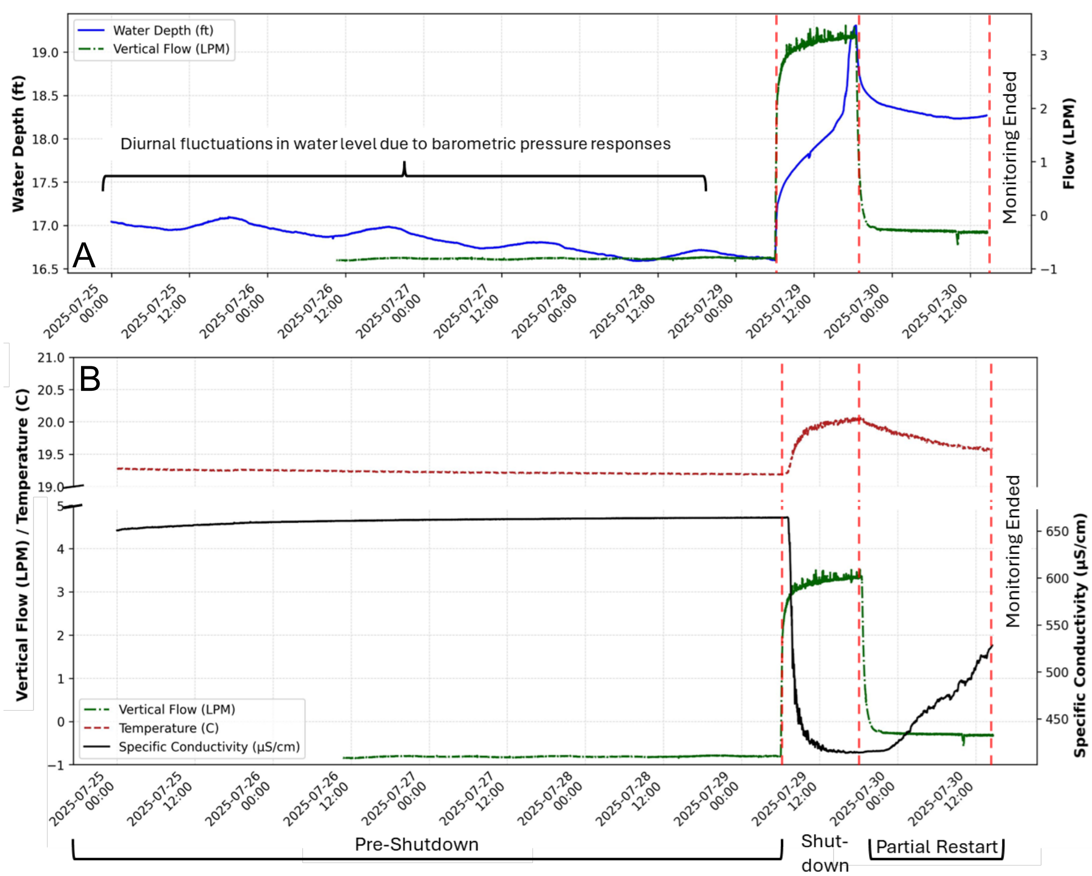

Figure 10. Groundwater monitoring results during P&T shutdown and partial restart event at 299-W11-116. Vertical flow is monitored at depth 414.5 ft bgs. (A) Water depth and vertical flow. (B) Vertical flow, temperature, and specific conductivity.

Ongoing Evaluations

Flow profiling and depth-discrete sampling were completed in four new extraction wells at Hanford to gain information that can be used to optimize P&T operations, monitor remedy implementation, and provide a basis for well construction decisions in the future. Analyses of the data are ongoing and are described below:

- **Estimating Hydraulic Properties**: The ambient and dynamic flow profiles will be used to estimate vertical hydraulic gradient and transmissivity in the screened intervals and compared to results from previous aquifer hydraulic testing.
- **Addressing Bypass Effects**: Preliminary interpretation of the dynamic EBF flow profiles indicates that groundwater is flowing around the EBF (e.g., within the filter pack and/or around the EBF's flow diverter skirt in the wellbore). The uncertainty and limitations caused by bypass need to be evaluated and considered in the analysis. Minimizing bypass is an area of ongoing research.
- **Integrating Flow and Concentration Data**: To estimate contaminant concentrations in the aquifer formation vertically, multiple approaches will be explored. Traditional mass-balance calculations and inversion-based methods will be used to estimate contaminant concentrations in the aquifer based on flow and concentration measurements from within the well under ambient and dynamic conditions.
- **Quantifying sensor of uncertainty**: Sources of uncertainty when using an EBF can affect measurement accuracy and data interpretation. To investigate the performance of the flowmeter and verify field-based measurements, a multi-point calibration in both the upward and downward flow directions was performed (Figure 11). Further evaluations are ongoing to quantify the error associated with flow measurements, which may include bypass, sensor drift, and setup conditions.

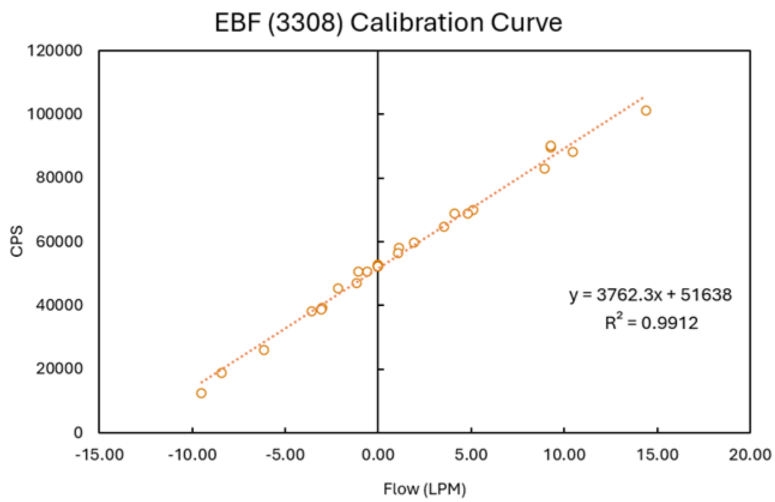

Figure 11. Linear regression curve generated by performing a multi-point calibration on the EBF in a both the upward and downward flow directions.

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