

Quality Assurance Project Plan

Characterization of in situ virus transport and inactivation in the groundwater of Columbia River basalt aquifers: Sampling

July 2026

Publication Number 26-12-016

IAA No. C2600001

Publication Information

Each study funded by the Washington State Department of Ecology (Ecology) must have an approved Quality Assurance Project Plan (QAPP). The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the final report of the study to the internet. This QAPP describes a project with key participants from both Ecology and the Washington State Department of Health (DOH) 2025-2026. Any use of product or firm names in this publication is for descriptive purposes only and does not imply endorsement by the author or the Department of Ecology.

Data for this project are available in EPA's Water Quality Exchange (WQX) database (https://www.epa.gov/waterdata/water-quality-data-wqx). This QAPP is valid through July 20, 2031.

This document is available on the Department of Ecology's website at: https://apps.ecology.wa.gov/publications/summarypages/2612016.html

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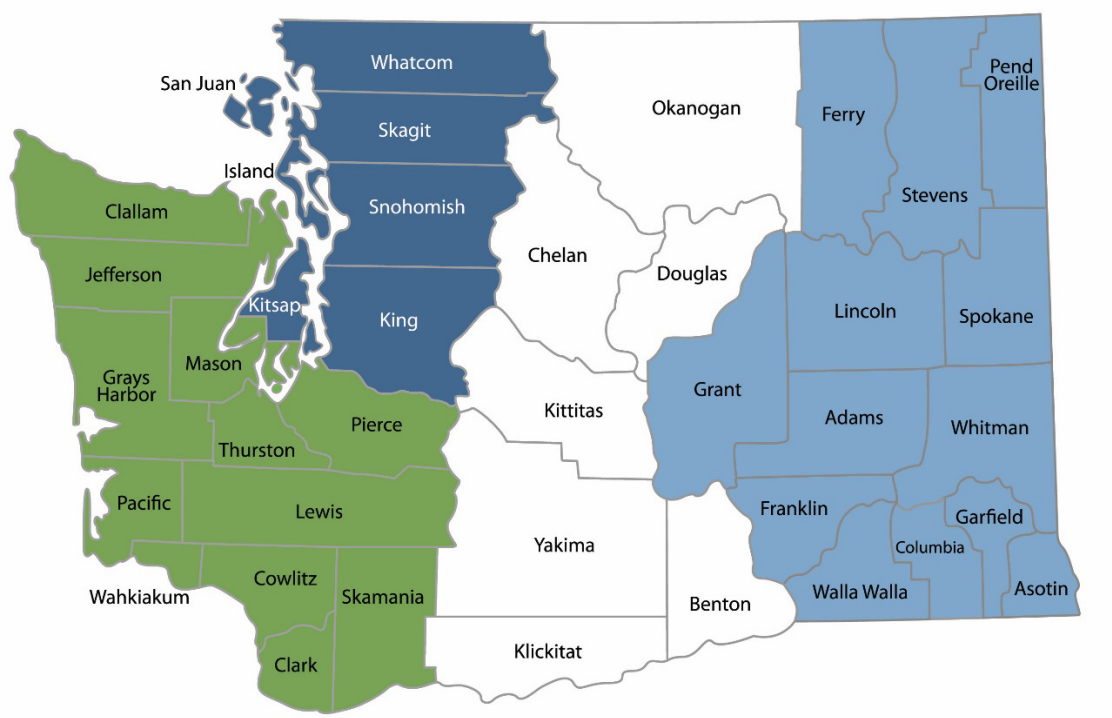
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Published July 2026

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2.0 Abstract

This study is intended to characterize pathogen transport and inactivation in groundwater to support evaluation of virus natural variability and transport processes under site-specific conditions. The scope of work focuses on establishing the existing viral profile as a baseline and determining the theoretical transport and inactivation of viruses using an analytical groundwater model that represents viral log-reduction rates in basalt aquifers.

The Washington State Department of Ecology's (ECY) Office of Columbia River is conducting this study in collaboration with Washington State Department of Health (DOH), since both have regulatory authority for groundwater quality protection, but differ on pathogen regulation for water used for domestic supply. To inform coordination of the regulatory requirements for groundwater protection and simplifying permitting for Aquifer Storage and Recovery (ASR) projects, the project deliverables define the minimum buffer (time and distance) between recharge injections to stored groundwater extraction to achieve virus inactivation adequate to protect public health consistent with the federal Safe Drinking Water Act pathogen treatment criteria.

In Columbia River basin basalt aquifers, ASR is conducted by injecting surface water originally sourced from the Columbia River into basalt aquifers, but water quality criteria for ASR permitting processes that protect public health, need appropriate site-specific storage times and distances for injected surface water expected to achieve $\log_{10}$ (4) removal. The virus inactivation risks related to ASR and the influence by natural processes are not yet well understood in basalt aquifers. Phase 1 Objective is to characterize virus inactivation rates in basalt aquifers to support development of standardized criteria for regulation of current and future ASR projects. We will be collecting water samples and biological measurements from surface and groundwater locations using an ASR project in Othello, Washington. The Phase 2 Objective is to predict viral transport and inactivation rates in basalt aquifers by using model simulations with site specific parameters.

This Quality Assurance Project Plan (QAPP) describes Phase 1: Sampling methods, data quality procedures, study design, and other field and laboratory project details for the study. Not included in this QAPP are Phase 2: Modeling and future work of in situ measurement of viral transport and recovery that is anticipated to be based on Phase 1.

3.0 Background

3.1 Introduction and problem statement

3.1.1 Problem Statement

For Aquifer Storage and Recovery (ASR), the State of Washington seeks to characterize the existing microbiological profile of organisms (viral, bacteria and protozoan communities) in the groundwater of Columbia River basalt aquifers and the surface water of Columbia Basin Project irrigation canals. Monthly water sampling from surface water supply, injection wells, and surrounding drinking water wells is needed to determine the spatiotemporal variability of native virus profiles relative to microbial and environmental groundwater quality. A native virus characterization is needed to establish a virus inactivation baseline, relative to the log-4 virus inactivation benchmark, required for permitting ASR projects consistent with state and federal guidelines.

3.1.2 Introduction

The goal of this project is to characterize pathogen transport and inactivation in groundwater during Aquifer Storage and Recovery (ASR) processes. The objective is to collect information about aquifer treatment processes to characterize existing microorganisms since pathogen transport can be a major health concern and define the time and distance of physical process transport that ensures public health is protected. This QAPP covers the first phase of the investigation. In Phase 1 we characterize existing virus populations to determine viral log-reduction inactivation rates in basalt aquifers. In Phase 2, we predict viral transport and inactivation rates in basalt aquifers using model simulations. In future work, based on project outcomes, we anticipate in situ measurement of viral transport and recovery based on lab defined and model predicted viral transport and deactivation. Results and analysis are intended to inform coordination of the regulatory requirements for groundwater protection and simplify permitting for ASR projects that utilize surface water injection and support development of a standardized criteria for regulation of current and future projects.

3.1.2.1 Aquifer Storage and Recovery (ASR)

ASR involves injecting water into an aquifer with the intention of storage and later recovery by extraction from the same (ASR) or nearby wells (Aquifer Storage and Transfer Recovery (ASTR)). An additional benefit is recharge of groundwater by diverting surface water to stabilize groundwater levels. ASR requires permitting, water treatment, and careful monitoring. Requirements increase if a project uses or impacts a groundwater well that is the source for drinking water and domestic supply. Differences in risk management are related to the well-known processes of water treatment that take place naturally when water infiltrates from the surface to recharge the aquifer (Mumberg et al., 2024). It is less well known, especially given the range of new chemicals and biological entities (e.g. coronaviruses), how natural processes provide water treatment to surface water that is injected directly into the aquifer. What are the ASR standards that need to be in place to protect human health? Should water treatment be required twice? before ASR injection and after ASR extraction? A risk-based regulatory

framework accounting for groundwater quality changes and use of advanced monitoring methods is required to support confidence in ASR project sustainability (Zheng, et al., 2022). The purpose of this project is to investigate the potential for viruses to be present in an aquifer after ASR.

3.1.2.2 Virus Ecology in Basalt Aquifers

In the United States, 2015-2020, drinking water associated outbreaks associated with septic and other (urban or stormwater) waste systems were most caused by biofilm-related Legionella bacteria (86%) and the most common water source was groundwater (38%) (Kunz, 2024). We do not know of any drinking water associated outbreaks or virus risk studies related to ASR using rural surface water sources (e.g. Columbia River and irrigation canal diversions). There are two main drivers for drinking water vulnerability related to groundwater and human health: pathogen source and transport processes (Hunt and Johnson, 2016). Mediating factors to the risk of outbreak include that not all virus species present in surface and groundwater are pathogenic or harmful to humans, and groundwater well drinking water is known to have natural protections via pore-scale transport and temperature dependent die off. Enteric viruses are the most likely human pathogens to contaminate groundwater since their extremely small size (25 to 100 nm) allows them to infiltrate soils and move through aquifers, with even an log10 (8) reduction in virus concentration during transport could still result in infectious virus present in potable groundwater (Borchardt et al., 2003), depending on transport distance and time, with mean viral inactivation rates ranging from 0.07−0.1 log10 day-1 for sandy, loamy and saturated soil conditions (Blanc and Nasser, 1996; Sjogren, 1994). Because the presence of soil substrates reveals more rapid inactivation (John and Rose, 200), we would expect higher risks or less inactivation in basalt interflow zones.

3.1.2.3 Mechanisms of Virus Transport

Viral transport and mobility is accelerated by continuous water flow and restricted through complex interactions at the air–water interface, capillary forces, and adhesion to mineral surfaces – which underscores the need for refined predictive models that account for virus-specific interactions under variable saturated and unsaturated conditions (Jat Bolach et al., 2026), but much of the data still needs to be determined on a site-by-site basis (Toze, 2004). We do not know of any studies on river water transported via irrigation canals that are injected into groundwater with basalt aquifer properties. Beyond the natural filtration processes that provide treatment of groundwater, regulations are in place to further protect the public from contaminants and disinfection byproducts in drinking water (Lee et al., 2000). State regulations for ASR, as well as federal and state regulations for drinking water are outlined in Section 3.2.4 of this QAPP.

Characterization of existing virus populations is useful for identifying suitable proxy indicators of virus presence or absence to determine the source of the virus, either in situ groundwater or surface water injection. Assessing the risk of viruses in groundwater aquifers is complicated by several factors: (i) labor-intensive methods for isolation and quantification of viruses in groundwater, (ii) temporal variability of viruses in water, and (iii) potential rapid transport (Race et al., 2024). Research on the incidence of viruses in groundwater reveals that viruses

can persist and be transported for considerable distances and over prolonged periods, with factors like aquifer type (fractured, e.g. basalt vs. porous media, e.g. sand) and groundwater storage conditions shaping their fate and attenuation patterns (Masciopinto et al., 2008).

The incidence of contamination of groundwater in public water systems and private household wells used for drinking water is of concern when located near wastewater treatment effluent or septic system infiltration (Borchardt et al., 2003), but guidance for managing the risk of groundwater contamination by injecting surface water from rivers, streams and canals is not clear. Accurate quantification of site-specific sub-surface treatment processes in Columbia River Basalts is required to ensure Aquifer Recharge, Storage and Recovery (ASR) permit conditions protect public health and are consistent with the Safe Drinking Water Act pathogen treatment criteria. This project is funded by the Washington State Department of Ecology's Office of Columbia River for the characterization of viral transport and virus inactivation in ASR systems by defining the minimum buffer (time and distance) between recharge injection to stored groundwater extraction to achieve virus inactivation adequate to protect public health.

3.1.2.4 Virus mobility and inactivation

The fate and transport of viruses in groundwater are controlled by physical characteristics of both the virus and the aquifer media. Signature virus characteristics include size (Figure 1. a) Separation of microorganisms by size with soil types classified based on grain size. Figure from Rusiñol, 2024). b) Isoelectric points (IEP) of waterborne pathogenic viruses with enteroviruses ranging from 4.8 to 6.8. (figure from Rusiñol, 2024 with data from Michen and Graule, 2010; Zhao et al., 2022; Heffron and Mayer, 2021; Gutierrez et al., 2009)., inactivation rate, and electrostatic properties that controls sorption (adsorption binds virus to the unsaturated media; absorption controls movement though the saturated media).

Signature aquifer properties include transmissivity, porosity, solid organic carbon content, temperature, pH (Figure 1. a) Separation of microorganisms by size with soil types classified based on grain size. Figure from Rusiñol, 2024). b) Isoelectric points (IEP) of waterborne pathogenic viruses with enteroviruses ranging from 4.8 to 6.8. (figure from Rusiñol, 2024 with data from Michen and Graule, 2010; Zhao et al., 2022; Heffron and Mayer, 2021; Gutierrez et al., 2009).), and mineral composition. Viruses possess a pH-dependent electrostatic surface charge, in water (which is polarized) this affects the mobility and sorption of viral particles. Plant, bacteria and animal viruses are found in pH range from 1.9 to 8.4; most frequently, they are measured in a band of $3.5 < IEP^2 < 7$ (Michen and Graule, 2010).

For another example, viruses are more mobile in aquifers than *Cryptosporidium*, with is about 100 times larger than viruses. Viral load in the water will be a function of source load, level of inactivation, physical removal and dilution. Soil composition and structure or the porous media will influence removal. Flow paths will affect transport. Microbiological activity will affect infectivity/viability. Lower temperatures (below 10°C) can allow viruses to survive for months or

[2] IEP: the isoelectric point is the pH at which a particle (here, a virus) has no net electrical charge at its surface. At pH values below the IEP, the viral surface is net positively charged; above the IEP, it is net negatively charged.

even years, while higher temperatures (above 20°C) promote rapid inactivation. Robertson and Edberg (1997) report virus transport to depths as far as 70 m below ground surface and horizontal migration as far as 400 m in glacial till and 1,600 m in fractured limestone with typical inactivation rate half-lives ranging from a few hours to a few weeks.

Gitter et al., (2024) used a quantitative microbial risk assessment (QMRA) to determine the risk of developing a gastrointestinal infection from various pathogens (viruses and *Cryptosporidium*) at 72 days of storage time of recharged water than enhanced pathogen inactivation.

Their findings emphasize that consideration of microbial inactivation, caused by storage time and environmental conditions within ASR storage zones, is critical for recharge water treatment processes. Gitter et al., (2024) further found that the value of imposing drinking water regulations for pre-treatment before injection into the aquifer, remains arguable. Inactivation rates were reported as 4 $\log_{10}$ reductions (1×10^{-4}) by days 31, 1, 52 and 80 for *Escherichia coli*, *Pseudomonas aeruginosa*, poliovirus type 1 and *Cryptosporidium parvum* in non-potable aquifer zones in geologic formations with fine-grained and frequently fractured limestone (hydraulic conductivities ranged between 1.5–15.2 m/day and 24.4–1524 m/day).

Ogorzaly et al., 2010 estimated how long enteric virus particles survive, and genetic (DNA or RNA) markers persist in an aquifer, and found indigenous microorganism activities and temperature to be the most important variables influencing viral stability. For predictive modeling, regression analysis was used to model the survival of each virus as a function of time. Simple linear regression models were fitted to experimental data to estimate T_{90} (predicted number of days to achieve a 1-$\log_{10}$ reduction) reduction times. Shown in Equation 1, the survival function characterizing each virus under the given experimental conditions (i.e., temperature fixed at 4°C or 20°C) was modeled as

$$\log_{10}\left(\frac{Q_t}{Q_0}\right) = at$$

where:

Q_t (Q_0) = viral density at time t (respectively 0), expressed in days,

a = first order rate constant describing how fast the viral density changes over time (t) (per day).

Results showed the reduction reached more than 5 $\log_{10}$ (virus removal) in 7 days at 20°C for infectivity and up to 35 days for detectability.

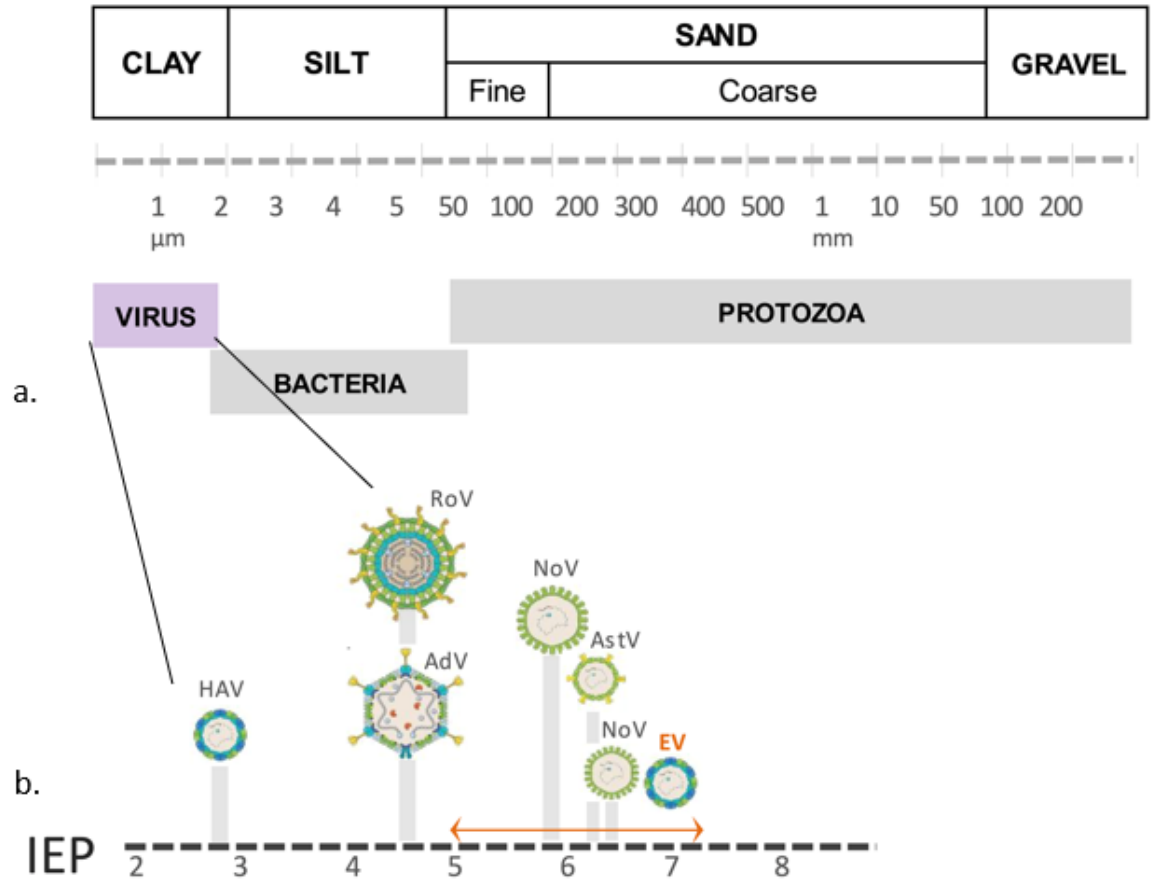


Figure 1. a) Separation of microorganisms by size with soil types classified based on grain size. b) Isoelectric points (IEP) of waterborne pathogenic viruses with enteroviruses.

Notes: b) ranging from 4.8 to 6.8. (figure from Rusiñol, 2024 with data from Michen and Graule, 2010; Zhao et al., 2022; Heffron and Mayer, 2021; Gutierrez et al., 2009).

3.1.2.5 Basalt Aquifer Characteristics

Columbia River Basalt lava flows of basaltic and basic andesitic composition that form the primary water source for the semiarid Columbia Plateau, a regional aquifer system of 150,000 square kilometers in Washington, Oregon, and Idaho (Newcomb, 1961; Figure 2) extending between the Selkirk Mountains and the Cascades Mountains. Portions of the aquifer system have seen significant water-level declines and do not receive significant, if any, natural recharge (Porcello et al., 2009). These aquifers have unique hydraulic properties with low vertical hydraulic conductivity that restrict vertical movement, and higher lateral permeability with water transmitted horizontally through interflow zones and fractures. The central part of the Columbia Basin basalt is more than 5,000 feet thick, with individual lava flows ranging from 5 to 150 feet. The average lava flow is 50 feet thick with dense partly fractured rock at the base, massive columnar-jointed rock in the center, and rubbly rock at the top, fractures cut the rock into irregular blocks that formed with the lava was cooling. Primarily, ground water moves

through the basalt rock in the permeable zones at the top and the base of some flows which are about 3 to 10 feet thick (Kahle et al., 2009).

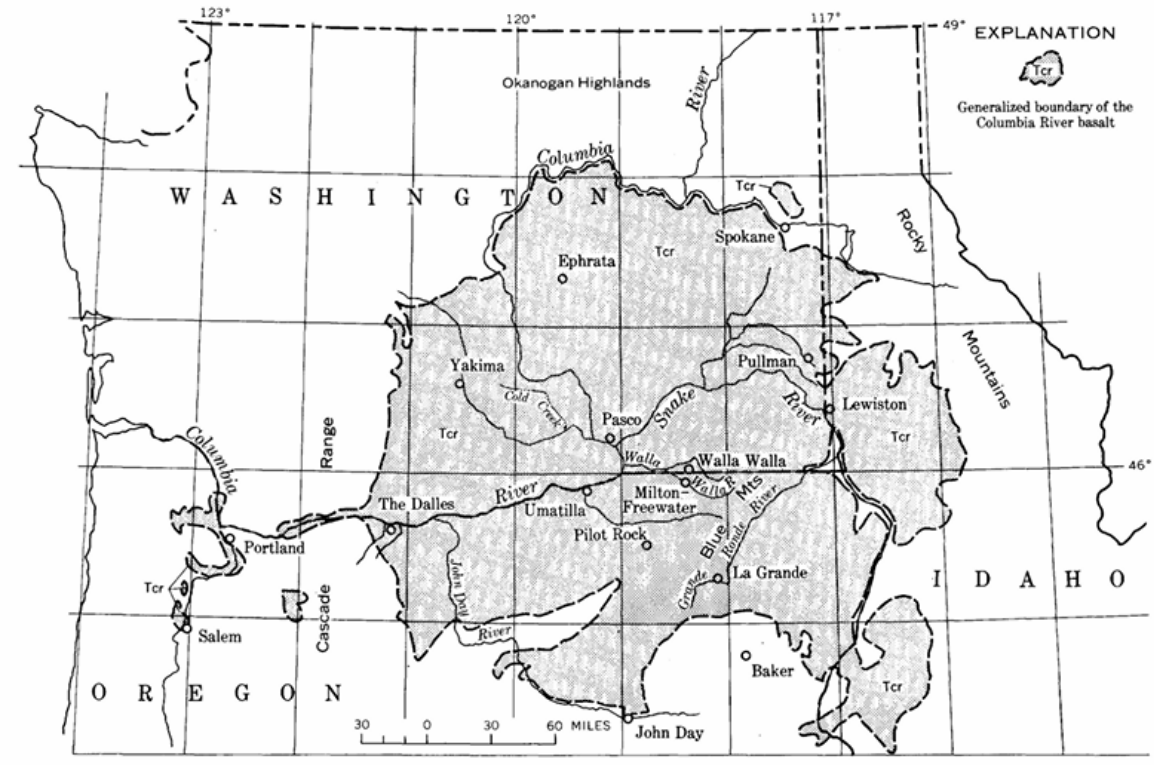


Figure 2. Map showing the main area underlain by the Columbia River basalt, Washington, Oregon, and Idaho (Figure from Newcomb (1961)).

3.1.2.6 Studies from other aquifer types

In a study of RNA transport in coarse alluvial gravel aquifers, Pang et al. (2005) found that every one-log reduction in microbial concentration in groundwater requires a few tens of meters of travel in clean coarse gravel aquifers, but a few hundreds of meters in contaminated coarse gravel aquifers. In contrast, a one-log reduction generally only requires a few meters of travel in sandy fine gravel aquifers and sand aquifers. Recommended setback distances for a worst-case scenario based on the results of this study, for a $\log_{10}$ (7) reduction, would require 125-280 m travel in clean coarse gravel aquifers, 1.7-3.9 km travel in contaminated coarse gravel aquifers, 33-61 m travel in clean sandy fine gravel aquifers, 33-129 m travel in contaminated sandy fine gravel aquifers, and 37-44 m travel in contaminated river and coastal sand aquifers.

They recommended methods that consider aquifer heterogeneities and site-specific conditions in calculating aquifer filtration factors and setback distances (note: worst case scenario is defined as injection of raw effluent into a saturated zone of an aquifer.). Hijnen et al. (2005) studied removal of phages, bacteria, bacterial spores, and protozoan (oo)-cysts at two velocities in fine sandy soils and gravel soils. Attachment was the most important process in overall virus (MS2) removal. For two soil types at two velocities, the attachment rate

coefficient (k_{att}) was estimated to be 4 times higher than the k_{att} estimated for the higher pH soil column (pH 8 vs pH 8.73) operated at the same velocity.

3.1.2.7 Project Overview

The methods used in this project rely on long-term flow characterization by identifying unique viral markers present exclusively in surface water and absent in groundwater for multiple wells within a representative study area. The approach of collecting seasonal water sample data allows characterization of each well, providing valuable data to inform our model about surface and groundwater sources of total viral load, seasonal changes, inactivation and transport. The analytical model experiment design requires a minimum configuration of one control well, one injection well, and three downstream wells arranged in a curtain formation to effectively analyze the groundwater flow. Through the synthesis of field observations, laboratory analyses, and analytical results, the project provides evidence-based methods for determining the processes present in Columbia River Basalt aquifers that affect viral transport and viability.

The project sampling plan is designed to better understand the native virus populations in surface water sources used for groundwater recharge in basalt aquifer ASR projects. Thorough characterization of native viral pathogens in groundwater and surface source water establishes a baseline for environmental conditions, facilitating more effective water quality monitoring and total viral load management. Virus inactivation in soil-groundwater systems is influenced by multiple factors, including aquifer storage residence time, travel distance, geological and environmental characteristics. A comprehensive understanding of these factors is crucial for developing robust ASR policies and regulations that safeguard public health and ensure the sustainable use of groundwater resources.

Phase 1 project deliverables include 1) design process for field and laboratory methods to determine variability of microbiological communities naturally occurring at injection and at downgradient water supply wells for a proposed ASR project, 2) bacteria, *Cryptosporidium*, giardia, and virus profile metagenomic characterization, 3) risk factors with environmental variability will be used in a risk assessment useful for integration with Phase 2 modeling, 4) identify a marker and develop a recommendation for Phase 3 tasks.

The risk assessment (RA) framework is a systematic approach to identify, analyze and incorporate knowledge about multiple aspects of risk, which will be used to quantify and rank identified risks based on likelihood and confidence levels. We are not assessing exposure to human populations in Phases 1 or 2 (Note: Risk = hazard * exposure).

Our risk assessment focuses on prediction accuracy and hazard identification, to determine with 95% confidence the likelihood of a 99.99% (log4) reduction in virus presence under a specific ASR plan. In the field study, we will have outcomes to provide information on sampling efficiency using the data streams (outlined in Section 14: Risk Assessment) to develop a series of sampling risk factors but does not include model sensitivity analysis (described in Phase 2 QAPP: Characterization of in situ virus transport and inactivation in the groundwater of Columbia River basalt aquifers: Modeling). In general, this will be accomplished using a series of

nested field and laboratory data output (e.g. native viral population diversity, total bacteria load) to allow us to understand individual contributions to certainty and uncertainty of our project risk values. We want to define the environmental conditions and associated risk factors to identify and define potential hazards of pathogen contamination in basalt ASR projects.

This study is intended to define the relative differences in processes affecting virus levels in groundwater before and after surface water is injected into a basalt aquifer, such that future policies can be developed to ensure stable groundwater and drinking water quantity and quality.

3.2 Study area and surroundings

The study will be conducted in the City of Othello, located in Adams County, southeastern Washington, centrally located in the mid region of the Columbia Basin (Figure 3). The climate is arid, with little to no groundwater recharge. The major geologic characteristics are basalt flows and coulees, and topographic signatures from Drumheller Channels and the Columbia Plateau. Largely due to the Columbia Basin Project adding water to the system and creating this type of habitat, hydrologic features of the area include marshes, lakes, Crab Creek, and irrigation canals, with unique scabland landforms, shrub-steppe and wetlands ecosystems supporting waterfowl and Sandhill Cranes. The area serves a key ecological function as a wildfowl migration stopover. Human uses include irrigated agriculture, recreation, industrial, and municipal water users.

Groundwater testing will occur in wells owned by the City of Othello and McCain Foods, within the city and surrounding commercial agricultural areas. Sampling locations include eight (8) owned by City of Othello (Figure 4; red circles and green circle (ASR feasibility study injection well, 2020)), three groundwater sampling locations owned by McCain Foods (Figure 4; orange circles), and two surface water canal locations (Figure 4; blue square identifies sampling location within City of Othello). Not shown in Figure 4 is the off-site surface water diversion north of the East Low Canal at the Columbia River.

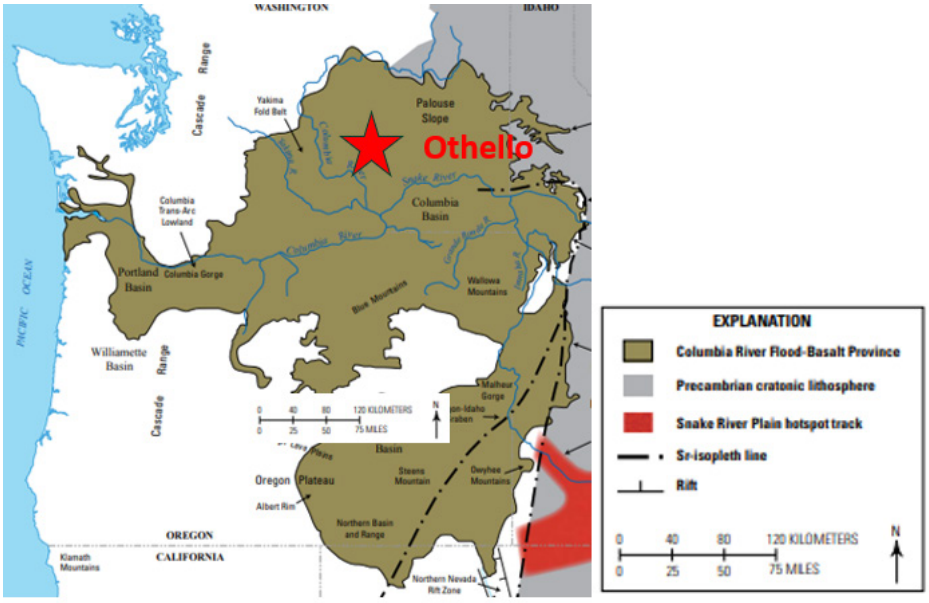
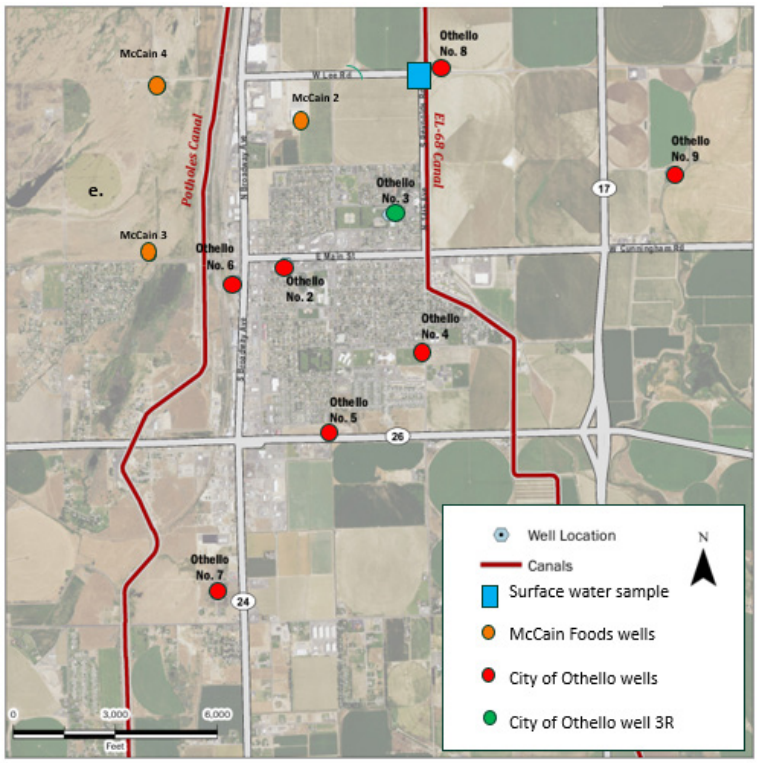


Figure 3. Map of the distribution of the Columbia River flood-basalt province that extends across eastern Washington and Oregon.

Notes: Basalt aquifers in the Columbia province are deep, and confined, with little to no annual natural recharge. Global and local food supply depend on these critical water resources for domestic, industrial and irrigation groundwater supply. Surface water from the region contributes to the Columbia River which drains west to the Pacific Ocean. (Figure modified from Camp et al., 2017).

a. 

b. 

Figure 4. a) City of Othello sampling well locations (red) and sampling locations; b) city drinking water .

Notes: a) Orange dots are owned by McCain foods. The green dot is the site of an ASR injection in 2020 and the location of the (b) city drinking water supply held in the tank near the City of Othello Well 3R shown on the right.

3.2.1 History of study area

3.2.1.1 Distant history

The Columbia Plateau regional aquifer system extends across southeastern Washington, between the Cascades Mountains and Selkirk Mountains (occupies about 50,600 square miles and extends across a small part of northern Idaho, northeastern Oregon). According to the USGS Groundwater Atlas (Whitehead, 1994) during 1984, about 3,500 wells were pumped to irrigate about 500,000 acres on the Columbia Plateau, while the Columbia Basin Irrigation Project diverts about 1.6-million-acre feet of Columbia River water to irrigate 700,000 acres annually. Figure 5 shows that groundwater flow through the Miocene basaltic-rock aquifers generally is toward the Columbia River from recharge areas near the boundaries of the plateau. Groundwater moves through the confining units that separate the aquifers but at a slower rate than through the aquifers (Whitehead, 1994, Figure 73; Lindholm and Vaccaro, 1988). The Wanapum Basalt accounts for about 5% of the total Columbia River Basalt volume. Basalt flows were emplaced 16.1 and 15.9 million years ago, from enormous fissure eruptions in the Miocene epoch. As the lava cooled and solidified, it formed the thick, columnar basalt flows typical of the Columbia Plateau (Figure 6) where the individual flows are distinguishable in six

formations (Figure 7): Imnaha Basalt, Picture Gorge Basalt, Prineville Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt (Swanson, 1979; Reidel et al., 2022). Beneath the unconsolidated sediments on the surface near Othello (Figure 8), groundwater aquifers formed within the permeable zones between the dense columnar flows. Figure 9 shows the location of groundwater wells that access the aquifer in the Wanapum layers below Othello.

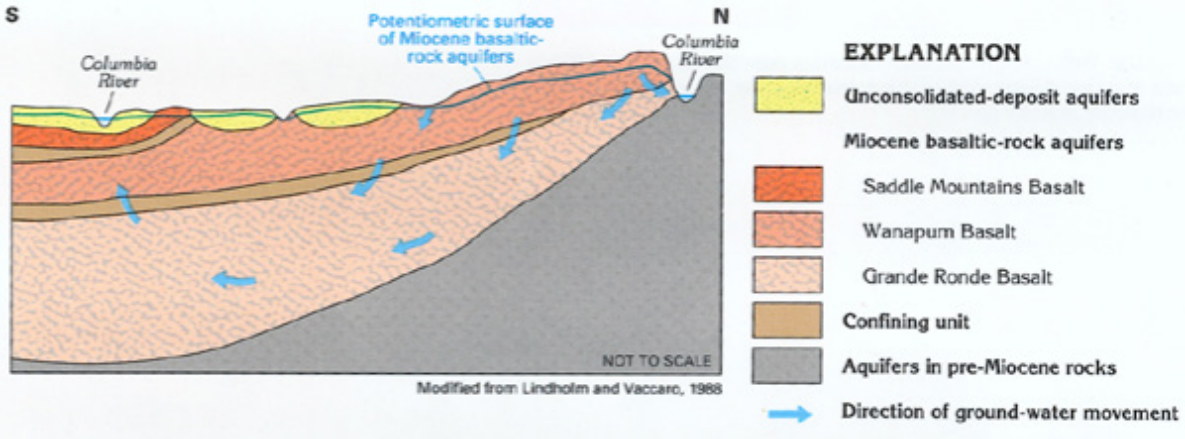
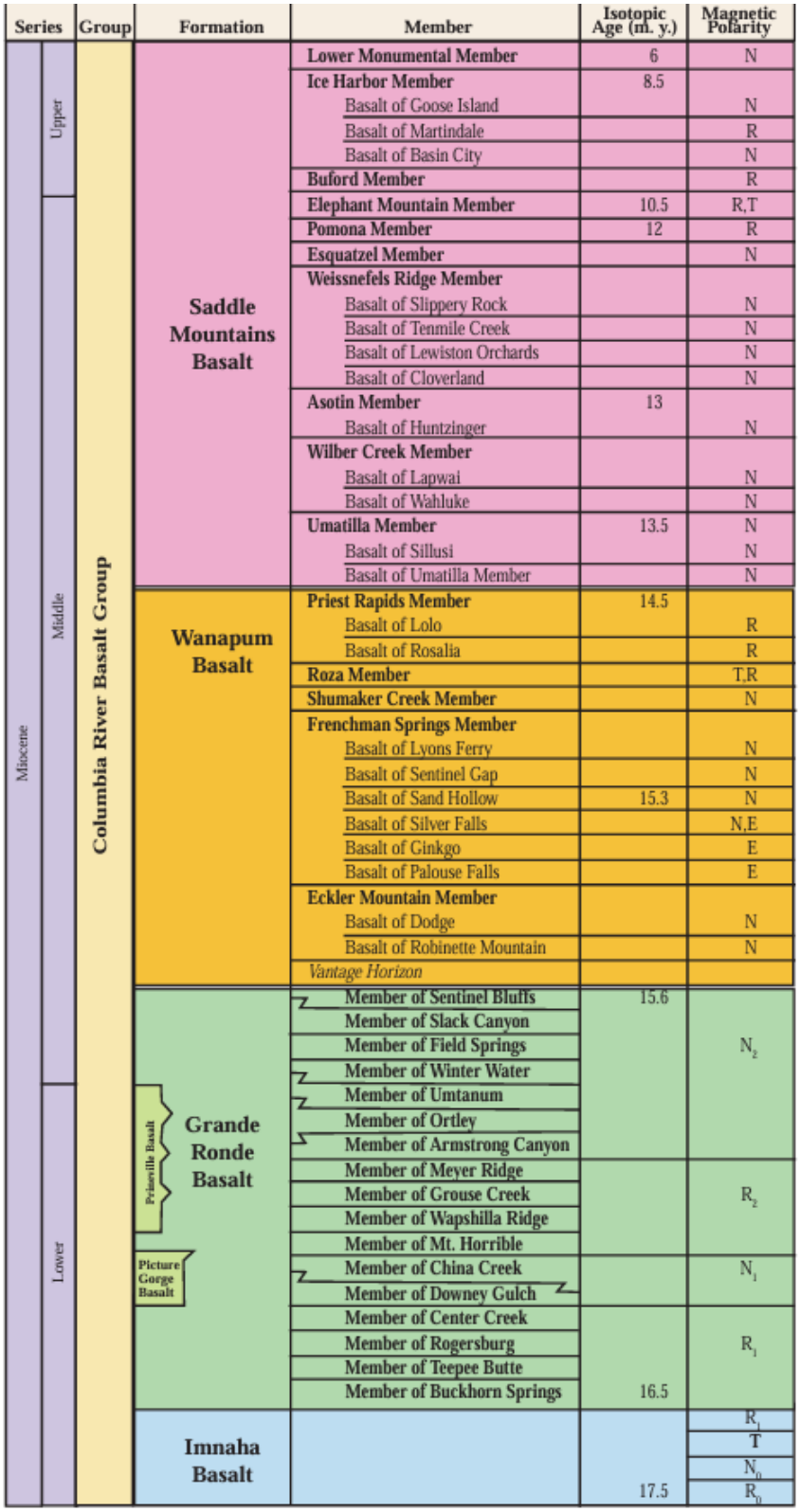


Figure 5. A generalized section of the northwestern part of the Columbia Plateau.
(Linholm and Vaccaro, 1988).



Figure 6. Photo of Drumheller Basalt layer exposed at the surface.
(Photo by Tom Foster; https:/hugefloods.com).



Series	Group	Formation	Member	Isotopic Age (m. y.)	Magnetic Polarity
Miocene, Upper	Columbia River Basalt Group	Saddle Mountains Basalt	Lower Monumental Member	6	N
			Ice Harbor Member	8.5	
			Basalt of Goose Island		N
			Basalt of Martindale		R
			Basalt of Basin City		N
			Buford Member		R
			Elephant Mountain Member	10.5	R,T
			Pomona Member	12	R
			Esquatzel Member		N
			Weissnefels Ridge Member		
			Basalt of Slippery Rock		N
			Basalt of Tenmile Creek		N
			Basalt of Lewiston Orchards		N
			Basalt of Cloverland		N
			Asotin Member	13	
			Basalt of Huntzinger		N
			Wilber Creek Member		
			Basalt of Lapwai		N
			Basalt of Wahluke		N
			Umatilla Member	13.5	N
			Basalt of Sillusi		N
			Basalt of Umatilla Member		N
Miocene, Middle		Wanapum Basalt	Priest Rapids Member	14.5	
			Basalt of Lolo		R
			Basalt of Rosalia		R
			Roza Member		T,R
			Shumaker Creek Member		N
			Frenchman Springs Member		
			Basalt of Lyons Ferry		N
			Basalt of Sentinel Gap		N
			Basalt of Sand Hollow	15.3	N
			Basalt of Silver Falls		N,E
			Basalt of Ginkgo		E
			Basalt of Palouse Falls		E
			Eckler Mountain Member		
			Basalt of Dodge		N
			Basalt of Robinette Mountain		N
			Vantage Horizon		
Miocene, Lower		Grande Ronde Basalt (Priest Rapids Basalt)	Member of Sentinel Bluffs	15.6	N_2
			Member of Slack Canyon		
			Member of Field Springs		
			Member of Winter Water		
			Member of Umtanum		
			Member of Ortley		
			Member of Armstrong Canyon		
			Member of Meyer Ridge		R_2
			Member of Grouse Creek		
			Member of Wapshilla Ridge		
			Member of Mt. Horrible		
		Picture Gorge Basalt	Member of China Creek		N_1
			Member of Downey Gulch		
			Member of Center Creek		R_1
			Member of Rogersburg		
			Member of Teepee Butte		
			Member of Buckhorn Springs	16.5	
		Imnaha Basalt		17.5	R_1 / T / N_0 / R_0

Figure 7. Columbia River Basalt Group Stratigraphy

Notes: By Swanson et al., 1979 and Reidel et al., 2022.

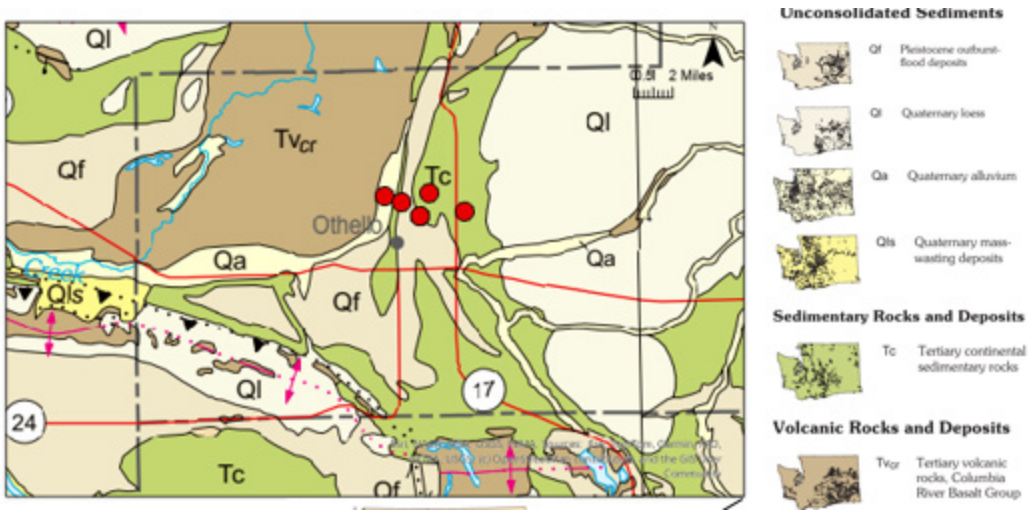


Figure 8. Surface area geology near Othello, WA with field sampling locations (red dots).
Notes: From the Southeast quadrant geologic map of Washington (Schuster et al., 1997).

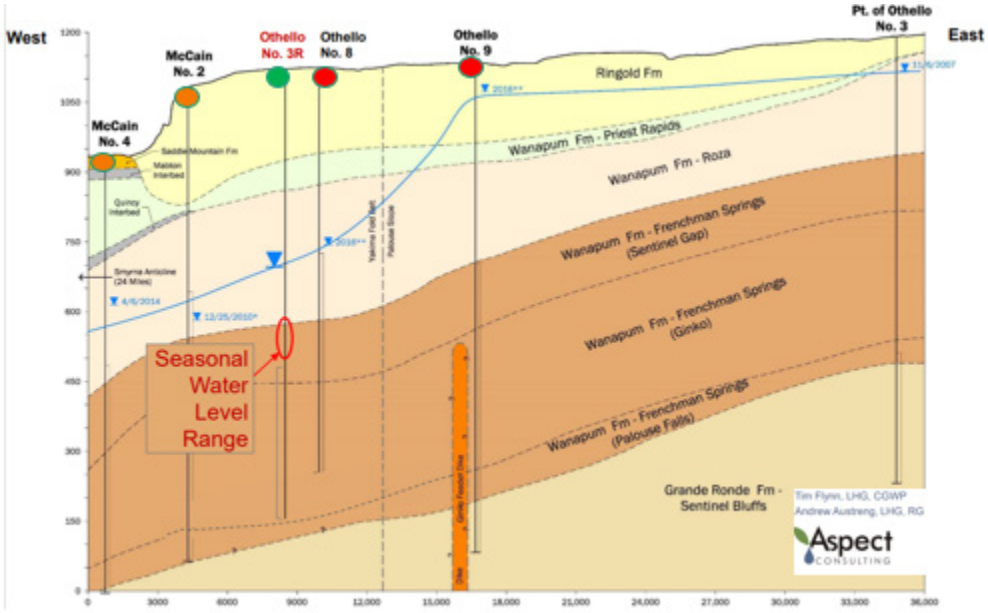


Figure 9. Horizontal view of local geology highlights well depths that source groundwater from the Wanapum layers. (Aspect Consulting, 2020)

3.2.1.2 Recent History

The City of Othello relies on groundwater supply from the Wanapum Basalt Aquifer. City wells have shown water level declines of approximately 300 feet since the 1960s construction. ASR has been explored since 2018 (Aspect, 2018, 2019, 2020) as a future water supply strategy. Within the project area, the Columbia Basin Irrigation Project canal system has allowed for irrigated agriculture based on surface water. . The city plans to utilize this surface water source to mitigate the rate of water level decline, since the demand is continuously increasing from

industrial food processors and residential users, and surface water is available from the Columbia Basin Irrigation Project (Figure 10).

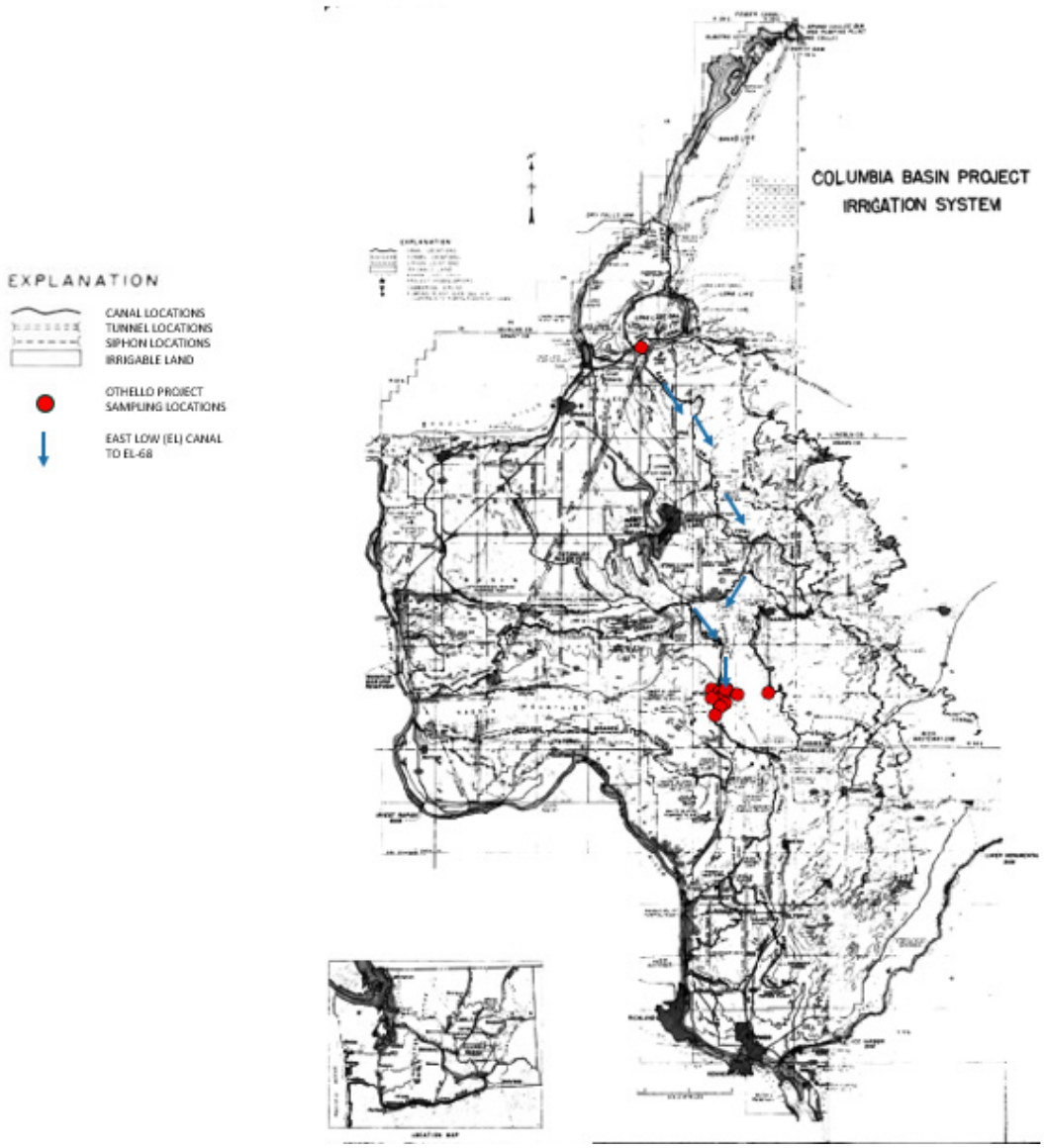


Figure 10. Regional map of Columbia Basin Project Irrigation System (circa 1960).

Notes: Surface water source in the north at the main canal (single red dot), direction of the East Low Canal connecting to the EL-68 Canal in Othello (blue arrows) and sampling wells in Othello (collection of red dots).

3.2.2 Summary of previous studies and existing data

The only available water supply source for the City of Othello is the Wanapum Basalt aquifer. As a component of the City's long-term water supply strategy, Othello is evaluating an ASR program that would offset declines in groundwater levels by augmenting groundwater recharge with a surface water source. The Groundwater Management Area (GWMA) committee identified ASR as a method to improve groundwater supplies within the GWMA of Adams, Franklin, Benton, and Grant Counties (GWMA, 2014).

The city completed an Aquifer Storage and Recovery Feasibility Study (Ecology Agreement #WROCR-VER1-Othell-00005), followed by a Phase I Pilot Test (Ecology Agreement #WROCR-2018-Othell-00003), followed by Phase II Pilot Testing (WROCR-VER1-00005). The study area has been characterized by several studies focused on water quality characterization (groundwater and canal water quality, cross-section development, and modeling (Aspect, 2018). The feasibility study includes a detailed reconnaissance of geology, hydrology, and water chemistry. The Phase 1 Pilot Test report (Aspect, 2020) also included estimated aquifer parameters, recharge, storage, and recovery of 106 acre-feet of chlorinated groundwater, and well performance. There is information from one irrigation season (July – September 2020) from surface water sampling for water quality of the EL-68 canal. Othello maintains a water level and flow database for their water supply wells.

3.2.3 Parameters of interest and potential sources

Parameters of interest are selected for evaluation of ASR program compliance with Washington State Groundwater Quality Standards (Chapter 173-200 Washington Administrative Code [WAC]) and Drinking Water Standards (Chapter 246-290 WAC).

Field Parameters

- Conductivity
- Oxidation-Reduction Potential (ORP)
- pH
- Temperature
- Dissolved Oxygen

Laboratory Viral and Parasite analysis

- RNA/DNA; Total nucleic acids of viral genome
- Cryptosporidium
- Giardia

Laboratory Bacteriological analysis

The following bacteria will be analyzed:

- E. coli
- Total coliforms
- Enterococci

3.2.4 Regulatory criteria or standards

Groundwater-supplied drinking water in Washington State is governed by a combination of federal and state regulations, implemented and enforced by the Washington State Department of Health (DOH) and Department of Ecology (ECY). DOH and ECY both have regulatory authorities for groundwater quality protection and the two governing systems are implemented through different authorizing laws with different regulatory approaches and requirements. Although both Water Quality and Drinking Water regulations rely on water quality defined by constituent concentrations, the public health protections for drinking water supply go farther to include treatment requirements for pathogen reduction.

ECY implements the ASR permitting process (Chapter 90.03 RCW) with standards for review established in Chapter 173-157 WAC. The permitting process is challenging, and requires applicants to provide documentation, including demonstration through actual and/or modeled hydrogeologic conditions, that they meet Ecology's permitting requirements for economic value, water rights, and ASR must not degrade groundwater quality in compliance with state water quality standards (Chapter 173-200 WAC).

DOH is the state agency responsible for ensuring compliance with federal regulations regulating drinking water established by the EPA by managing drinking water system operating permits based on system size and type (see Chapter 246-294 WAC). DOH does not have primary responsibility to oversee or approve ASR projects (Torpie et al., 2020) but does provide guidance that any ASR project in an aquifer used for drinking water supply must eventually satisfy public drinking water source requirements and concurrently satisfy all applicable sections of Chapter 246-290 WAC.

3.2.4.1 State regulations for Aquifer Storage and Recovery (ASR) and Groundwater Quality (ECY)

Chapter 90.03 RCW Water Code

This code fosters the improvement in the water supplies available to meet the needs of the state. The goal is to strengthen the state's economy while maintaining and improving the overall quality of the state's environment. [1997 c 360 s 1.] Since 1997, the State of Washington legislature has included artificial recharge of aquifers in the list of beneficial uses in the public interest. The impoundment of excess water and other measures that can be used to offset seasonal basis of water availability. For as ASR project to qualify for issuance of a reservoir permit, an underground geological formation must meet standards for review and mitigation of adverse impacts identified, for the following issues: (i) Aquifer vulnerability and hydraulic continuity; (ii) Potential impairment of existing water rights; (iii) Geotechnical impacts and aquifer boundaries and characteristics; (iv) Chemical compatibility of surface waters and groundwater; (v) Recharge and recovery treatment requirements; (vi) System operation; (vii) Water rights and ownership of water stored for recovery; and (viii) Environmental impacts.

RCW 90.03.005 describes how, based on the tenet of water law which precludes wasteful practices in the exercise of rights to the use of waters, the ECY "shall reduce these practices to

the maximum extent practicable, taking into account sound principles of water management, the benefits and costs of improved water use efficiency, and the most effective use of public and private funds, and, when appropriate, to work to that end in concert with the agencies of the United States and other public and private entities [1989 c 348 s 2; 1979 ex.s. c 216 s 8.]."

The only mention of 'virus' in Chapter 90.03 Water Code occurs in RCW 90.03.675 Stormwater retention ponds—Mosquito abatement and is limited to West Nile virus or other mosquito-borne human disease viruses in mosquitoes, last update 7/24/2024.

Chapter 173-157 WAC Underground artificial storage and recovery. This chapter is for any person or entity that intends to obtain a reservoir permit to develop an underground artificial storage and recovery project. **WAC 173-157-010** establishes the standards for review of applications for underground artificial storage and recovery projects and, when necessary, identify options for mitigation of potential adverse impacts to groundwater quality or the environment. The rule also outlines the process the department of ecology will use to evaluate applications, and issue permits to artificially store water in underground geological formations and subsequently recover it for beneficial use. [Statutory Authority: RCW 90.03.370 (2)(b) and 90.44.460. WSR 03-03-081 (Order 02-06), § 173-157-010, filed 1/15/03, effective 2/15/03.] **WAC 173-157-020**: In 2000, the Washington state legislature passed Engrossed Second Substitute House Bill 2867 (E2SHB 2867), which amended chapters 90.03 and 90.44 RCW. This bill expanded the definition of "reservoir" in RCW 90.03.370 to include "any naturally occurring underground geological formation where water is collected and stored for subsequent use as part of an underground artificial storage and recovery project."

There are no mentions of 'virus' in Chapter 173-157 WAC, last update 1/15/2003.

Chapter 173-200 WAC Water quality standards for groundwaters of the state of Washington. This chapter implements chapter 90.48 RCW, the Water Pollution Control Act and chapter 90.54 RCW, the Water Resources Act of 1971 and applies to all groundwaters of the state that occur in a saturated zone or stratum beneath the surface of land or below a surface water body. The goal of this chapter is to maintain the highest quality of the state's groundwaters and protect existing and future beneficial uses of the groundwater through the reduction or elimination of the discharge of contaminants to the state's groundwaters.

This chapter establishes groundwater quality standards which, together with the state's technology-based treatment requirements, provide for the protection of the environment and human health and protection of existing and future beneficial uses of groundwaters.

There are no mentions of 'virus' in Chapter 173-200, last update 10/31/1990.

3.2.4.2 State regulations protecting sources of drinking water (DOH)

Chapter 246-290 WAC group A public water supplies. The purpose of this chapter is to define basic regulatory requirements and to protect the health of consumers using public drinking water supplies. **WAC 246-290-310:** All microbial and chemical contaminants must meet Washington State drinking water standards (Wash. Admin. Code § 246-290-310). The

Washington Administrative Code (WAC) 246-290 governs drinking water standards for Group A public water systems (serving 25 or more people for 60+ days per year), including specific groundwater monitoring, contaminant limits, construction, and treatment standards. Group A systems must follow groundwater sampling protocols, including testing for microbiological and chemical contaminants (e.g., nitrate, arsenic, coliform bacteria) and submit Consumer Confidence Reports annually. **WAC 246-290-416**: if there is no total coliform or E. coli MCL violations since the last sanitary survey; there is no significant deficiency requiring additional sanitary survey, if the treatment provides at least 4-log treatment of viruses (using inactivation, removal, or a department-approved combination of 4-log inactivation and removal) before or at the first customer for all its groundwater sources. **WAC 246-290-300:** fecal contamination monitoring is required if contamination is present or suspected in the water system.

WAC 246-290 was last updated in 2026 that include requirements which take effect January 1, 2027. Virus treatment technique requirements specified in Part 6 of this chapter include 99.99 percent (4-log) removal and/or inactivation of viruses.

Water System Design Manual (WAC 331-123)

Other virus regulations that are related to ASR and drinking water can be found in the Water System Design Manual (WAC 331-123; Torpie et al., 2020): section 5.8 (New Surface Water Supplies); section 5.10.4 (Aquifer Storage and Recovery); chapter 10 (General treatment); chapter 11 (surface water treatment).

'Virus' is recognized as a primary drinking water contaminant which can affect human health with extensive requirements for 4-log virus inactivation described in Section 10.2.1.5 and Tables 10-1, 10-7, and Chapter 11, Appendix A and Appendix F.

3.2.4.3 Federal regulations that protect surface and groundwater sources of drinking water

Federal regulations that protect the public from contaminants and pathogens in drinking water include:

Safe Drinking Water Act (SDWA):

Safe Drinking Water Act (SDWA) is the primary federal law that ensures the quality of America's drinking water. All public water systems in the United States must meet all applicable SDWA requirements, including its implementing regulations (40 C.F.R. § 141) for chemical and microbial contaminants and pollutant discharges from a point source for surface water augmentation require a federal National Pollutant Discharge Elimination Systems (NPDES) permit (40 C.F.R. § 122). The United States Congress enacted the Safe Drinking Water Act (SDWA) in 1974, later amending and reauthorizing it in 1986 and 1996. Since 2019, the EPA has used the National Primary Drinking Water Regulations (NPDWR) as legally enforceable primary standards and treatment techniques that apply to public water systems. Primary standards and treatment techniques protect public health by limiting the levels of contaminants

in drinking water. EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to

1. Disinfect their water, and
2. Filter their water, or
3. Meet criteria for avoiding filtration so that contaminants are controlled at the following levels: Viruses: 99.99% removal/inactivation.

Ground Water Rule (GWR)

GWR establishes water quality regulations for public water systems that use groundwater to protect against illness caused by microbial pathogens, especially viruses and bacteria from fecal contamination. Systems determined to be “sensitive" (e.g., karst, gravel, or fractured bedrock aquifers) may require additional monitoring.

- If a groundwater system is at risk or contaminated, it must use disinfection or another process to reliably achieve $\log_{10}(4)$(99.99%) inactivation or removal of viruses.
- Compliance monitoring is required to ensure that any installed treatment technology meets this virus inactivation or removal standard.
- Systems not treating for at least 99.99% ($\log_{10}(4)$) virus inactivation/removal are required to conduct "triggered" monitoring of the source water whenever there is a positive total coliform result in routine distribution sampling (or as otherwise directed by the state).
- Systems using treatment technologies to meet the rule must conduct compliance monitoring to prove that $\log_{10}(4)$virus reduction is reliably achieved.

The federal Ground Water Rule (GWR) was signed by EPA leadership and published in the federal register in 2006.

Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)

The Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) is a federal regulation that strengthens protection against microbial contaminants (especially *Cryptosporidium*) in public water systems using surface water or groundwater under the direct influence of surface water (GWUDI). Public Water Supply Systems must conduct regular source water monitoring for *Cryptosporidium*. The frequency and duration depend on system size and risk classification. Systems are then assigned a "bin" level (1-4) based on observed *Cryptosporidium* concentrations.

- Unfiltered systems must enhance disinfection processes to ensure at least a $\log_{10}(2)$ (99%) inactivation/removal of *Cryptosporidium*.
- Covered finished water reservoirs are required, or systems must treat discharges from uncovered reservoirs to achieve at least $\log_{10}(4)$ virus removal/inactivation before distribution.
- A second round of source water sampling is required after initial compliance, to determine if treatment requirements need adjustment over time.

The LT2ESWTR was established by the EPA in 2003 to protect vulnerable surface water supplies based on sampling.

Revised Total Coliform Rule and Total Coliform Rule (RTCR)

Total coliforms are a group of related bacteria that are (with few exceptions) not harmful to humans. A variety of bacteria, parasites, and viruses, known as pathogens, can potentially cause health problems if humans ingest them. Last updated in 2014, EPA considers total coliforms a useful indicator of other pathogens for drinking water. Total coliforms are used to determine the adequacy of water treatment and the integrity of the distribution system.

3.3 Water quality impairment studies

Not applicable. Not in the project scope.

3.4 Effectiveness monitoring studies

Not applicable. Not in the project scope.

4.0 Project Description

4.1 Project Goals

This study is being conducted to collect additional hydrogeologic, surface and groundwater quality data to characterize endemic, established resident virus populations. This information will be used for public health related to both drinking water regulations and aquifer storage and recovery (ASR) permit applications. Field work will collect water quality samples from surface and groundwater locations over multiple seasons in a case study at a proposed ASR project in Othello, WA. Laboratory analysis of virus data will provide a metagenomic characterization of native viral populations. Baseline viral data will be evaluated to determine whether source surface water, injection well water, and surrounding groundwater wells are at risk of contamination based on transport and virus inactivation rates unique to Wanapum basalt in Columbia River aquifers. As part of risk assessment, additional samples will be analyzed for regulatory compliance with drinking water microbiological standards for bacteria, *Cryptosporidium* and giardia. Project data will be used in an analytical groundwater transport model and guide the scope of future virus studies in ASR feasibility and pilot testing efforts.

4.2 Project objectives

Objective 1 -- Conduct water quality sampling for site-specific native virus, with standard environmental and microbial organisms' characterization, within a risk assessment framework.

Objective 2 -- Characterize viral profiles of surface and groundwater in a Columbia River Wanapum basalt aquifer.

Objective 3 -- Evaluate variations in relative quantification of virus, bacteria and protozoa (*Cryptosporidium* and giardia) and environmental conditions between well sites in Othello, WA.

Objective 4 -- Identify a non-pathogenic marker and develop a recommendation for use in future studies.

4.3 Information needed and sources

Data collected from a range of wells prior to any aquifer recharge, and after storage at injection well to evaluate any impacts to the aquifer or differences between wells. This information will be collected as new data during this project. Water quality data is also required to characterize aquifer conditions influencing water levels, pathogen, bacteria and virus transport, inactivation, sorption and degradation.

We will use existing specific information about geology and well characteristics and past water quality data at locations in the City of Othello as part of past wellfield operations, past ASR studies (Aspect, 2017 and 2020), and well log data provided by the Department of Ecology.

GIS layers include:

- Well locations
- Surface water sampling locations
- Geology

4.4 Tasks required

4.4.1 Task 1: Water Quality Sampling and Laboratory Analysis

Collect non-potable water quality samples to characterize viruses, bacteria, other pathogens and environmental properties at surface water and groundwater well locations over multiple seasons. This project involves coordination with City of Othello, McCain Foods, Ecology and DOH. Although groundwater samples are taken from regulated drinking water wells, the samples will be collected before treatment and therefore considered non-potable samples.

Task 1.1 Viral profile: This task includes collecting up to 144 virus samples. For groundwater samples, there are eight well locations over 7 months with duplicate samples (2), for a total of 112 groundwater samples. For surface water, there are 2 locations over 5 months with duplicates (2), for a total of 22 surface water samples. Twelve (12) samples will be used for QA.

Task 1.2 Bacteria profile: For each virus sample taken this task includes an additional collection of bacteria and analysis for *E.coli*, coliforms, and Enterococcus. This task includes collecting up to 144 samples in parallel with the virus samples.

Task 1.3 Environmental water quality: a simultaneous collection of standard water quality data over the duration (~1 hour) for each virus sample (using flow cell and Aqua TROLL 400 sensor for dissolved oxygen, oxidative reduction potential/conductivity, pH, temperature, total dissolved solids).

Task 1.4 Other regulated pathogens: In parallel with a subset of virus samples, we will include an additional collection of *Cryptosporidium* and giardia with up to 22 samples. Analysis of these samples is based on EPA and Ecology standards (see Section 9.5 Laboratories accredited for methodology; see Appendix E sections E-1 and E-2). During the irrigation season with surface water flowing from the East Low Canal, we will collect *Cryptosporidium* and giardia analysis from surface water and from groundwater injection and control wells.

4.4.2 Task 2: Characterization of Viral Profiles with Genome Sequencing

Task 2.1 Bioinformatics Classification for Native Virus Baseline and Non-pathogenic Virus Markers: Analyze variations in viral populations based on well, season, and surface and groundwater sources to establish a baseline for relating non-pathogenic markers to up to eight wells surrounding ASR site in Othello, WA, for potential future tracer studies.

Task 2.2 Characterize Virus Populations: Identify groundwater and surface water endemic, resident or established virus populations to determine virus species that are present in the highest concentrations, with attention to any public health concern (e.g. enterovirus from human or animal fecal inputs to surface water source for potential injection at ASR site in Othello, WA).

4.4.3 Task 3: Analysis of Viral Profiles and Field Data

Task 3 will estimate and document factors that affect viral fate and transport in ASR projects with relative load of viral targets in surface and ground water sampling locations. Task 3 outputs will be descriptive plots, graphs and scenarios to be used as model inputs. The modeling QAPP describes how the model output from the project will estimate reduction of virus over time and distance between injection wells and other wells.

Task 3.1 Virus Populations

- Time series of viral target populations at all surface water and groundwater sampling locations (by site and month).
- Spatial comparison of relative viral profiles (e.g., boxplots or grouped bars by location and surface and groundwater type).

Task 3.2 Bioindicator Concentrations

- Boxplots of observed bioindicator concentrations (*E. coli*, Coliforms, Enterococci, *Cryptosporidium*, Giardia) compared to literature ranges (log10 scale).
- Correlation plots between bioindicators and viral targets by location and month.

Task 3.3 Environmental Conditions

- **Conductivity:** Scatter plots of removal rate vs. electrostatic predictors (IEP, pH, conductivity) to estimate three classes (by site and month)
- **Conductivity:** Classification plot of samples into removal regimes (attachment-dominated, reversible, free-decay) based on *k.*
- **Temperature:** Plot of temperature vs. viral inactivation rate using $I=0.018T-0.144$ (Rose et al., 2004)).
- **Temperature:** Time series of temperature with corresponding inactivation rates (by site and month).
- **Temperature:** Sensitivity curve showing inactivation rate across observed temperature range

Dissolved Oxygen: Boxplots or bar charts comparing inactivation/removal rates under oxic vs. anoxic conditions.

- **Dissolved Oxygen:** Scatter plot of DO vs. inactivation rate with class thresholds (oxic/anoxic)
- **Dissolved Oxygen:** ORP vs. removal/inactivation rate plot

Task 3.4 Develop baseline scenarios:

Injection and no injection scenarios for fate and transport between Othello Well 8 and other groundwater well locations.

- **Spatiotemporal Baseline**: Distribution of estimated log-4 reduction rates *k* (histogram or density) by site and month and water source (surface and groundwater).
- **Multivariate Baseline**: Multivariate plots linking environmental water quality controls (e.g., pH, DO, temperature) to viral persistence.
- **Bioindicator Baseline:** Bioindicator plots comparing locations and months (e.g., bioindicators of bacteria and protozoa)

4.5 Systematic planning process

This QAPP has been prepared to satisfy the systematic planning needs for this project.

Amendments to the study plan will be justified and approved by the dated signature of the principal investigator and maintained with the project plan. Deviations from the project plan will be described, explained, acknowledged, and dated in a timely fashion by the Principal Investigator, or his designee, and maintained with the project raw data and this QAPP will be amended as necessary.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1. Organization of project staff and responsibilities (continued to next page).

Staff	Title	Responsibilities
Christina Norton Institute for Risk Analysis & Risk Communication University of Washington Phone: 425-501-4191	Project Manager, Lead Research Scientist	Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into WQX. Responsible for project management, groundwater model development, software delivery, reports, and presentations.
Elaine Faustman Institute for Risk Analysis & Risk Communication University of Washington Phone: 206-399-5455	Principal Investigator	Responsible for the overall risk assessment, ensuring compliance with sponsor requirements, university policies, and ethical standards, and overseeing the proper use and administration of project funds. Responsible as a UW official for this project overseeing all the activities required to complete this project.
TBD University of Washington	Field Assistant	Supports field collect sampling and records field information.
J. Scott Meschke OU, Chair, Department of Occupational and Environmental Health. Formerly at: UW, DEOHS, Environmental and Occupational Health Microbiology Lab (EOHML) Phone: 405/271-2070 Ext. 46761	Former PI of the EOHML and current expert consulting advisor	Provides internal review and approval of the QAPP, provides expert guidance on field and laboratory sampling methodology.
Nicola Beck UW Environmental and Occupational Health Microbiology Lab (EOHML) Phone: 206-616-1171	Lab Manager and Research Scientist	Writes the QAPP. Oversees laboratory methods and QA review of data. Reviews draft QAPP, coordinates with Project Manager and research scientists on field and laboratory methods.
Nicolette Zhou UW Environmental and Occupational Health Microbiology Lab (EOHML) Phone: 206-616-1171	Research Scientist and Engineer	Writes the QAPP. Oversees laboratory methods and QA review of data. Reviews draft QAPP, coordinates with Lab , Project Manager and research scientist. Leads sequencing activities.
Cathleen Horng UW Environmental and Occupational Health Microbiology Lab (EOHML) Phone: 206-616-1171	Research Scientist	Performs laboratory analysis of samples including concentration, nucleic acid extraction, sequencing preparation under the direction of senior scientists.
Kethanh Duong Institute for Risk Analysis & Risk Communication Phone: 206-685-5378	Quality Assurance Project Officer (QAPO)	Program Operations Specialist providing professional-level administration, independent judgment, and strategic support for specific programs, ensuring conformity with institutional policies.
Llyn Doremus Department of Ecology Phone: 1-360-927-3078	Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP. Reviews the draft QAPP and recommends the final QAPP for approval.
McKenna Murray Department of Ecology Phone: 360-407-6070	Ecology Grant Manager and Quality Assurance Officer	Reviews the draft QAPP and recommends the final QAPP for approval.

5.1.2 Principle Investigators

Principal Investigators (PIs) are Ph.D. level independent researchers, who have the overall responsibility for research and management of the project, including oversight of technical conduct of study; interpretation, analysis, documentation, and reporting of results; and serving as single point of control. Specific duties of the PIs will include (1) design and oversight of individual project plans, (3) design of a comprehensive QA/QC program, (4) oversight of activities of Laboratory Manager and Biosafety/Chemical Hygiene Officer, and (5) review and authorization of proposed SOPs. In the absence of a Laboratory Manager or Biosafety/Chemical Hygiene Officer, the duties of those positions fall to the Principal Investigator(s), who may choose to temporarily designate duties to other laboratory staff. Any temporary duties will be documented, and records will be maintained on the duration and actions taken.

5.1.3 Project Manager

A project manager in a water sampling project with a software deliverable is responsible for planning and coordinating all project activities, ensuring proper resource allocation and timeline adherence, overseeing field and laboratory sampling procedures to meet quality standards, managing data collection and integration into the software system, maintaining communication among team members and project partners, and delivering the final software tool and reports on time and within budget while ensuring compliance with regulatory requirements.

5.1.4 Laboratory Manager

The Laboratory Manager's duties include: (1) oversight of the daily operations of the EOHML, (2) direction of technical personnel in the proper performance of laboratory procedures and the reporting of results, (3) ensuring that appropriate methods are used and equipment is properly maintained and operated, (4) planning activities leading to testing and modification of analytical procedures, and (5) review and implementation of the comprehensive QA/QC program. The Laboratory Manager is responsible for initiating the QA/QC program, providing information and training to the staff, and periodically reviewing QA/QC activities. Additionally, the Laboratory Manager will oversee equipment and supply acquisition, and general maintenance of records.

5.1.5 Quality Assurance Project Officer

A Quality Assurance Project Officer (QAPO) oversees the development, review, and implementation of Quality Assurance Project Plans (QAPPs) to ensure EPA and State of Washington funded environmental projects meet data quality and regulatory requirements. They evaluate sampling, analytical, and data management procedures for technical soundness and consistency with EPA and State of Washington QA standards. The position involves coordinating with project managers, laboratories, and field teams to verify adherence to approved protocols and correct any deficiencies. The officer also provides training and guidance on quality assurance principles to improve overall project performance and data integrity.

5.2 Special training and certifications

Dr. Elaine Faustman (PhD) is a toxicologist and Professor in the UW Department of Environmental & Occupational Health Sciences and Director of the Institute for Risk Analysis and Risk Communication (IRARC). She is also the Risk Analysis and Communication Resource Hub Lead for STOP Spillover, a USAID-funded project bringing together experts in human, animal and environmental health to understand and address risks posed by zoonotic viruses with the potential to spill over and affect humans. Dr. Faustman received the 2019 Merit Award from the International Union of Toxicology for her intellectual contributions to the field and a career dedicated to mentoring scientists around the world. She also was elected in 2019 to the Washington State Academy of Sciences, recognizing her work on risk assessment of chemical hazards and her contributions to neurodevelopmental toxicology.

Dr. Christina Norton (PhD), is a senior research scientist at the University of Washington specializing in developing computational data resources to link water resource management with theoretical physical hydrology and analytical model development. Her research includes numerical modeling and software development focused on flood, drought, and future water scenarios. She leads research projects on flood model integration, participates in the development of the Landlab open-source Python modeling toolkit, and contributes to HydroShare, a collaborative platform for sharing water data and models. Notably, she led an NSF RAPID team creating cyberinfrastructure to improve disaster prevention and population health, with a pilot addressing the humanitarian crisis in Puerto Rico after Hurricane Maria which included water sampling for drinking water quality and anti-bacterial resistant source water modeling. Christina received her Project Management Professional (PMP) certification in 2024.

Dr. Scott Meschke is an environmental and occupational health microbiologist with more than 25 years of experience specializing in the fate, transport, detection, and control of pathogens in environmental media, including air, water, food, and surfaces. He currently serves as Chair of the Department of Occupational and Environmental Health at the University of Oklahoma and was formerly Associate Chair and Graduate Program Coordinator in the University of Washington's Department of Environmental and Occupational Health Sciences, as well as Adjunct Professor in Civil and Environmental Engineering. Dr. Meschke's research focuses on environmental surveillance for infectious agents and the development of methods for sampling and detecting viruses and bacteria in environmental media. His work spans bacterial and viral disinfection, quantitative microbial risk assessment (QMRA), and policy implications of infectious disease control. Over the past decade, he has led efforts to develop, validate, and field-test wastewater-based epidemiology methods for *poliovirus*, *Salmonella Typhi*, SARS-CoV-2, and other pathogens in collaboration with the WHO, CDC, and research partners in Kenya, South Africa, Pakistan, India, Bangladesh, and other locations.

Dr. Nicolette Zhou is an environmental engineer and research scientist working in the Environmental and Occupational Health Microbiology Lab(EOHML) at the University of Washington. She has extensive experience in environmental microbiology, molecular methods, and bioinformatics, with a focus on shotgun metagenomic analysis of environmental

concentrates. Dr. Zhou leads sequencing and data analysis activities for environmental surveillance projects, including studies in Kenya and Pakistan, and has developed a novel synthetic long-read next-generation sequencing approach for identifying poliovirus serotypes and strains in environmental samples. Her work also includes comparing sampling kits and concentration methods to optimize pathogen recovery and detection in complex matrices for organisms such as poliovirus and S. typhi. Earlier in her career, Dr. Zhou investigated enhanced biological trace organic contaminant removal (EBTCR) during wastewater treatment, isolating and characterizing bacteria capable of degrading trace organic contaminants, performing bioaugmentation in lab-scale reactors, and identifying proteins involved in contaminant degradation. She will lead viral sequencing activities for this project.

Ms. Nicola (Nicky) Beck, MS, is the Laboratory Manager of the Environmental and Occupational Health Microbiology Lab (EOHML) at the University of Washington, with over 20 years of experience in environmental micro and molecular biology. She oversees laboratory operations, including project planning and budgeting, QA/QC implementation, equipment calibration, and staff and student training, and serves as the EOHML's Biosafety and Chemical Hygiene Officer. Her research focuses on environmental surveillance and the development of methods to detect and control viruses and bacteria in water, food, air, and on surfaces. Her research has included studies on microbial disinfection, pathogen quantification, and environmental water and food safety and surveillance. Ms. Beck has also played a key role in developing and field-testing environmental surveillance and wastewater-based epidemiology methods for poliovirus, Salmonella typhi, and SARS-CoV-2 in collaboration with government agencies, NGOs, and international partners.

5.3 Organization chart & Distribution List

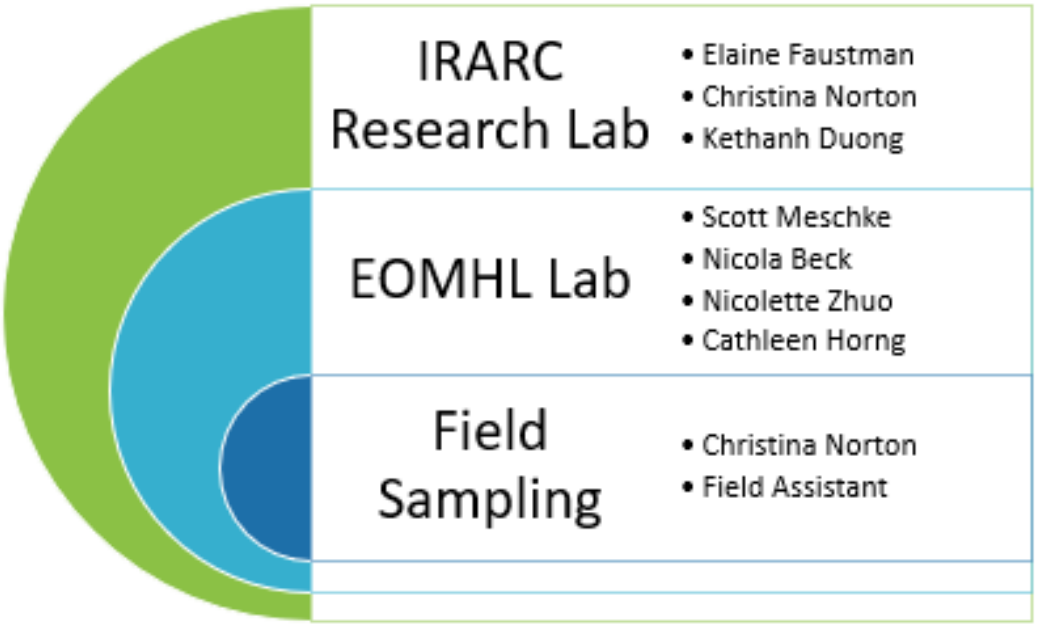


Figure 11. Organization chart.

Notes: Christina Norton leads as the top-level Project Manager, overseeing the Field Work Coordinator directly. Elaine Faustman serves as Principal Investigator and IRARC Director, with Kethanh Duong reporting to her as Program Operations Specialist and QAPO. Scott Mescke directs the EOMHL lab, managing Nicola Beck as Lab Manager, who in turn supervises Research Scientists Nicolette Zhuo and Cathleen Horng.

We have identified 22 individuals with various roles including QAPP Reviewers, QAPP authors, and those who will be notified about the project progress. Partners and collaborators include individuals that form the distribution list are from 8 different organizations include: State of Washington Department of Ecology, State of Washington Department of Health, Yakama Nation, McCain Foods, City of Othello, Aspect Consulting, and the Bureau of Reclamation.

5.3.1 QAPP Reviewers

State of Washington, Department of Ecology, Office of the Columbia River

1) Llyn Doremus, Inter-agency Project Coordinator, LDOR461@ecy.wa.gov
2) McKenna Murray, Project Manager, MCMU461@ecy.wa.gov

QAPP Authors

University of Washington

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2) Elaine Faustman, Risk Assessment Lead, Project PI, faustman@uw.edu
3) John Scott Meschke, EOHML Laboratory Director, Virus Lead, jmeschke@uw.edu
4) Nicola Beck, EOHML Laboratory Manager, nkj2@uw.edu
5) Nicolette Zhou, EOHML Laboratory Technician, nicolette.zhou@gmail.com

Notification of Quarterly Reports

McCain Foods

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2) Josh Sanders, Environmental Supervisor Othello, joshua.sanders@mccain.com
3) Jeremiah Ohara, Engineering manager Othello, Jeremiah.OHara@mccain.com

Bureau of Reclamation

4) Jennifer Haverloo, Project Manager, JHeaverlo@usbr.gov

City of Othello

5) 5) Robin Adolphson, Engineer, radolphsen@othellowa.gov

Aspect Consulting

6) Tyson Carlson, Senior Principal Hydrogeologist, tcarlson@aspectconsulting.com

State of Washington, Department of Health

7) Kim Moore, Forensic Care Associate, kim.moore@dshs.wa.gov

State of Washington Department of Ecology

8) Ingrid Ekstrom, Hydrogeologist, ieks461@ecy.wa.gov

5.4 Proposed project schedule

Virus genetic results will be reported 6-8 weeks after submitting in three batches to optimize cost for DNA and RNA.. Batch A: 10 DNA and 10 RNA samples; two months. Batch B & C: 60 samples (30 DNA; 30 RNA) from five months of field work (Table 2). The schedule for Water Quality Exchange (WQX) data entry is in Table 3 and the schedule for final reporting in Table 4. Batch sampling will not impact the results of the study because appropriate preservation methods will be followed. Samples will be filtered and held on cold chain, then eluted and extracted within 48 hours of receipt in the laboratory. After processing, DNA and RNA extracts will be frozen and held at -80°C prior to library prep and sequencing. Nucleic acids are stable at -80°C.

Table 2. Schedule for completing field and laboratory work in months (1 – 7) with three sequencing batches (A, B, C) and four reports (1 – 4).

Sequencing Batch	Task	Due date	Lead staff
A	Field work [1, 2] July, Aug 2026	Results in Report 1 Aug 2026.	Christina Norton
	EOMHL Laboratory analyses [1, 2]	Results in Report 1 Aug 2026.	Nicola Beck
	Viral sequencing bioinformatics A [1]	Results in Report 1 in Aug 2026. Month 2 virus results may be reserved for Report 2.	Nicolette Zhou
B	Field work [3, 4, 5] Sep – Oct2026	Results in Report 2 in Sep 2026, and Report 3 in Nov 2026.	Christina Norton
	Laboratory analyses [3, 4, 5]	Results in Report 2 in Sep 2026, and Report 3 in Nov 2026.	Nicola Beck
	Lab sequencing bioinformatics B. [2, 3, 4]	Results in Report 3 Nov 2026.	Nicolette Zhou
C	Field work [6, 7] Nov-Dec 2026	Results in Final Report 4 in Jan 2026.	Christina Norton
	Laboratory analysis [6, 7]	Results in Final Report 4 in Jan 2026.	Nicola Beck
	Sequencing bioinformatics C. [5, 6, 7]	Results in Final Report 4 in Jan 2026.	Nicolette Zhou

Table 3. Schedule for Water Quality Exchange (WQX) data entry

Task	Due date	Lead staff
WQX data loaded	Aug 2026, Oct 2026, Dec 2026	Christina Norton
WQX QA	Sep 2026, Nov 2026, Dec 2026	Kethanh Duong
WQX complete	Jan 2027	Elaine Faustman

Table 4. Schedule for final report

Task	Due Date	Lead Staff
Draft to supervisor	Oct 2026	Christina Norton
Draft to client/ peer reviewer	Nov 6, 2026	Christina Norton
Draft to external reviewers	NA	NA
Final draft to Partners & Collaborators	Dec 18, 2026	Christina Norton
Final report due on web	Jan 15, 2027	Christina Norton

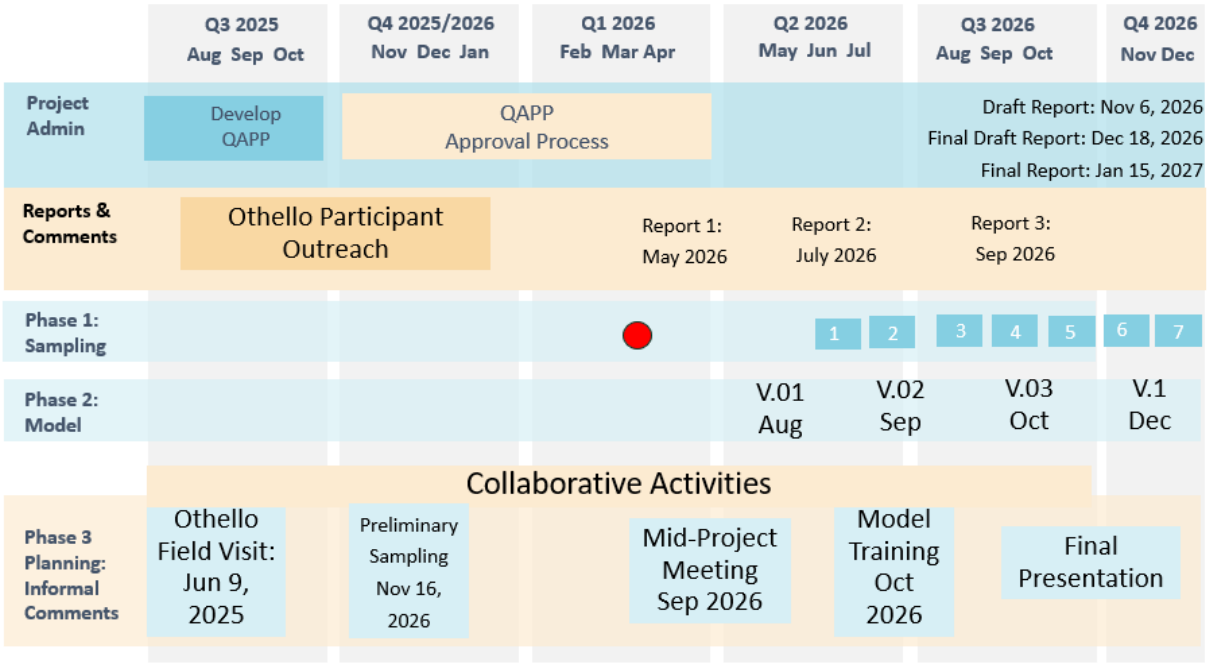


Figure 12. GAANT chart of project timeline and project phases (2025-2026).

5.5 Budget and funding

Table 5. Project budget and funding as of August 2025 contract.

Cost Category	Cost
Salary & Wages	$111,203
Benefits	$31,889
Travel and other	$6,745
UW Indirect Costs (37%)	$94,794
Laboratory (See Table 6 for details.)	$106,363

Table 6. Laboratory budget details.

Parameter	Number of Samples	Number of QA Samples	Total Number of Samples	Cost Per Sample ($)	Lab Subtotal ($)
VIRUS: RNA/DNA; Total nucleic acids of viral genome (Personnel, Supplies, Collection, Extraction, Quantification, Sequencing).	RNA (66) + DNA (66)=132	7 QA+5 Contingency=12	132 + 12 = 144	$1637/routine sample (66)	$117,907
PROTOZOA: Cryptosporidium & Giardia (Contracted Lab & Shipping). Injection well, control well, surface water location.	4 months x 2 SW+ 3 months x 3 GW=17	5	17 + 5= 22	$673/sample	$14,800
BACTERIA: E. coli, Total coliforms, Enterococci	132	12	132 + 12 = 144	Included in virus cost/sample above	Included in virus cost/sample above.

Notes: See also Table 14 . Sample collection plan for irrigation season (2026) including surface water and groundwater (GW) sampling and non-irrigation season (2026) GW sampling. See Table 15 for tests per location and Figure 14 for map of locations within a radius of 1.5 miles of injection well Othello 3R.

6.0 Quality Objectives

6.1 Data quality objectives

The main data quality objective (DQO) for this project is to collect a minimum of 66 virus water samples from a range of groundwater and surface water locations representing a managed area for ASR over multiple months period. The analysis will use standard field, laboratory and modeling methods to obtain viral characterization as well as other chemical, bacterial, and pathogen data to meet the measurement quality objectives (MQOs) described in Table 7 below. We anticipate two field duplicates for one location per sampling event for a total of 7 field duplicates for *E.coli,* total coliforms and enterococci. Field duplicates are not standard nor required by EPA methods 1623.1 for *Cryptosporidium* and *Giardia*. Rather there are sub-sampling methods suggested if there is excessive debris, sediment, or high turbidity that would overload the microscope slide or obscure target *Cryptosporidium* oocysts and *Giardia* cysts. Results will be comparable to study results from previous studies in the project area, as available.

Table 7. Measurement Quality Objectives (MQO) Summary Table.

Parameter / Method	Routine Samples	Field Duplicates	Laboratory Replicates	Positive Controls	Negative Controls
Viral RNA Extraction/ Sequencing	66	0	7	0	0
Viral DNA Extraction/ Sequencing	66	0	7	0	0
E. coli (IDEXX Colilert)	66	7	7	7	7
Total Coliforms (IDEXX Colilert)	66	7	7	7	7
Enterococci (IDEXX Enterolert)	66	7	7	7	7
Cryptosporidium **	1720	0	up to 3 IMS replicates	5	5
Giardia **	1720	0	up to 3 IMS replicates	5	5

Notes: There will be a duplicate at one location for bacterial analysis for each field sampling event. There will be one lab replicate, one positive and negative control per lab analysis batch. There will be one recovery control per location.

6.2 Measurement quality objectives

The MQO is to quantify the relative abundance of the most abundant genomes in each sample as in Figure 13 to compare the viral profiles between sampling locations. Unknown viruses in an environmental sample can be found and characterized by bulk sequencing followed by metagenomics analysis. In this project we are bulk sequencing all viral genomes. This reduces the sequencing resolution if we were targeting a specific subpopulation, but in this project we are not. The MQO is to characterize unknown viruses to understand the profile, genomic diversity, and differences (if any) in viral ecology between surface water and groundwater comparing multiple wells. The need exists for methods that can reliably detect and recover the complete genome of any given viral species from a complex sample (Chen et al., 2024).

To successfully sequence an existing viral genome from a water sample, the sample must be sufficiently concentrated to contain enough viral particles for detection and sequencing. This typically involves filtering large volumes of water (we are filtering 100 liters) through a 2-3 µm membrane (ViroCap; Fagnant et al., 2017), at a rate of 2 L/min, followed by storage of the filter at 4°C for less than 24 hours, to preserve nucleic acids. The extracted viral RNA or DNA should be free of inhibitors and contaminants, and the minimum amount of DNA required for sequencing is usually at least 1 ng, with higher amounts (≥250 ng) preferred for robust next-generation sequencing workflows. Effective concentration and purification steps are critical, as low viral loads and sample inhibitors can impede genome recovery and sequencing quality.

Studies show that complete or nearly complete genomes (>99% coverage) can be recovered in about 30–40% of wastewater samples when viral RNA concentrations exceed roughly 25 genome copies/µL (Ct ≤ 33) (Crits-Christoph et al., 2021; Nishikawa et al, 2024). Partial genome recovery (50–80%) is common in samples with lower viral loads (Barbé et al, 2022), which is what we expect from the groundwater samples in this project.

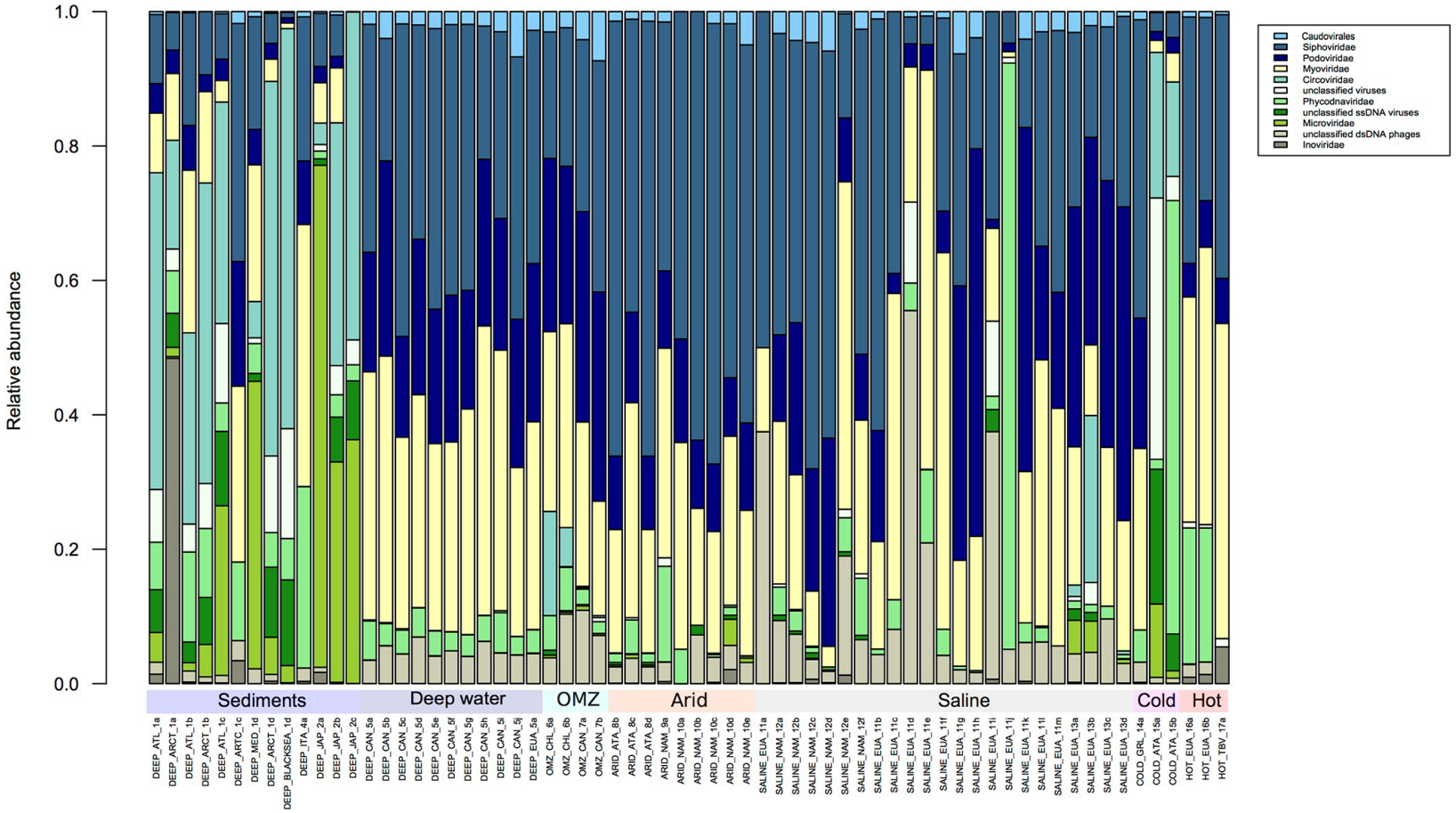


Figure 13. Comparison of the 10 most abundant virus families according to the Metavir database.

Notes: The taxonomic composition is expressed in relative abundance at the virus family level. The families *Siphoviridae*, *Podoviridae*, and *Myoviridae* are ubiquitous in extreme environments. (The figure was constructed from an abundance matrix, using the number of sequences reported in the Metavir database, from which the relative abundance was obtained; using the R program; citation: Dávila-Ramos S, Castelán-Sánchez HG, Martínez-Ávila L, Sánchez-Carbente MR, Peralta R, Hernández-Mendoza A, Dobson ADW, Gonzalez RA, Pastor N and Batista-García RA (2019) A Review on Viral Metagenomics in Extreme Environments. Front. Microbiol. 10:2403. doi: 10.3389/fmicb.2019.02403)

6.2.1 Targets for precision, bias, and sensitivity

The MQOs for project results, expressed in terms of acceptable precision, bias, and sensitivity, are described in this section and summarized in Table 8, Table 9, Table 10 and Table 11.

Table 8. Laboratory and Field Duplicates and corresponding Level of Detection (LOD) and Measurement Quality objectives (MQO) for laboratory analyses of water samples.

Parameter	Laboratory Duplicate (RPD)	Field Duplicate (RPD)	Level of Detection (MQO)
RNA/DNA; Total nucleic acids	2	NA	1 to 10 ng/µL in nucleic acid extract. 40 genome copies/L in sample*
Cryptosporidium	2	NA	10 – 100+ oocysts per 100 liters
Giardia	2	NA	10 – 100+ cysts per 100 liters
E. coli	2	2	> = 1 MPN/100 mL
Total coliforms	2	2	> = 1 MPN/100 mL
Enterococci	2	2	> = 1 MPN/100 mL

Notes: Most probable number (MPN) calculates the concentration using probability based on the number of positive or negative test results for a bacterial assay.

A practical threshold in many studies is around 1 to 10 ng/µL of nucleic acid in the extract for quality sequencing libraries. Concentrations below this range often reduce sequencing success due to insufficient template availability and increased noise from inhibitors (Jiang et al., 2024). For membrane-based concentration techniques, viral genome copies as low as 40 genome copies per liter can still be detected and sequenced with optimized protocols (El Soufi et al., 2024).

RPD: relative percent difference is used to measure precision and reproducibility between two duplicate measurements in a scientific lab.

Table 9. Details for Measurement of quality objectives (MQO) of laboratory analyses of water samples.

Parameter	Equipment	Accuracy	Resolution	Range	Expected Range	MQO
RNA/DNA; Total nucleic acids	Concentration, TNA extraction, sequencing	Recovery efficiency after concentration and extraction may vary between 30% and 70%*	0.078 copies/µL (dPCR)	Sequencing input requirements (Illumina/ONT) typically range from 0.5 ng to 250 ng of total nucleic acid per reaction **	effective detection and assembly of viral genomes is most reliable with ≥5–20 ng input **	1 to 10 ng/µL in nucleic acid extract. 40 genome copies/L in sample*
Cryptosporidium and Giardia	Immunomagnetic separation (IMS) and immunofluorescence assay (FA) microscopy	Recovery accuracy ranges from 36% to 75% (crypto) and 0.5% to 61% (giardia), depending on sample turbidity and environmental conditions.	Quantitative results are reported as organisms per sample or per liter, based on immunofluorescence assay counting.	Typical limit of detection is between 1–10 oocysts (Cryptosporidium) or cysts (Giardia) per 100 L sample	membrane pore size is 1.0 µm	10 – 100+ oocysts/cysts per 100 liters
E. coli, Total coliforms	Sterile membrane filtration, incubation EPA Method 1604, Method 1103.2	E. coli: ~95.7% Total coliform: ~93.1%	E. coli: 3.3%–27.3% within a single lab, up to 40.5% between labs Total coliform: 2.5%–5.1% within a single lab, up to 27.7% between labs	1 to >800,000 CFU/100 mL	Total coliforms were present in native groundwater at Well 8 in the sample collected on May 10, 2021	1 MPN/100 mL
Enterococci	Sterile membrane filtration, incubation	~94–98%	10–40% coefficient of variation between labs	1 CFU/100 mL up to tens of thousands (CFU/100 mL)	TBD	1 MPN/100 mL

Notes: Reference sites

*https://www.sciencedirect.com/science/article/pii/S0048969723050672

**https://pmc.ncbi.nlm.nih.gov/articles/PMC11097627/

Table 10. Measurement quality objectives (MQO) of field analysis of water samples using Aqua TROLL 400 Multiparameter Probe (In-Situ Inc., 2023).

Parameter	Methodology	Accuracy	MQO: Resolution	Range	Units of Measure
Conductivity	Std. Methods 2510 EPA 120.1	Typical ±0.5% + 1 µS/cm; ±1% max.	0.1 µS/cm	5 to 100,000 µS/cm	Actual conductivity (µS/cm, mS/cm) Specific conductivity (µS/cm, mS/cm) Salinity (PSU) Total dissolved solids (ppt, ppm) Resistivity (Ohms-cm)Density (g/cm3)
Dissolved Oxygen	EPA-approved In-Situ Methods 1002-8-2009 1003-8-2009 1004-8-2009	±0.1 mg/L ±5% of reading	0.01 mg/L	0 to 20 mg/L 20 to 60 mg/L Full operating range: 0 to 60 mg/L	mg/L, % saturation, ppm, ppO2
ORP	Std. Methods 2580	±5.0 mV	0.1 mV	±1400 mV	mV
pH	Std. Methods 4500-H+ EPA 150.2	±0.1 pH unit	0.01 pH unit	0 to 14 pH units	pH units, mV Std. Methods 4500-H+ EPA 150.2
Temperature	EPA 170.1	±0.1° C	0.01° C or better	-5 to 50° C (23 to 122° F)	Celsius, Fahrenheit

6.2.1.1 Precision

Virus quantification protocols aim for precision targets for Coefficient of Variation (CV) around ±20–25%, with recovery and detection limits aligning to provide reliable, reproducible results suitable for surveillance and risk assessment (Ishii et al., 2014).

The field instrument for general chemistry, Aqua TROLL 400 Multiparameter Probe, accuracy and resolution details are available in Table 10 (In-Situ Inc., 2023).

Bacterial values are based on EPA and Standard Methods protocols for ambient and drinking water in Table 11.

Table 11. Targets for acceptable precision in terms of Coefficient of Variation (CV) for bacterial laboratory analyses of water samples.

Indicator	Accuracy	Precision (CV)	Range (CFU/100 mL)	Resolution
E. coli	~95.7%	3.3 - 40.5%	1 – 800,000	1 CFU
Total coliform	~93.1%	2.5 – 27.7%	1 – 800,000	1 CFU
Enterococci	~94-98%	10 - 40%	1 – 10,000+	1 CFU

6.2.1.2.2 Bias

In field water chemistry measurements, potential bias will be assessed using calibration methods of the digital tools following the Aqua TROLL 400 Manual (In-Situ Inc., 2023). These sensors provide high precision (e.g., ±3% accuracy for Dissolved Oxygen readings), but the overall sampling bias includes all upstream variabilities such as temporal/spatial variations, sample handling, or environmental interferences (temperature fluctuations, particulates). Regular recalibration and replicate measurements help distinguish instrument bias vs. true environmental variability. Positive bias indicates overestimation; negative bias indicates underestimation.

Steps to Calculate Field Sampling Bias:

1. Calibrate Instrument Properly: Ensure the instrument is well-calibrated with standard buffer solutions (pH) and conductivity standards before sampling to minimize instrument bias.
2. Collect Multiple Samples & Measurements: Take replicate water samples from the source to quantify variation due to sample heterogeneity.
3. Use Reference or Control Values: Compare measurements with trusted reference standards or lab-analyzed samples representing "true" values or accepted baselines.
4. Calculate Sampling Bias: Bias is the average difference between measured and true values across replicates (Equation 2).

$$Bias = \frac{\sum_{i=1}^{n}(Measured_i - True\ or\ Reference_i)}{n}$$

In laboratory processes for viruses, bacteria, *Cryptosporidium* and giardia, potential bias will be assessed using blank samples. Bias is determined using a spiked sample, and bias will be calculated as Recovery (%).

- RNA/DNA; Total nucleic acids: Recovery (%) may vary between 30% and 70% Cryptosporidium and Giardia: Recovery accuracy ranges from 36% to 75% (crypto) and 0.5% to 61% (giardia), depending on sample turbidity and environmental conditions.
- Bacteria: Using EPA Method 1604, Method 1103.2, Recovery (%) is expected as follows:
    - E. coli: ~95.7%
    - Total coliform: ~93.1%

- Enterococci: ~94–98%

6.2.1.3 Sensitivity (Resolution)

Targets for acceptable sensitivity of all field and lab measurements are provided in Table 9, Table 10 and Table 11 in columns labeled 'resolution'.

Laboratory Detection Limits:

- RNA/DNA; Total nucleic acids: 1 to 10 ng/µL in nucleic acid extract. 40 genome copies/L in sample.
- Cryptosporidium, Giardia: 10 – 100+ oocysts/cysts per 100 liters
- E. coli, Total coliforms, Enterococci: 1 MPN/100 mL

Field Instrument Sensitivity (Aqua TROLL 400; In-Situ Inc., 2023 see also Table 9 and Table 10)**:**

- Conductivity: expected range 5 to 100,000 µS/cm with 0.1 µS/cm resolution
- Dissolved Oxygen: expected range 0 to 60 mg/L with 0.01 mg/L resolution
- ORP: expected range ±1400 mV with 0.1 mV
- pH: expected range 0 to 14 pH units 0.01 pH unit with 0.01 resolution
- Temperature: expected range of 18 to 25°C and 0.01°C (0.01°F) resolution

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Field Chemistry Comparable

In 2018, Aspect Consulting completed a laboratory analysis for a full suite of chemical analysis for water samples collected at the end of a 24-hour pumping test at Othello Well 3R and state in their February 2019 draft report (pg. 8, Project No. 140207-007-02) that major chemistry at Well No. 3R, including temperature and pH, is like other City wells. Based on their results, we have a local standard with which to compare our monthly samples. Their results are provided below in Table 12 and will be used for comparability for the highlighted parameters collected as part of this project (TDS, Temp, Conductivity, DO, pH).

Table 12. Results for Major Chemistry (collected 12/13/2018 provided in Table 2 of Aspect Consulting (2019)).

Constituent	Concentration (in mg/L, unless noted)
Cond (µS/cm)	452.9
Dissolved Oxygen	0.09
ORP (mV)	51.9
pH (s.u.)	8.43
Temp (C)	22.8

Notes: Selected parameters will be compared to samples collected in this project and any significant differences will be assessed for representativeness and completeness.

6.2.2.2 Bacterial Comparable

Prior to the 2018 pumping test at Othello Well 3R, the well was disinfected in accordance with AWWA standard C654-133, including shock chlorination with a residual of 50 mg/L and chlorination of sampling ports. Bacterial results at the end of the pump test were positive for total coliforms and negative for *E. coli* (Aspect Consulting, 2019).

6.2.2.3 Comparability

Comparability is achieved by using standard techniques to collect and analyze samples. The list of SOPs is provided in Table 13 and Appendix E: Standard Operating Procedures (SOP).

Table 13. List of project Standard Operating Procedures (SOP).

Appendix	Sample	SOP	Filename	Method Description
E-1 pg. 2-6	Cryptosporidium & Giardia	USEPA Method 1623 and 1623.1	110_EPA_Method_1623_and_1623_ASI.pdf	UW Field & Analytical Services, Inc. (ASI) Lab
E-2 pg. 7-8	Cryptosporidium & Giardia	Chain of Custody	Analy Services Chain_of_Custody_2025.pdf	UW Field & Analytical Services, Inc. (ASI) Lab
E-3 pg. 9-17	Bacteria: *E. coli,* Enterococci, Coliphage	Analytical Methods Compliance Monitoring under the Ground Water Rule 40 CFR 141.402(c)(2)	EPA_gwr_approved_methods.pdf	EPA methods at UW EOMHL
E-4 pg. 18-20	Bacteria: Enterococci	Enterolert®	Enterolert_IDEXX_DS_EN.pdf	IDEXX methods at UW EOMHL
E-5 pg. 21-23	Bacteria: Enterococci	Enterolert®	IDEXX_Enterolert_Procedure Insert.pdf	IDEXX methods at UW EOMHL
E-6 pg. 24-31	Bacteria: Total coliforms, E.coli	Colilert®	IDEXX_Colilert_ Procedure.pdf	IDEXX methods at UW EOMHL
E-7 pg. 32-60	Virus: DNA	DNeasy® Power Water Kit	HB-2267-003_HB_DNY_PowerWater_0722_WW.pdf	Qiagen methods at UW EOMHL
E-8 pg. 60-89	Virus: RNA	RNeasy® Power Water Kit	HB-2268-004_HB_RNY_PowerWater_1023__WW.pdf	Qiagen methods at UW EOMHL
E-9 pg. 90-100	Virus: DNA	Qubit®dsDNA HS Assay Kit	User Guide_ Qubit dsDNA HS Assay Kits.pdf	Life Technologies methods at UW EOMHL
E-10 pg. 101-111	Virus: RNA	Qubit®dsRNA HS Assay Kit	User Guide_ Qubit RNA HS Assay Kits.pdf	Life Technologies methods at UW EOMHL
E-11 pg. 112-148	Virus: DNA	Nextera® DNA Library Preparation Kit	Nextera DNA Library Prep Reference Guide (15027987).pdf	Illumina methods at methods at UW EOMHL
E-12 pg. 149-180	Sample Collection	EPA SESDPROC-301-R3 Groundwater Sampling	Groundwater-Sampling.pdf	UW Field with EPA SESD methods
E-13 pg. 181-236	Quality Sensor	Aqua TROLL 400 Instrument Manual	Aqua_TROLL_400_Manual.pdf	UW Field with In-Situ methods EPA SOPs
E-14 pg. 237-240	SOP	Preparation of Project Specific Standard Operating Procedures	EOMHL-SOPpreparation.pdf	UW Environmental Health Microbiology Lab (EOMHL)
E-15 pg. 241-247	Labs Accredited	Crypto; Waiver	260203R Analytical Services - EXP 2027-0217.pdf; AccreditationWaiver_UW.pdf	ASI EOMHL

6.2.2.4 Representativeness

There are five groundwater wells, and two surface water sampling locations selected to be representative of Wanapum Basalt characteristics in the Columbia Basin aquifer. The study is designed to include one sampling campaign per month over one year, to collect a representative sampling across the range of seasons to capture any range of flow conditions or seasonal variations.

6.2.2.5 Completeness

Completeness will be calculated as follows (Equation 3):

$$Completeness\ \% = \frac{V}{P}\ x\ 100$$

where:

V = number of valid measurements
P = number of planned measurements

Valid and invalid data (i.e., data qualified with the R flag [rejected]) will be identified during data validation. The completeness target for the study is 100 percent of water quality samples.

6.3 Acceptance criteria for quality of existing data

This project will collect new environmental data from groundwater and surface water samples.

6.4 Model quality objectives

Not applicable. This is described in Phase 2 QAPP: Characterization of in situ virus transport and inactivation in the groundwater of Columbia River basalt aquifers: Modeling.

7.0 Study Design

7.1 Study boundaries

The project study area is shown in Figure 14 with a satellite image and with groundwater sampling locations (wells) owned by McCain Foods (orange) and City of Othello (red and green), and the surface water sampling location along the irrigation canal (turquoise). Othello Well 9 is the control well, known to be upgradient of Othello Well 3R (green). These wells were selected to compare any differences between Othello Well 3R (green) that has had surface water injected in a previous test (2020) and wells thought to be downgradient of the injection well (Othello Well 8, McCain Well 4, and McCain Well 2). Estimates of the hydraulic gradient direction are based on previous studies shown in Figure 15 (Aspect, 2020) and historical regional groundwater contour information shown in Figure 16 (Lane and Whiteman, 1989).

Figure 17 shows the groundwater gradient interpreted from available well logs (Appendix C: Well Logs, Well Reports and Available Information for Wells) and prior studies. Based on this information, it is difficult to assess which wells are likely to be impacted (theoretically) downgradient of Othello Well 3R. Using available static water level from various years and well logs, Figure 17 gives a view of the hydraulic gradient(s) in the study vicinity based on available well information in the project area. This interpretation will be supplemented and reevaluated with data collected during this study.

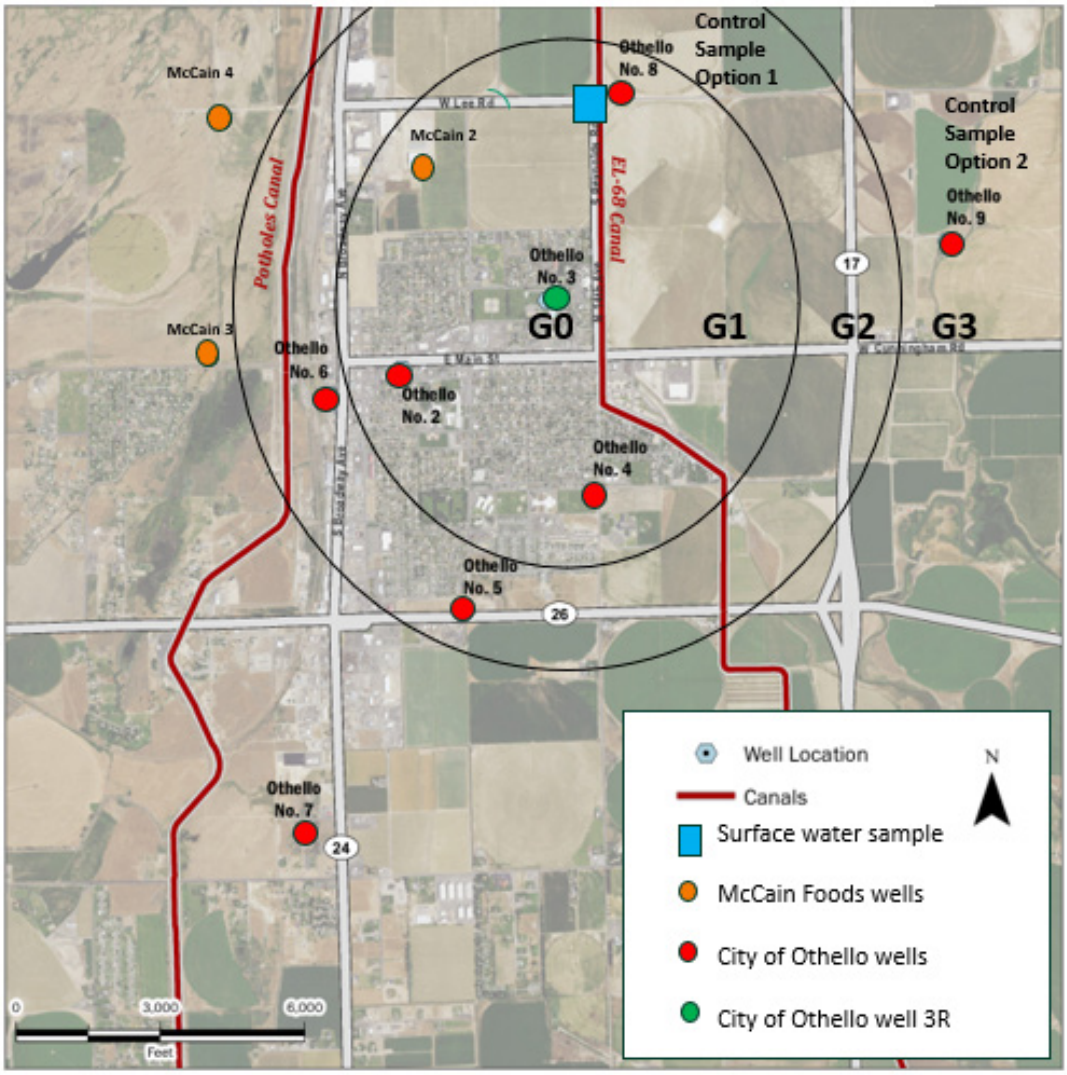
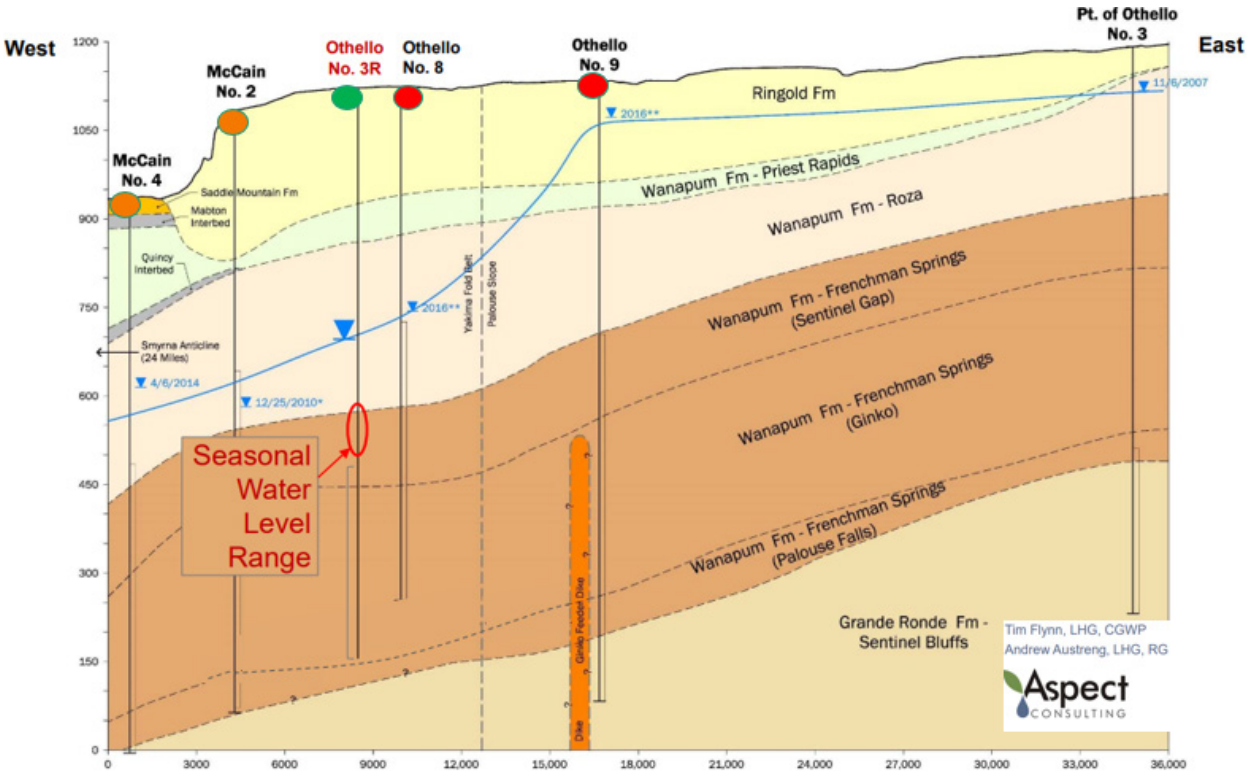


Figure 14. Map showing boundary of project study area and sampling wells.

Notes: Sampling wells within distances from the Othello 3R injection well (G0), where G1: < 1 mile radius, G2: 1 - 1.5 mile radius, and G3: > 1.5 mile radius.



*Funded by **Office of Columbia River** Grant No. WROCR-VER1-Othell-00005*

Figure 15. Map showing horizontal cross section of project study area with an East-West groundwater flow direction. (Figure from Aspect, 2020).

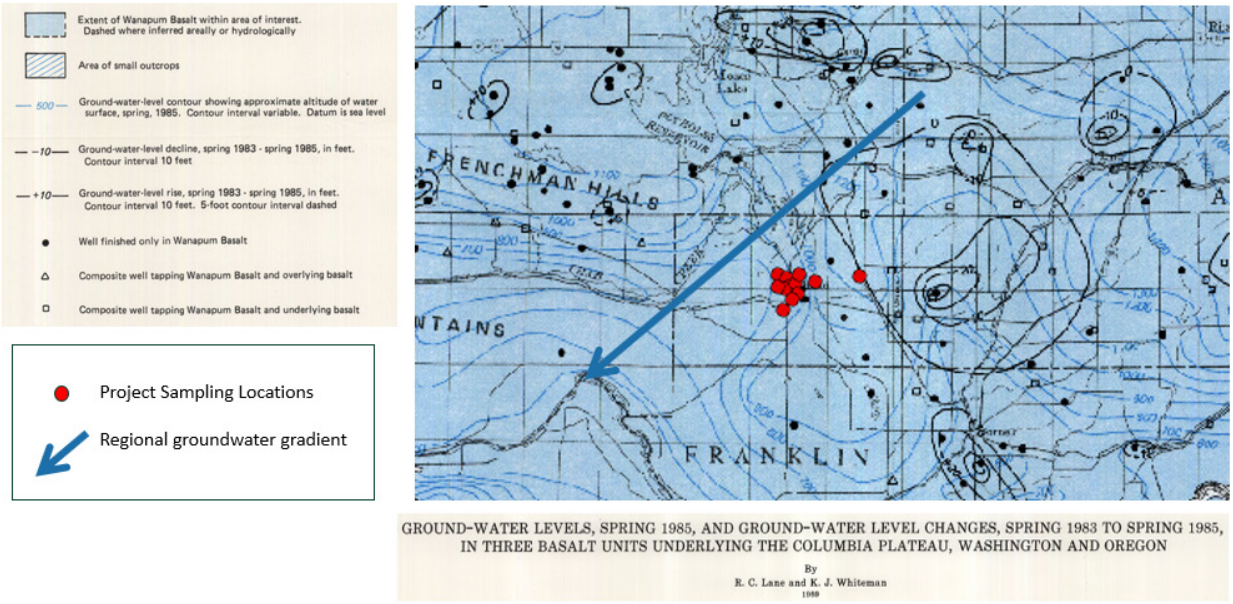


Figure 16. Wanapum basalt aquifer groundwater.

Notes: Contour lines from groundwater levels in 1983-1985 (Lane and Whiteman, 1989) with a generalized groundwater flow gradient from the northeast to the southwest (blue arrow). Sampling well locations near Othello are shown as red dots.

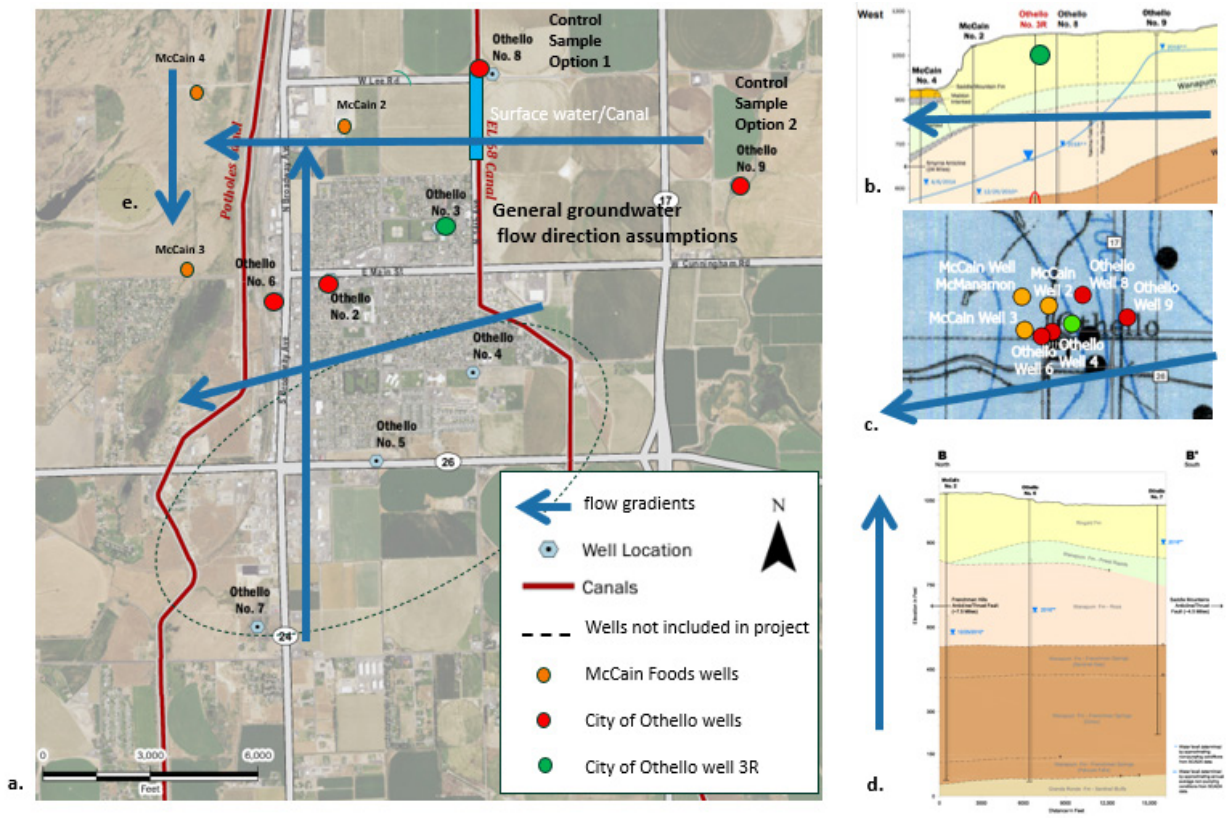


Figure 17. a) Sampling locations shown with groundwater gradient. b) East-West transect shown in Figure 15, c) Southwest flow direction shown in Figure 16, d) South-north cross section.

Notes: From Aspect, 2020 for Othello Well 7, Othello Well 6 and McCain Well 2,

Location	SWL_ft	Year
Othello Well 9	51	2015
Othello Well 7	125	1998
Othello Well 5	277	1987
McCain Well 4	310	2014
McCain Well 2	353	2003
Othello Well 8	380	2002
Othello Well 4	396	1994
McCain Well 3	402	2021
Othello Well 6	536	2011
Othello Well 3R	537	2018

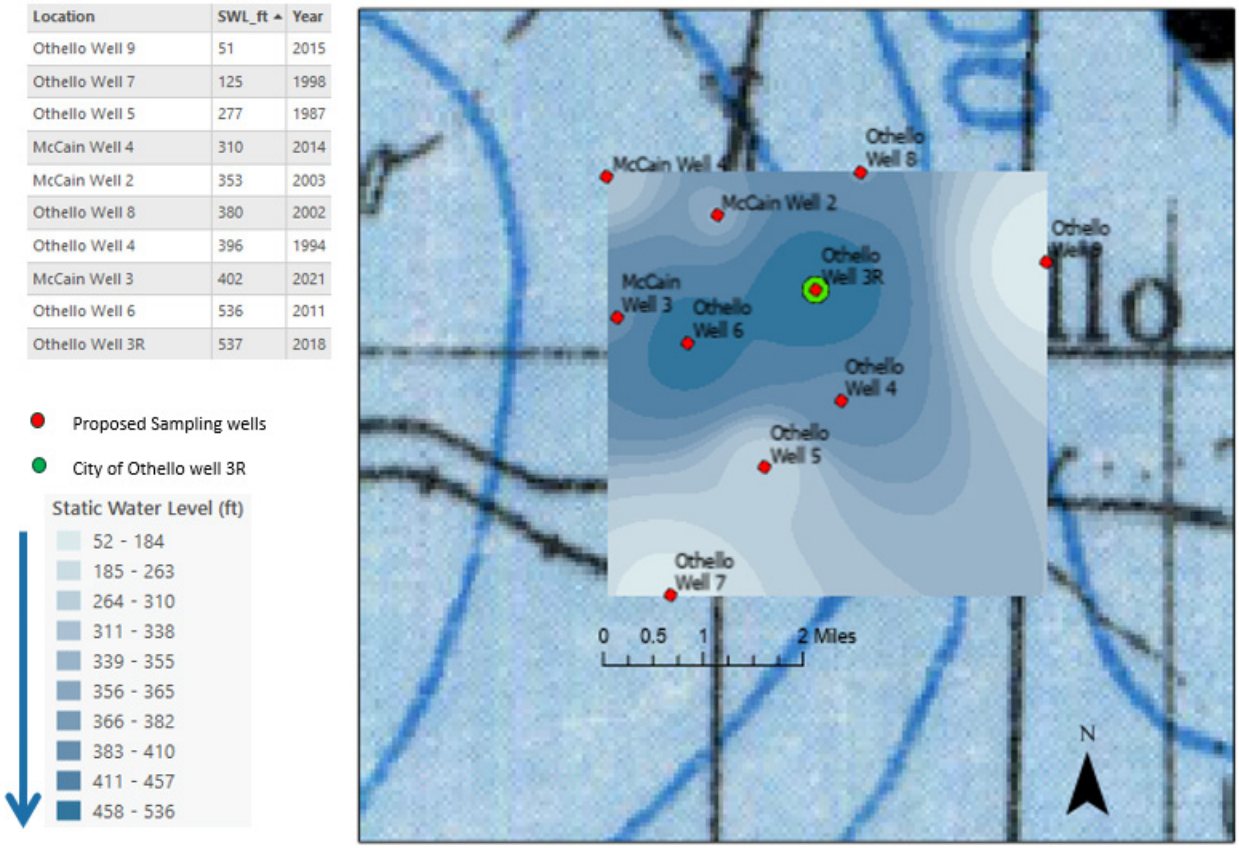


Figure 18. Groundwater levels in the Othello area.

Notes: Groundwater levels are based on an interpolation of Static Water Level from Appendix C: Well Logs, Well Reports and Available Information for Wells, using inverse distance weighting in various years.

7.2 Field data collection

7.2.1 Sampling locations and frequency

We are using Distance Sampling as a sampling strategy. This is appropriate for the study because it uses geographic distance to design a sampling plan surrounding an area of interest. In this study, our area of interest is the aquifer surrounding Othello well 3R which received surface water injection as part of an ASR project in 2020, and Othello well 8, which is proposed for a future ASR project. Control sampling locations are based on known groundwater gradients where control samples are upgradient of other Othello Wells. The selection of the control location and wells for monthly sampling is described below and outlined in Table 14. Sampling locations are shown in Figure 4 and Figure 14.

Each field sampling will occur as close to possible on the third Tuesday of each month with each sample location taking 1-2 hours per location to process two 100 L samples with two total days in the field for each data collection month. We will attempt to coordinate such that McCain wells will be sampled in the morning (9-12 pm) followed by the Othello wells (12 – 5 pm) and

the surface water sampled at the end of the water sampling or on the second day. Grouping sampling by the well owner is required to coordinate access and staff time, but grouping and timing may change depending on staff availability.

7.1.1 Field parameters and laboratory analytes to be measured

See Section 3.2.3.

Table 14. Sample collection plan for irrigation season (2026).

Time	Sample Tests	Sample Type (Location Count)	Locations
Field work [1, 2, 3, 4] Irrigation season 2026 Sequencing Batch A & B	Virus (Lab Duplicate) Flow Cell (pH, DO, T, TDS, conductivity) Bacteria (*E. Coli,* Coliforms, Enterococci) (Duplicate)	Surface Water (2): Injection supply	EL Canal #1 EL-68 Canal #2
		Groundwater (8): GW Injection Well Test Proposed Injection Well Control Curtain < 1.5 mile Curtain > 1.5 mile	Othello Well 3R Othello Well 8 Othello 9 Othello 5, 6; McCain 2 McCain 3, 4
	Cryptosporidium Giardia	Surface Water (2): Injection supply	EL Canal #1 EL-68 Canal #2
		Groundwater (3): GW Injection Well Test Proposed Injection Well Control	Othello Well 3R Othello Well 8 Othello 9
Field work [5, 6, 7] Non-irrigation season 2026 Sequencing Batch C	Virus (Lab Duplicate) Flow Cell (pH, DO, T, TDS, conductivity) Bacteria (*E. Coli,* Coliforms, Enterococci)	Groundwater (8): GW Injection Well Test Proposed Injection Well Control Curtain < 1.5 mile Curtain > 1.5 mile	Othello Well 3R Othello Well 8 Othello 9 Othello 5, 9 McCain 2, 3, 4
	Cryptosporidium Giardia	Groundwater (3): GW Injection Well Test Proposed Injection Well Control	Othello Well 3R Othello Well 8 Othello 9

Notes: This includes surface water and groundwater (GW) sampling and non-irrigation season (2026) GW sampling. See Table 15 for tests per location and Figure 14 for map of locations within a radius of 1.5 miles of injection well Othello 3R. Surface water sampling will begin on canal transport from 10 miles north of Moses Lake, at bifurcation of East Low (EL) Canal and bridge near Well 8 (EL-68 Canal #1).

7.3 Modeling and analysis design

Not applicable. This is described in Phase 2 QAPP: Characterization of in situ virus transport and inactivation in the groundwater of Columbia River basalt aquifers: Modeling.

7.4 Assumptions of study design

When we originally designed this study, the wells included assumed the downstream gradient East-West sampling from Well 3R which was used as an injection well and Well 8 which is proposed for future injections. Well 9 was proposed as a control well since it is upgradient to the injection sites and not expected to be impacted by any surface water injection. Figure 17 shows that these assumptions may be more complicated at the scale of the investigation that a regional assumption.

7.5 Possible challenges and contingencies

There are various challenges that could arise in this study, including:

1. If filter samples experience temperature fluctuations, that could impact sample results. Therefore, samples will be transported on cold chain and the samples and ice packs checked upon receipt in the laboratory. If the samples are stored for any length of time after receipt prior to processing, they will be placed in the refrigerator. The chain of custody forms will be utilized to track collection-to-processing times, to ensure processing within timeframes specified in the protocols for each analyte. **Contingency**: If received samples are found to exceed 10°C, samples will be discarded, and the field visit will be rescheduled.

2. If no microbial detection is measured, matrix spike controls will be tested to examine matrix inhibition effects. Controls will be run to ensure functionality of the processing and analysis methods used. **Contingency:** If inhibition is detected additional nucleic extraction methods will be evaluated to minimize inhibition. If inhibition persists after incorporation of inhibition technology, samples will be disregarding and new samples will be collected. If inhibition persists in second sampling, inhibition will be noted, minimized as much as possible and analysis will proceed.

3. If there is no *Cryptosporidium* in our samples, then we will use the spiked GC samples to be able to characterize our ability to detect *Cryptosporidium* and giardia. This allows us to incorporate 0 as an endpoint with 95% (standard deviation of 5% around spiked sample contributions). We expect that *Cryptosporidium* and giardia will be highest at the opening and first pulse of irrigation water. **Contingency:** If method controls behave as intended results will be reported, if method controls are not as expected, a seeded recovery study will be initiated.

Cryptosporidium and Giardia are not being used as biomarkers for viruses. They are included as another relevant target under the provisions of enhanced surface water treatment rule regarding groundwater under the direct influence of surface water.

We will consult with the project partners and collaborators to review our prioritization for the next steps and to optimize sampling and information obtained.

7.5.1 Logistical problems

Potential problems associated with logistics:

- Access to private property owned by McCain Foods and City of Othello requires coordination with multiple staff.
- Surface water sampling assumes EL-58 canal has water flow March – August.
- Coordination of *Cryptosporidium* and giardia tests with Analytical Services, Inc.

7.5.2 Practical constraints

Practical constraints that can interfere with a project include scheduling problems with sampling one day per month in coordination with laboratory steps as well as equipment failure, although we have made plans to have backup systems in place for power, pumps, and all electrical and mechanical equipment. Shakedown tests of the sampling process have been conducted at the University of Washington in Seattle, but practical issues may arise with water sampling in Othello.

7.5.3 Schedule limitations

No schedule limitations have been identified.

8.0 Field Procedures

8.1 Invasive species evaluation

Washington law prohibits the transportation of all aquatic plants, animals, and many noxious weeds. Assess the possibility of invasive species contamination of both protective gear and sampling equipment, including boats, rafts, waders, nets, and other devices used in the water. Ecology's SOP EAP070 (https://fortress.wa.gov/ecy/publications/SummaryPages/1803201.html) addresses how to minimize invasive species transport and contamination.

Field activities are not located within an Area of Extreme Concern. As such, decontamination procedures are not required. Equipment that will contact water, sediments, plants, or the ground include:

- Waders and shoes
- Probes
- Collection bag with tubing, clamp, and rope
- Pump, volumizer, and tank

Waders and shoes will be assessed and cleaned using clean water and scrub brushes as necessary. Probes will be rinsed with deionized water before and after use, and cleaned by soaking the electrodes in alcohol, then rinsing. The collection bag, tubing, clamp, and rope are single use items and will be placed in a biohazard bag for autoclaving upon return to the laboratory. The pump, volumizer and tank will have the sample flow through them. They will be cleaned using clean water and for the tank, a scrub brush as necessary.

8.2 Measurement and sampling procedures

8.2.1 Data for pH, Temperature, Conductivity, Dissolved Oxygen, ORP

The manual describes the characteristics, operation, calibration, and maintenance of the Aqua TROLL 400 Instrument (In-Situ Inc., 2023), with integrated sensors for DO, conductivity, pressure (level), temperature, and optional pH/ORP.

Key Features

- **Sensors:** RDO optical DO (EPA-approved), 4-electrode conductivity, thermistor temp (±0.1°C), vented pressure, smart pH/ORP plug-in.
- **Output:** Modbus/RS485 or SDI-12; customizable cable up to 1,219 m; no internal logging (external controller needed).
- **App Integration:** VuSitu mobile app for Bluetooth setup, single/continuous readings (2-sec intervals), data transfer, reports.

Calibration and Maintenance

- **Cal**: 1- or 2-point pH (buffers), DO via air saturation or yeast; auto salinity/baro/density corrections available.
- **Caps**: Replace RDO cap every 1-2 years; pH storage in buffer; clean with soap for oils, rinse for inorganics; O-ring kits for seals.
- **Safety**: IP68 rated; electrical precautions for wiring.

Low-Flow Flow Cell

Aqua TROLL 400 Low-Flow Flow Cell includes flow cell with removable end cap (installed with O-ring and stainless-steel sleeve). The Low-Flow Sampling equipment is used to direct the flow of water past the sensors of the Aqua TROLL 400 Instrument during purging and low-flow sample tests. The seal between the instrument and the flow cell prevents water oxygenation prior to analysis. The 3- way intake valve can be used to divert flow for sample collection. The anti-siphon check valve prevents back flow at the outlet.

8.2.2 *Cryptosporidium* & Giardia Sampling Protocol

Sampling for *Cryptosporidium* and *Giardia* will follow EPA Method 1623.1 Section 12.2 with Envirochek® HV Sampling Capsules. See Table 15 for sample container information.

8.2.3 Viral Sampling Protocol

Purpose: Collect sufficient water at a rate that allows efficient sample filtering to collect a representative virus sample. To filter environmental samples for surveillance and characterization of native viruses in surface and groundwater samples.

Principle: Surface water samples will be collected by placing a hose/tubing into the source water and pumping it through a ViroCap filter. The groundwater samples will be collected from a spigot at the wellhead, then temporarily stored in a tank/carboy for filtration by pumping through a ViroCap filter. When water is filtered through the ViroCap filter, microorganisms such as viruses are captured, or adsorbed, onto the filter material through electrostatic interactions. This results in high-sensitivity virus surveillance from environmental waters. The filters must be eluted to recover viruses and assay samples.

Biosafety: Although working with the water sources in this project has a low risk of biological safety hazard, adherence to best biosafety practices and proper use of personal protective equipment are necessary. Gloves exposed to the source water or potentially biohazardous materials will be removed and discarded. New, clean gloves will be donned prior to resuming sample collection activities. Gloves will be changed prior to touching other “clean” materials.

See Table 15 for sample container information.

8.2.4 Pre-Sampling, at Laboratory:

1. Freeze cold packs at -20°C. When ready for sample collection, place frozen cold packs in cold chamber.
2. Label ViroCap filter with proper identifying information as described in section 8.5
3. Pack car kit with the following:
    - Sample station components:
        A. Sprinkler pump (Dayton 5RWH6 or similar)
        B. Voltage regulator (15 amp minimum)
        C. Power station (1800 kWh minimum)
        D. Long tubing (3 ft minimum) with two tubing adapters with a hose barb and threaded female fitting (source water/carboy to pump inlet)
        E. Collection tank/carboy (40 L or larger)
        F. Medium tubing (~2 ft) with two tubing adapters with a hose barb and threaded female fitting (pump outlet to ViroCap filter inlet)
        G. ViroCap filter
        H. Medium tubing (~2 ft) with two tubing adapters with a hose barb and threaded female fitting (ViroCap filter outlet to volumizer inlet)
        I. Volumizer
        J. Long tubing (3 ft minimum) with one tubing adapter with a hose barb and threaded female fitting (volumizer outlet to discharge water)
    - Sample collection and transportation items
        - Frozen cold packs (2 per sample)
        - Cooler
        - Whirl-pak bag
        - Large autoclave bag
        - Medium autoclave bags
        - Bag fasteners
        - Wipes
        - Bottle with 70% ethanol
        - Appropriately sized gloves
        - Hand sanitizer
        - Clipboard with chain-of-custody form
        - Permanent marker
        - Pen
        - Lab Notebook
        - Meter/Thermometer/pH/TDS

8.2.5 At field sampling location:

Assemble sampling station as in Figure 19 (see above packing list for component details):

- Connect (A) pump to (B) voltage regulator and the (B) voltage regulator to electrical outlet or (C) portable power station
- Connect (D) hose from water ([E] tank or source water) to (A) pump
- Connect (F) hose from (A) sprinkler pump to (G) ViroCap filter
- Connect (H) hose from (G) ViroCap filter to (I) volumizer. Tubing is new for each sample.
- Connect (J) hose from (I) volumizer to drainage location approved by the well owner
- Connect (K) from well spicket into water tank (E). This connection will include a three-way splitter valve for dual parallel sampling and the third line for the low flow cell water quality sampling using the Aqua TROLL 400 (not shown in Figure 19).

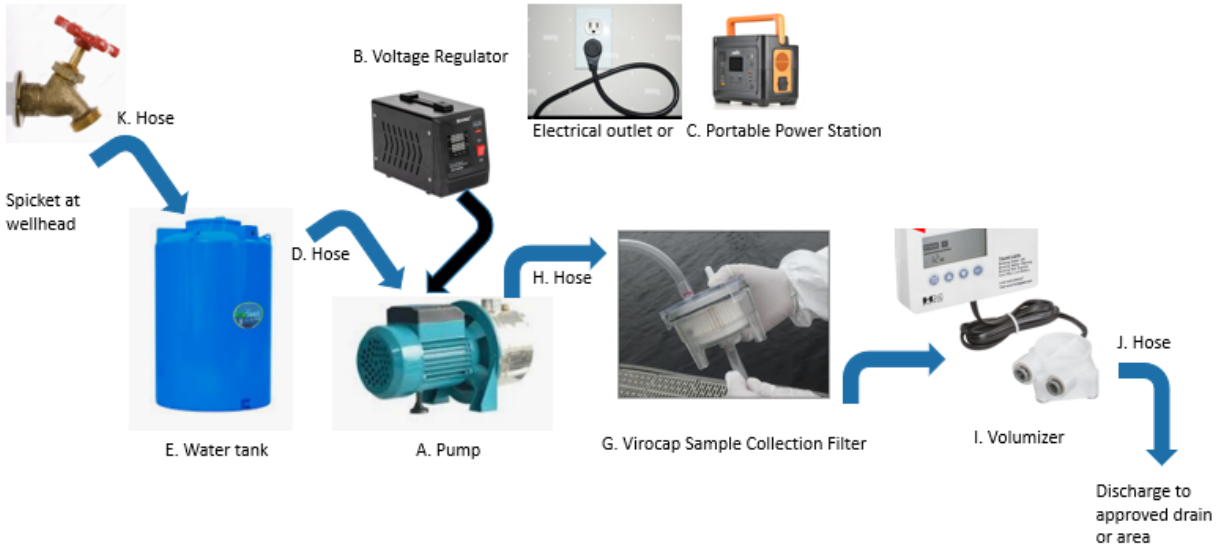


Figure 19. Virus sampling workflow from wellhead spigot of groundwater well, reservoir/tank, pump, filter, volumizer to outlet/discharge.

8.2.6 Prepare to collect the samples

- At a groundwater sampling location, sterilize spigot with flame prior to tubing connection, connect the tubing adapter directly to the spigot and fill the tank/carboy.
- Prepare to collect water sample by turning on the spigot from the groundwater well for 20 min.
    - Once the water tank is half full, run the pump for 3 minutes and flush all the other tubing three times with all water draining to the approved drain or area agreed to in advance with the well owner.
- Fill water tank/carboy.
- At a surface water sampling location, remove the tubing adapter from the long tubing and place the end of the tubing directly into the water source.

- Prepare to collect water sample by running the pump for 3 minutes and flush all other tubing three times with all water draining to the approved drain or area agreed to in advance with the well owner.
- Fill water tank/carboy.
- Collect samples
- Ensure the pump is primed
- Turn on the pump and voltage regulator
- Adjust the voltage regulator so the volumizer reads 2 L/min
- Use the volumizer to record the water volume that has passed through the filter and time (expect approximately 50 minutes to filter 100 L)

Dissemble the setup

- Detach the filter from the pump and volumizer. Drain any remaining water in the filter into the identified drainage area.
- Drain from the inlet and outlet.
- Gentle shaking or rotation may be required.
- Spray 70% ethanol onto a wipe and gently wipe the filter housing, avoiding the inlet and outlet ports.
- Place the filter in a dedicated individual Whirl Pak bag and store it in cooler with ice packs for return to the laboratory.
- Drain any water remaining in the tank/carboy by connecting the pump to the volumizer.
- If the last sample of the day, place reusable tubes into a biohazard bag for return to the laboratory and disinfection.
- Place any additional disposable items in a separate biohazard bag for disinfection and disposal.
- Sanitize hands with alcohol-based hand sanitizer.

8.3 Containers, preservation methods, holding times

Table 15. Sample containers, preservation, and holding times.

Parameter	Matrix	Container	Preservative	Holding Time
Conductivity	Water	P, FP, G	Cool, ≤6°C	28 days
Total dissolved solids	Water	P, FP, G	Cool, ≤6°C	7 days
pH	Water	P, FP, G	Cool, ≤6°C	14 days
Viruses	Water	Virocap	1-10°C	48 hours from receipt
Cryptosporidium	Water	Envirocheck	1-10°C	96 hours
Giardia	Water	Envirocheck	1-10°C	96 hours

8.4 Equipment decontamination

The risk of contamination from outside the sampled environment is low. This laboratory has standard operating procedures using a combination of procedures using new filters, sterilized tubing, and sterilization and flushing of major equipment. We will not be using new equipment for each sampling event, except for Virocap and Envirocheck filters that are new for each sample. The tubing and tank/carboy will be sterilized with 70% ethanol before each sampling day. Throughout the day, tubing will be replaced with sterile tubing (H. in Figure 19), whereas the tank/carboy, pump, and volumizer will be flushed prior to each sample collection. Additionally, the filter housing and tubing connected to the new ViroCap sample collection filter (G. in Figure 19) will be sterilized for each sampling event and location. ViroCap filters are not reusable, but the housing surrounding the filter and the tubing are sterilized and set up to reduce contamination risk before each field trip. Due to the mechanism of capture on the electropositive filter and pathogen survival, it is unlikely pathogens will remain and be measurable from the tubing, tank/carboy, pump, or volumizer throughout the day after flushing with sampling source water at each site before collecting samples.

8.5 Sample ID

Sample IDs will be established with the following format: Collection date (yyyymmdd), site ID (4 characters), filter purpose (2 characters; virus [vr] or *Crypto/Giardia* [cg]), and replicate number (2 numbers).

8.6 Chain of custody

Virus Transport and Inactivation in Groundwater

Chain of Custody Record: Sample Collection

Sample ID: _____ Collected by: _____

Date collected: _____ Time collected: _____

Site Location:

_____

Weather conditions:

_____

Volume: _____

Filter used: _____

Sample source (examples: well, irrigation channel):

_____

Water characteristics:

Characteristics	Measurement
Conductivity	
Total dissolved solids	
Salinity	
pH	

Notes:

_____

_____

Delivered/shipped with cold packs? Yes No

8.7 Field log requirements

A field log is an important component of many projects. It is used to record irreplaceable information, such as:

- Name and location of project
- Field personnel
- Sequence of events
- Any changes or deviations from the QAPP or SOPs
- Environmental conditions
- Date, time, location, ID, and description of each sample
- Field instrument calibration procedures
- Field measurement results
- Identity of QC samples collected
- Unusual circumstances that might affect interpretation of results

Recommended field log practices include:

- Use bound, waterproof notebooks with pre-numbered pages.
- Use permanent, waterproof ink for all entries.
- Make corrections with single line strikethroughs, initial and date corrections. Do not use correction fluid such as White-Out.

Electronic field logs may be used if they demonstrate equivalent security to a waterproof, bound notebook. A bound, waterproof notebook will be used as the field log to note any changes from the QAPP or SOPs. This is in addition to the Chain-of-custody forms, which will be used for sample specific information.

8.8 Other activities

These may include:

- Briefings and training for field staff.
- Periodic maintenance for field instrumentation.
- Procedures and equipment for homogenizing non-aqueous matrices.
- Procedure for lab notification regarding sampling and other topics.
- Field checks to compare planned data collection with actual data or samples collected to ensure any additional information can be recorded or measured prior to departing the sampled sites.

9.0 Laboratory Procedures

9.1 Lab procedures table

Laboratory procedures are outlined in Figure 20., as well as in Table 16, Table 17, and Table 18.

Table 16. Measurement methods for each analyte: virus.

Analyte	Sample Matrix	Samples (locations (LOC)* duplicate (LAB)* months (M))	Expected Range of Results	Detect Limit	Sample Prep Method	Analytical (Instrument) Method
Viruses	Groundwater	112: 8 LOC x 2 LAB x 7 M	genome completeness: 90-95%, range [45% - 100%]	1–100 copies of viral RNA or DNA per 100 L	Concentration of field filtrate, nucleic acid extraction	sequencing
Viruses	Surface water	20: 2 LOC x 2 LAB X 5 M	genome completeness: 90-95%, range [45% - 100%]	1–100 copies of viral RNA or DNA per 100 L	Concentration of field filtrate, nucleic acid extraction	sequencing
Viruses	QA/QC	7: 1 LOC x 7 M				
Viruses	Contingency	5 samples				
Viruses		Total Budgeted Samples: 144				

Notes: Months (M) include continuous sampling once per month. One QA/QC sample will be collected (in month 2) at each location (LOC). Single field samples will be used to generate duplicate laboratory samples extracted during lab analysis for duplication of the sequencing process (LAB).

Table 17. Measurement methods for each analyte: Protist.

Analyte	Sample Matrix	Samples (locations (LOC)* duplicate (LAB)* months (M))	Expected Range of Results	Sample Prep Method
Crypto. Giardia	Groundwater	15 samples: 3 LOC x 3 M. Up to 3 Sub-samples	< 1 to 100+ oocysts per 100 liters	Envirocheck filtration and concentration. EPA Method 1623.1
Crypto. Giardia	Groundwater: spike sample	3 samples: 3 LOC x 1 M	known quantity of protozoa	EPA Method 1623.1 Matrix Spike (MS)
Crypto. Giardia	Surface water	8 samples: 2 LOC x 4 M Up to 3 Sub-samples	< 1 to 100+ oocysts per 100 liters	Envirocheck filtration and concentration
Crypto. Giardia	Surface water: spike sample	2 samples: 2 LOC x 1 M	known quantity of protozoa	EPA Method 1623.1 Matrix Spike (MS)
Protists		Total budgeted samples: 22		

Notes: Months (M) include alternating months of sampling to capture the beginning, middle, and end of the collection period seasonality. One QA/QC spike sample will be collected (in month 3 or 4) at each location (LOC). Single field samples will be used to generate sub-samples from < 2 mL packed pellet, extracted during lab analysis (LAB) following EPA Method 1623. Detection limit is 10 – 100+ oocysts /cysts per 100 liters using immunomagnetic separation (IMS) and immunofluorescence assay (FA) microscopy analytical methods.

Table 18. Measurement methods for each analyte: Bacteria. Months (M) include continuous sampling once per month.

Analyte	Sample Matrix	Samples (locations (LOC)* duplicate (FIELD)* months (M))	Expected Range of Results	Detect Limit	Sample Prep Method	Analytical (Instrument) Method
E. coli, coliform Enterococci	Groundwater	112 samples: 8 LOC x duplicate FIELD (2) x 7 M	1-2419.6 MPN/100mL	1 MPN/100 mL	9223 B Colilert® 9230 D Enterolert®	Standard Methods for the Examination of Water and Wastewater, 23rd Edition, 2017
E. coli, coliform Enterococci	Surface water	20 samples: 2 LOC x duplicate FIELD (2) x 5 M	1-2419.6 MPN/100mL	1 MPN/100 mL	9223 B Colilert® 9230 D Enterolert®	Standard Methods for the Examination of Water and Wastewater, 23rd Edition, 2017
Bacteria	QA/QC	7:1 LOC x 7 M				
Bacteria	Contingency	5 samples				
Bacteria		Total Budgeted Samples: 144				

9.2 Sample preparation method(s)

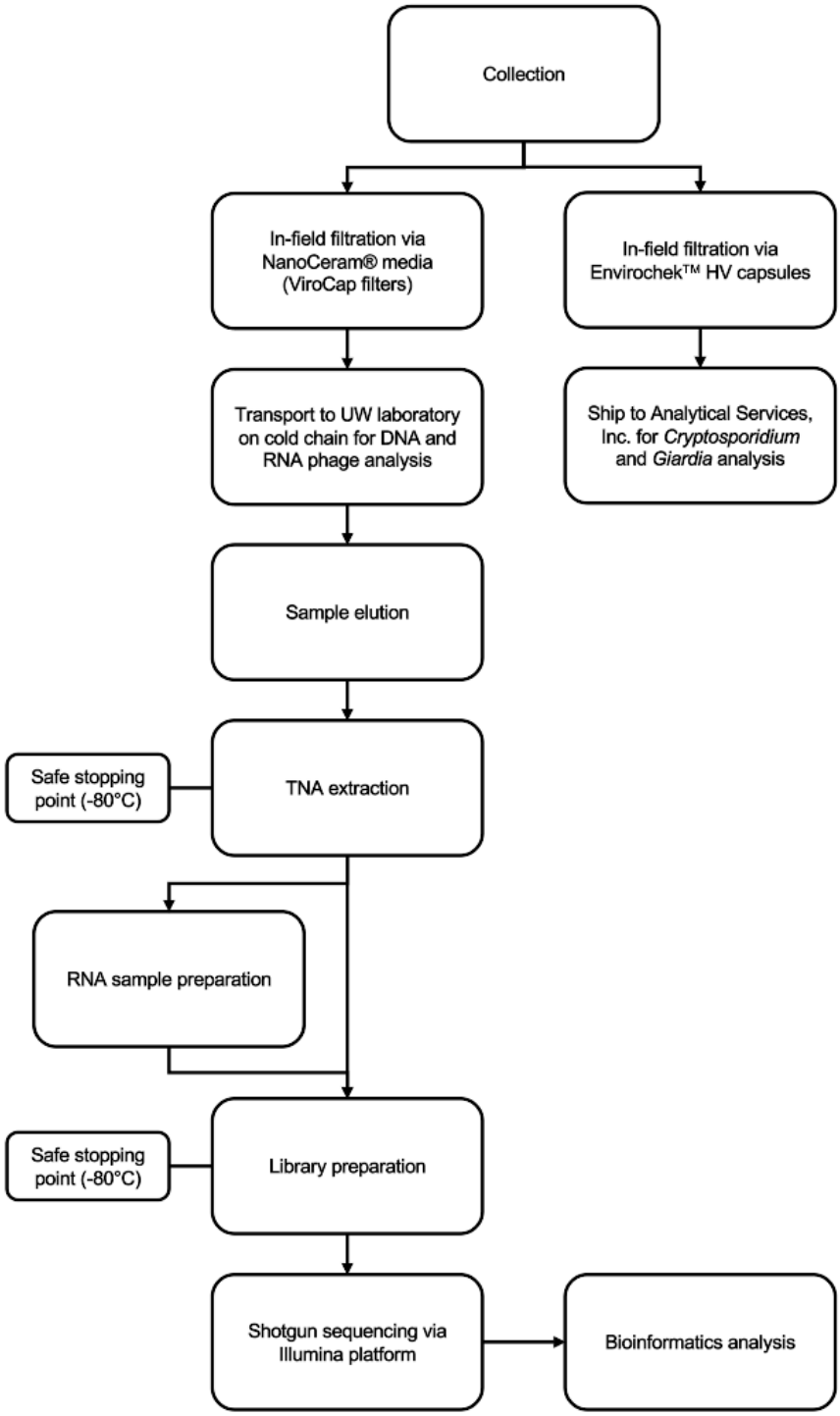


Figure 20. Virus, *Cryptosporidium* and *Giardia* sample processing workflow.

Notes: After water collection, filtration, transport and elution, total nucleic acid extraction (TNA) includes both DNA and RNA sample preparation into libraries submitted to the genetic sequencing platform.

9.2.1 Virus Methods

9.2.1.1 Filter Elution Protocol

Purpose: To elute viruses from 5" ViroCap filter in filter housing.

Principle: When water is filtered through the ViroCap filter, viruses are captured, or adsorbed, onto the filter material through electrostatic interactions. This results in high-sensitivity virus surveillance from environmental waters. The filters must be eluted to recover viruses and assay samples. A high-protein, high-pH beef extract eluent is used to elute viruses from the ViroCap filter for later analysis.

Biosafety: Adherence to best biosafety practices and proper use of personal protective equipment (PPE) (*e.g.*, gloves, lab coat) are recommended.

Cross contamination: To help prevent cross-contamination, elute filters in a biosafety cabinet and use sterile technique. Disinfect spills using an appropriate primary disinfectant (*e.g.*, bleach, Virkon, etc.).

Reagents:

- Beef extract eluent
    - 1.5% beef extract (Becton Dickinson, Franklin Lakes, USA; Part # 212303)
    - 0.05 M glycine (Tokyo Chemical Industry, Tokyo, Japan; Part # G0099)
    - pH 9.5
- 5 M hydrochloric acid (HCl) (VWR International, Radnor, USA, Part # BDH7419-1)
- 5 M sodium hydroxide (NaOH) (VWR International, Part # BDH7225-1)
- 0.5% bleach (1:10 dilution of 5% bleach [sodium hypochlorite])

Materials:

- ViroCap filter inside reusable filter housing
- Syringe
- Bilge pump with associated tubing attachments or peristaltic pump
- Sterile collection cup with lid
- sterile collection bottle
- (2) VacuGuard filters
- Silicone Tubing:
    - 33-cm collection cup outlet tubing (B1)
    - 3.3-m bilge pump inlet tubing (B2)
    - 10-cm filter air vent tubing (B3)
    - 10-cm filter inlet tubing (C1)
    - 6.4-cm filter outlet tubing (C2)
    - pH strips (range 6-10)
    - 1-mL pipet tips

Preparation:

- Prepare eluent (1.5% beef extract, 0.05 M glycine, pH 9.5)
- Autoclave at 121°C and 18 psi
- Cool to room temperature prior to use
- Store at 4-8°C for up to one week or at -20°C for up to three months
- Ensure all necessary tubing is autoclaved (121°C and 18 psi)
- Label a collection bottle with sample name, date, and other relevant information

Method:

- Don personal protection equipment (e.g., gloves and lab coat).
- Sterilize workspace surfaces with an appropriate primary disinfectant (e.g., 0.5% bleach solution, UV disinfection, Virkon, etc.).
- Sterilize workspace surfaces with an appropriate primary disinfectant (e.g., 0.5% bleach solution, UV disinfection, Virkon, etc.).
- Secure pump outside of a Class II biosafety cabinet (BSC) using two C-clamps.
- Assemble metal filter stand by placing legs inside slots on base. Circle supports attach to shorter legs and semi-circle supports attach taller legs, with opening facing circle support.
- In the BSC, place metal filter stand inside a tray or on bench paper (optional).
- Place collection cup in circle collection cup holder.
- Attach the collection cup to the pump. The collection cup attaches to the 33 cm silicone collection cup outlet tubing (B1). To prevent aerosols entering the pump, attach a VacuGuard filter to the B1 tubing, with the inlet facing the collection cup. Connect the VacuGuard outlet and the bilge pump using the 3 m silicone bilge pump inlet tubing (B2).
- Attach the 6.4 cm silicone filter outlet tubing (C2) to the collection cup.
- If any liquid remains in the filter, empty into a waste container with disinfectant (e.g., bleach).
- Carefully remove bottom black cap from filter outlet, then attach to the C2 tubing on the collection cup and place in the filter stand.
- Remove the white cap from filter vent, then attach the 10 cm silicone filter air vent tubing (B3) and VacuGuard filter. The VacuGuard inlet should face the ViroCap filter. This helps prevent cross-contamination.
- Remove black caps from the filter inlet, then attach the 10 cm silicone filter inlet tubing (C1).
- Suction 150 mL eluent into syringe, then slowly inject eluent through the injection tubing.
    - Watch to ensure liquid does not contact the VacuGuard filter.
    - If the filter cavity completely fills with liquid prior to injection of the full 150 mL, stop injection and dispose of excess eluent in the syringe into a waste collection container (*e.g.*, bleach).

    - If liquid contaminates the VacuGuard filter, pause injection and replace the VacuGuard filter.
- Let stand for 15 minutes contact time.
- Slowly and methodically move the bilge pump handle until all eluate exits the filter.
    - Do not pump with excessive force, as this may damage the bilge pump.
- Eluates should collect in enclosed collection cup.
    - If eluate does not exit the filter, re-tighten the collection cup lid and check tubing connections for sealing.
- Do not overfill the collection cup.
    - If the collection cup fills and eluent remains in the filter, remove the collection cup, pour the eluate into the collection bottle, and reattach the collection cup.
    - Continue pumping.
- Avoid liquid in tubing
- Perform a second elution by repeating steps 10.3.14-10.3.16 using 150 mL fresh eluent.
    - First and second eluates are combined in the collection cup, which should have sufficient capacity for both.
- Carefully detach the tubing (B1, B2, B3, C1, and C2), and place used tubing in an autoclavable bag or bucket for sterilization and reuse (11.2.2).
- Pour the remaining eluate into the labeled collection bottle.
    - Immediately adjust eluate pH to 7.0 - 7.5 using 5 M HCl and 5 M NaOH.
- Store sample at 4°C until secondary concentration.

Clean up:

- After use, autoclave the following items at 121°C and 18 psi. Then, wash the items and re-autoclave so they can be re-used:
    - Elution device tubing
    - Elution device stand (at end of experimental day – can re-use between filters on a given day, if no spills occur)
- Do not autoclave the following:
    - Bilge pump. Wipe down with appropriate disinfectant (*e.g.,* Virkon).
    - VacuGuard filters. Non-contaminated VacuGuard filters can be re-used.
    - Syringe. Rinse three times with sterile deionized water and store in secure, clean location for reuse.
- Sterilize all surfaces in elution area with an appropriate disinfectant (e.g., 0.5% bleach solution, Virkon, UV disinfection, etc.).

9.2.1.2 Secondary Concentration: PEG/NaCl Precipitation Protocol

Purpose: To concentrate ViroCap filter eluate to a volume of ~10 mL.

Principle: Polyethylene glycol (PEG)/sodium chloride (NaCl) precipitation concentrates viruses, which further concentrates ViroCap filter eluate. Using this method, viruses bind to dissolved PEG polymer chains. The sample shakes overnight in a cold chamber to maximize virus binding and survival. After shaking, the sample is centrifuged, the supernatant discarded, and the pellet

collected for analysis. This results in a high recovery of viruses after elution from ViroCap filters.

Biosafety: Working with virus filters presents a biological safety hazard. Adherence to best biosafety practices and proper use of personal protective equipment (PPE) (*e.g.*, gloves, lab coat) are necessary.

Cross contamination: To help prevent cross-contamination, perform secondary concentration in a biosafety cabinet and use sterile technique. Disinfect spills using an appropriate primary disinfectant (*e.g.*, bleach, Virkon, etc.).

Reagents:

- 14 g PEG 8000 (VWR International, Radnor, USA; Part # 97061-102)
- 1.17 g NaCl (Merck Millipore, Burlington, MA; Part # EMD-SX0420-1)
- 10 mL sterile phosphate-buffered saline (PBS), pH 7.4 (VWR International, Part # E404-100TABS)

Materials:

- Lab coat
- Gloves
- (1) 125-mL bottle
- (3) 50-mL conicals
- (1) 250-mL graduated cylinder
- (1) waste collection bottle
- (1) 10-mL pipet

Equipment:

- Shaker in a cold chamber
- Centrifuge
- Vortex
- Scale
- Biosafety cabinet

Method:

- Don personal protection equipment (*e.g.*, gloves and lab coat).
- Sterilize workspace surfaces with an appropriate primary disinfectant (*e.g.*, 0.5% bleach solution, UV disinfection, Virkon, etc.).
- Collect sample from previous step (elution/primary concentration).
- Measure sample volume in sterile graduated cylinder.
- Transfer sample to a sterile 125-mL bottle.
- Per 100 mL sample, add 14 g PEG 8000 and 1.17 M NaCl (final concentration: 0.2 M NaCl).

- For example, if the sample volume is 110 mL, add 15.4 g PEG 8000 and 1.29 g NaCl.
- $\frac{14\ g\ PEG\ 8000}{100\ mL} \times 110\ mL = 15.4\ g\ PEG\ 8000$

- $\frac{1.17\ g\ NaCl}{100\ mL} \times 110\ mL = 1.29\ g\ NaCl$

- Parafilm sample bottle.
- Shake sample vigorously by hand until all PEG 8000 and NaCl are dissolved.
- Shake sample on a shaker overnight (14-18 hours) at 4°C, 200 RPM.
  - If no cold chamber is available, place cold packs around sample in shaker.
- After shaking, transfer sample to centrifuge conicals compatible with available centrifuge rotor (*e.g.*, 150-mL bottle, (3) 50-mL conicals, etc.).
- Spin sample at 6500 x G, 4°C for 30 minutes (swinging bucket rotor).
  - If centrifuge does not spin at 6500 x G, sample can be spun at slower speed (down to 3000 x G), as needed
- Discard supernatant into a waste collection bottle.
- Add 10 mL sterile PBS, pH 7.4 to pellet.
- Vortex 5-10 minutes at maximum speed to completely resuspend pellet.
- Sample is ready for chloroform extraction (purification).
- Prepare sample for appropriate next step. Select one of the following:
  - Immediately perform purification/chloroform extraction Store overnight at 4°C.
  - Store short term (<2 weeks) at -20°C.
  - Store long term (>2 weeks) at -80°C.

Clean-up:

- Autoclave waste collection bottle at 121°C for 30 minutes or add 5% bleach to bottle for a 1:10 bleach dilution and let contact for 30 minutes (Ex. add 20 mL bleach for 200 mL waste).
- Collect all other waste items in a biohazard bag and autoclave at 121°C for 60 minutes.
- Disinfect all work surfaces with UV light, bleach, or other primary disinfectant.

9.2.1.3 Molecular Methods: Nucleic Acid Extraction

Purpose: Nucleic acid extraction is a method to extract RNA or DNA from concentrated environmental groundwater and surface water samples for subsequent use with molecular methods such as PCR or sequencing.

Principle: RNA/TNA is extracted from concentrated environmental water samples via lysis, mechanical disruption (vortexing and/or bead-beating), removal of inhibitors, purification, and elution of RNA/TNA.

Reagents:

- 0.5% HOCl bleach solution (1:10 dilution of 5% bleach [sodium hypochlorite])
- 70% EtOH

Materials:

- Qiagen RNeasy PowerWater or PowerFecal Kit
- Qiagen DNeasy PowerWater or PowerFecal Kit
- Waste collection container
- 1-mL pipet tips
- 200-µL pipet tips
- 20-µL pipet tips
- 1.5-2 mL microcentrifuge tubes
- Bead-beating tubes
- Permanent marker
- Lab coat
- Nitrile gloves
- Other consumables
- Equipment:
- Class II biosafety cabinet
- Serological pipettor
- 100-1000 µL pipettor
- 20-200 µL pipettor
- 2-20 µL pipettor
- Autoclave
- Vortexer
- Microcentrifuge

Preparation:

- Label microcentrifuge tubes with sample name, date, and other relevant information.

Method:

- Don personal protection equipment (*e.g.*, gloves and lab coat).
- Sterilize workspace surfaces with an appropriate primary disinfectant (*e.g.*, 0.5% HOCl bleach solution, UV disinfection, Virkon, etc.).
    - If the samples were stored at -20°C or -80°C prior to DNA extraction, thaw on ice.
- Perform extraction in the biosafety cabinet according to manufacturer's instructions (See Appendix)
- Input sample:
- Beads used:
- Elution in: xx µL

Notes:

- After nucleic acid extraction, the sample should be stored at -20°C (<1 month) or -80°C (>1 month).
- Back-up aliquots of all samples should be preserved/stored for repeat extraction if needed.

Clean up:

- Autoclave liquid waste at 121° and 125 kPa or add 5% HOCl bleach to bottle for a 1:10 bleach dilution and let contact for 30 minutes (e.g., add 100 mL bleach for 1000 mL waste).
- Autoclave the following items at 121°C and 125 kPa. Then, wash the items and re-autoclave so they can be re-used:
    - Tube racks
    - All other reusable supplies
- Sterilize the following items by autoclaving at 121°C and 125 kPa, and then discard:
    - Waste (e.g., tubes, pipette tips, etc.)
- Disinfect all work surfaces with an appropriate disinfectant (e.g., 0.5% HOCl bleach solution, Virkon, UV disinfection, etc.).

9.2.1.4 Molecular Methods: RNA and DNA Quantification

RNA and DNA concentrations in extracted samples will be measured using Qubit™ RNA High Sensitivity (HS) and Qubit™ DNA High Sensitivity (HS) Assay Kits, following the manufacturer's protocols (see Appendix). Quantification will be performed using a Qubit™ 4 Fluorometer located in the EOHML. These assays are designed for accurate quantification of low concentrations of nucleic acids using fluorescent dyes that selectively bind to RNA or DNA.

Brief Method Summary

Preparation of Working Solution:

- Prepare the Qubit™ working solution by diluting the Qubit™ reagent 1:200 in the Qubit™ buffer according to the manufacturer's instructions.

Sample and Standard Preparation:

- Label assay tubes for standards and samples.
- Add 1–20 µL of each RNA or DNA sample to the appropriately labeled tubes.
- Add Qubit™ working solution to each tube to reach the total assay volume specified by the kit (typically 200 µL).
- Mix thoroughly by vortexing for 2–3 seconds.

Incubation:

- Allow samples to incubate at room temperature for 2 minutes to ensure dye binding.

Measurement:

- Insert each tube into the Qubit™ Fluorometer and select the corresponding assay type (RNA HS or DNA HS).
    1. The instrument automatically calculates sample concentration based on the standard curve generated by the included calibration standards.

Data Recording:

- Record concentrations (ng/µL) as displayed by the fluorometer.
    1. For quality assurance, replicate measurements will be performed, and average values will be reported.

Sequencing Preparation and Analysis

Samples will be prepared for sequencing using Illumina's Nextera DNA Flex Library Preparation Kit**,** following the manufacturer's guidelines (see Appendix). Sample input concentrations will be determined based on Qubit™ quantitation results to ensure optimal library preparation and sequencing quality.

Brief Methods Summary: Library Preparation and Pooling

- Tagmentation and Amplification:
  DNA samples will undergo simultaneous fragmentation and adapter tagging (tagmentation) as per the Nextera DNA Flex protocol. Indexed adapters will be added during PCR amplification to enable multiplexing.
- Library Quantification and Normalization:
  Prepared libraries will be quantified using Qubit™ fluorometric analysis, and fragment size distributions will be assessed using an Agilent Bioanalyzer or TapeStation for quality control (QA/QC). Libraries will be normalized to appropriate concentrations for pooling.
- Pooling:
  Libraries prepared for sequencing in the same batch will be pooled in equimolar amounts to create a composite library pool. Pool quality will be verified via Bioanalyzer/TapeStation trace evaluation to confirm expected fragment size and absence of adapter dimers.

9.2.1.5 Molecular Methods: Sequencing

The sequencing will be conducted by SeqMatic, Fremont, CA, using an Illumina platform with 2 × 150 bp paired end reads. All sequencing will follow Illumina's standard quality assurance procedures, including cluster generation, sequencing-by-synthesis chemistry, and post-run data quality assessment.

9.2.2 Protozoan Methods: *Cryptosporidium* and Giardia Analysis

After in-field filtration, filters will be shipped overnight under cold-chain conditions to Analytical Services, Inc. (ASI) in Williston, VT, for analysis. ASI will use U.S. EPA Method 1623.1 to quantify

Cryptosporidium and *Giardia* levels in both groundwater and surface water samples. Detailed analytical procedures are provided in ASI Technical Document #110.). The Appendix also includes ASI's Chain of Custody form.

9.2.3 Bacteria Methods

9.2.3.1 Enterococci Analysis

Enterococci levels will be assessed in 100 mL of source water transported from the field site to the Environmental and Occupational Health Microbiology Laboratory (EOHML) under cold-chain conditions. Analyses will be conducted using IDEXX's **Enterolert®** method in accordance with the manufacturer's protocol (see Appendix E: Standard Operating Procedures (SOP)). This method is U.S. EPA-approved and included in the *Standard Methods for the Examination of Water and Wastewater*.

Brief Method Summary: Quanti-Tray® Enumeration Procedure:

- Add the contents of one Enterolert® reagent pack to a 100 mL water sample in a sterile vessel.
- Cap the vessel and shake until the reagent is fully dissolved.
- Pour the sample–reagent mixture into a Quanti-Tray® or Quanti-Tray®/2000 and seal using an IDEXX Quanti-Tray® Sealer.
- Incubate the sealed tray at 41 ± 0.5°C for 24 hours**.**
- After incubation, interpret results Table 19 according to the criteria below. Count the number of positive wells and refer to the MPN table provided with the trays to determine the Most Probable Number (MPN) of enterococci.

Table 19. IDEXX's Enterolert® Result Interpretation

Appearance	Result
No fluorescence	Negative for *Enterococci*
Blue fluorescence under 365 nm UV light	Positive for *Enterococci*

9.2.3.2 *E. coli* and Total Coliform Analysis

E. coli and total coliform levels will be assessed in 100 mL of source water transported from the field site to the Environmental and Occupational Health Microbiology Laboratory (EOHML) under cold-chain conditions. Analyses will be conducted using IDEXX's **Colilert®** method Table 20 in accordance with the manufacturer's protocol (see Appendix E-4). This method is U.S. EPA-approved and included in the *Standard Methods for the Examination of Water and Wastewater*.

Brief Method Summary: Quanti-Tray® Enumeration Procedure:

- Add the contents of one Colilert® reagent pack to a 100 mL water sample in a sterile vessel.
- Cap the vessel and shake until the reagent is completely dissolved.

- Pour the sample–reagent mixture into a Quanti-Tray® or Quanti-Tray®/2000 and seal using an IDEXX Quanti-Tray® Sealer.
- Incubate the sealed tray at 35 ± 0.5°C for 24 hours**.**

After incubation, interpret results as described below and determine the Most Probable Number (MPN) using Table 20 provided with the trays (included in Appendix).

Table 20. Result interpretation for IDEXX's Colilert® method.

Appearance	Result
Less yellow than comparator	Negative for total coliforms and *E. coli*
Yellow equal to or greater than comparator	Positive for total coliforms
Yellow and fluorescent (≥ comparator under 365 nm UV light)	Positive for *E. coli*

9.3 Laboratory Facilities

9.3.1 Size and Layout

The Environmental and Occupational Health Microbiology Laboratory (EOHML) includes over 2,000 sq. ft. of space dedicated to environmental microbiology research. The facility consists of six laboratories:

- Four smaller labs (~100 sq. ft. each).
- Two larger labs (~650 and 1,000 sq. ft., respectively), with the largest subdivided into three specialized workspaces.

This layout allows for the physical separation of tasks and ensures sufficient room for staff to perform procedures without interference, supporting a controlled and efficient workflow designed to minimize cross-contamination.

9.3.2 Functional Design and Containment Controls

The EOHML is intentionally designed to prevent intra-laboratory contamination through clear spatial separation of work areas and a unidirectional workflow from "clean" to "dirty" zones. Movement of materials, supplies, or equipment from "dirty" to "clean" areas is strictly prohibited.

9.3.3 Key Facilities and Zones

Receiving & Staging Area:

- The entryway and clean bay are used for catalog storage, laboratory archives (notebooks), and staging of incoming supplies and samples.

Cleanrooms and PCR Preparation Areas:

- Media Preparation Cleanroom

- Clean PCR Reagent Preparation Workstation (reagent prep hood in a clean bay), isolated from nucleic acid handling areas.

Primary Experimental Laboratories:

- BSL-2 Laboratory – subdivided for multiple experimental workflows
- Water Quality Laboratory – similarly subdivided
- Tissue Culture Laboratory – a single workspace nested within the BSL-2 lab
- Field Laboratory – dedicated to unseeded sample processing; seeded sample work is restricted to the BSL-2, Tissue Culture, and Water Quality labs to reduce the risk of contamination by laboratory strains.

9.3.4 PCR Workflow and Contamination Control

Given the high risk of nucleic acid contamination, PCR-related tasks are spatially separated to protect result integrity:

- Reagent Preparation: Conducted in a clean hood within the clean bay
- Sample Preparation: Performed in BSL-2, Tissue Culture, or Field Labs, all under negative pressure to contain target organisms and nucleic acids
- Post-Amplification Detection: Conducted in a dedicated lab under negative pressure to prevent release of amplified products

Additional Containment Measures:

- Dedicated BSCs or laminar flow hoods for positive controls and test sample processing
- Each room includes:
    - Dedicated, adjustable pipettes
    - Plugged, aerosol-barrier pipette tips
    - Room-specific lab coats and gloves, always worn and not transferred between rooms.

9.3.5 Bench Space

Each dedicated workspace in the EOHML provides sufficient bench space to accommodate necessary equipment and allow laboratory staff to perform assigned tasks without constraint. As a guideline, a minimum of 6 sq. ft. of clear bench space per staff member is maintained, in addition to the footprint required for essential equipment.

9.3.6 Storage Space

Each dedicated workspace within the EOHML includes adequate storage for disposables, labware, and reagents specific to that location. Centralized storage is available for common supplies prior to distribution, and cold storage units are in place to hold reagents and environmental samples prior to processing.

9.3.7 Lighting

All workspaces are equipped with adequate overhead lighting, ensuring visibility and allowing for the unhindered performance of laboratory tasks.

9.3.8 HVAC System

The EOHML's heating and cooling system is maintained at 22 ± 2°C, with continuous monitoring of temperature and relative humidity by building management. Staff are instructed to report any deviation of ≥5°C from the set point if not already addressed by the system.

The laboratory operates under negative pressure relative to the rest of the building to control airborne contamination:

- BSL-2 Laboratory: −0.05 in. H_2O relative to adjacent spaces
- Tissue Culture Anteroom: −0.05 in. H_2O relative to BSL-2
- Tissue Culture Lab: −0.25 in. H_2O relative to the anteroom

The bag-in/bag-out filter on the Tissue Culture Lab maintains a 1 in. H_2O pressure differential across the filter. Pressure conditions are monitored by both magnahelic gauges and the building's alarmed HVAC system, which immediately alerts maintenance personnel of any deviations. All abnormalities are reported to building management for prompt resolution.

9.3.9 Hoods and Biological Safety Cabinets (BSCs)

The Environmental and Occupational Health Microbiology Laboratory (EOHML) is equipped with four types of hoods, each designed to meet specific laboratory needs:

Types and Specifications

Class II B2 Biological Safety Cabinets (BSCs)

- Quantity: 3
- Models: Baker Sterile Chemgard III Advance (SG603-TX and SG403-TX).
- Serial Numbers: 77412, 77430 (Room 2223, BSL-2 Lab); 77413 (Room 2223c, Tissue Culture Lab).
- Exhaust: Hard-ducted, total exhaust system.
- Use: Suitable for Biosafety Level 2 and 3 agents, and use with toxic chemicals or radionuclides (per NSF Standard #49).
- Face Velocity: 100–110 ft/min.
- Safety Features: AirGARD® airflow monitors to detect insufficient exhaust flow.

Class II A2 Biological Safety Cabinets (BSCs)

- Quantity: 1
- Models:
- Airflow: Recirculates 70% of cabinet air, exhausts 30% through HEPA filters.
- Face Velocity: 100–110 ft/min

- Safety Features: Large, easy-to-read magnehelic gauges.
- Restrictions: Not suitable for use with volatile chemicals or radionuclides.

Horizontal Laminar Flow (HLF) Cleanbench

- Model: NuAire AireGard 201 (NU-201-330)
- Serial Number: 80173100902
- Use: For sterile procedures (e.g., media, reagent, and tissue culture prep); not for use with biological agents (Risk Groups 1–4).
- Monitoring: Minihelic gauge to monitor HEPA filter pressure (0–2 in. H_2O).
- Note: Provides product protection only—not user protection.

PCR Workstation

- Model: AirClean Systems 600
- HEPA filtered environment
- 254 nm UV light sterilization with 15 min timer
- UV safety interlock switch
- Surface decontamination between runs.

Operation Procedures

General Use Guidelines (All Hoods):

- Staff must be trained and familiar with operation protocols.
- Clean and dirty materials must be clearly separated in workspaces.
- Items must not obstruct front intake grills.
- No open flames (e.g., Bunsen burners) allowed in laminar flow hoods or BSCs. Use incinerators or pilot-light burners when necessary.
- Work surfaces must be decontaminated before and after use.

BSCs (Class II A2 and B2):

- Startup:
    - Wipe with 70% ethanol.
    - Wipe with disinfectant such as Oxivir.
    - UV irradiate for 15 minutes (moving light to cover surface).
    - Purge for 2–3 minutes after materials are placed inside.
- Shutdown:
    - Allow the cabinet to run 15 minutes post-use.
    - Decontaminate with disinfectant such as Oxivir.
    - Decontaminate with 70% ethanol.
    - UV irradiate for 15 minutes.
- Power Cycling:
    - B2 BSCs must always remain on, except during maintenance.

- A2 BSCs may be turned off 30 minutes after use, and should be turned on 30 minutes prior to use.

HLF Cleanbench:

- Startup: Turn on 15 minutes before use to allow any settled dust to be removed; wipe down with 10% bleach followed by 70% EtOH.
- Follow similar best practices as for BSCs regarding material layout and workflow.

PCR Workstations:

- Startup: Wipe with Ethanol followed by DNA/RNA away. Run 15-minute UV cycle prior to use.
- Shutdown:
  - Wipe down with 10% bleach or Oxivir, then 70% ethanol.
  - Avoid movement that can introduce contaminants.
- Follow BSC best practices for organization and cleanliness.
- Personal Hygiene:
  At a minimum, wash hands and arms (to elbow) with germicidal soap before and after using BSCs, clean benches, or PCR workstations.

Maintenance

Monthly:

- All BSCs are decontaminated using manufacturer-recommended disinfectants.

Annually:

- Certification and calibration of all BSCs and the HLF cleanbench are performed by a qualified provider (e.g., University of Washington Environmental Health & Safety).
- Certification reports are stored in the facility's records.

9.3.10 House Vacuum

The EOHML is equipped with a house vacuum system, with suction controlled by a local tap. For procedures requiring precise vacuum levels, a regulator with a pressure gauge is installed as needed.
To protect the vacuum system, hydrophobic HEPA filters (Vacuguards) or traps are used for all vacuum applications. Maintenance includes:

- Filter replacement every six months or as needed.
- Daily emptying of pre vacuguard flasks following use.

9.3.11 Laboratory Water

General Precaution: Before collecting or using laboratory water**,** allow the tap to run for 30 seconds to flush stagnant water from the lines.

Water Types

The EOHML utilizes four types of laboratory water:

1. City Tap Water (Seattle)
    - Used only for washing dirty labware and general cleaning.
2. Deionized Water (DI Water)
    - Produced centrally in the building's mechanical room.
    - Distributed via dedicated taps to each lab.
    - Uses: preparation of bacterial culture media prior to autoclaving, and final rinsing of labware.
    - System Components:
        - Carbon filter
        - Reverse osmosis
        - Mixed-bed ion exchange columns
        - Ultraviolet (UV) disinfection
    - Maintenance:
        - Biannual service arranged by building management.
        - Routine monitoring by building management and the service provider.
3. Autoclaved distilled water
    - Purchased from local vendors.
    - Uses: Filling water baths, autoclaves.
4. Molecular Reagent-Grade Water
    - Used for sensitive molecular biology applications, such as PCR.
    - Maintained in clearly labeled, contamination-controlled containers.

9.3.12 Water Disposal System

The EOHML maintains a robust waste management system that ensures safe collection, decontamination, and disposal of waste materials:

- Waste Collection:
    - Segregated by area to avoid cross-contamination
    - Follows established laboratory workflow
- Infectious Waste:
    - Collected in foot operated biohazard bins or in small benchtop biohazard bags.
    - Autoclaved prior to disposal to ensure decontamination.
- Chemical Waste:
    - Collected and disposed of by University of Washington Environmental Health and Safety (EH&S)
    - Pickups occur monthly unless requested at a greater frequency for specific waste generation
- Janitorial Services:
    - Occurs throughout the lab except in the cell culture facility and the PCR detection area

- These areas are cleaned exclusively by trained laboratory staff

9.3.13 Security

The EOHML is secured to prevent unauthorized access and ensure contamination control:

- Access Controls:
  - All external lab doors secured with key locks
  - The main lab door (2323) is secured by keycard which locks automatically after business hours
  - The main lab door can be locked via a remote from the inside during the day when BSL2+ work is being completed and access must be limited to specifically trained staff/students
  - Central building and lab wings are secured with card key access
  - Tissue Culture Lab has additional card key-only access
- Access Restrictions:
  - Laboratory access is limited to authorized personnel only
  - Guests must register at the front desk (Suite 100) and be always escorted by lab staff
- Receiving Area:
  - Located near the catalog library and/or in the clean bay
  - Used for receipt and cataloging of supplies, reagents, and incoming samples
  - Physically separated from experimental areas to maintain cleanliness

9.3.14 Workflow

The EOHML follows a strict unidirectional workflow from “clean” to “dirty” areas to minimize contamination risk:

- Color/Name-Coding System:
  - Each lab room or workspace is assigned a specific color and or name
  - All equipment, reagents, lab coats, and supplies are coded accordingly
  - Cross-use between areas is strictly prohibited
- Personnel Flow Control:
  - Analysts who work in “dirty” areas (e.g., PCR product room) may not return to cleaner zones without:
    - Full change of personal protective equipment (PPE)
    - Hand and arm scrubbing

9.3.15 Laboratory Cleaning

Maintaining sterility and cleanliness in the laboratory is essential to ensure the integrity of samples and analytical procedures. Laboratory access is restricted to authorized personnel actively conducting work, particularly during analytical processes.

All compatible work surfaces must be cleaned before and after each use with a freshly prepared 10% bleach solution. However, bleach can cause pitting on stainless steel countertops and in

biological safety cabinets (BSCs); therefore, these surfaces should be disinfected with an appropriate EPA-registered disinfectant, such as Oxivir.

Other laboratory surfaces should be wiped down before and after use with surface disinfectants such as bleach, oxivir, and/or 70% ethanol. For sensitive RNA work, an RNase inhibitor should be used to clean countertops and equipment. When working in the clan PCR set up hood or in other areas where nucleases are a concern, commercial products like RNase Away and DNase Away should be used for surface decontamination.

Thermocyclers, centrifuges, and pipettes are cleaned routinely (or whenever contamination is suspected) using either a fresh 10% bleach solution or an EPA-registered disinfectant. Racks, trays, chamber trays, gel trays, and gel combs should be rinsed with water or a mild detergent after each use.

Antimicrobial soap is provided at various laboratory sinks to facilitate hand washing before and after laboratory work. Nitrile gloves are available for procedures that require clean gloves. Used gloves must be discarded in designated biohazard boxes, which are autoclaved prior to disposal.

Dirty glassware should be placed in an autoclave bin on a cart in the designated central area, away from critical workspaces. It must be autoclaved, then washed with an appropriate laboratory-grade, phosphate-free detergent, followed by rinsing with tap water. Items are then wrapped and re-autoclaved prior to storing them in the clean bay.

Cleaning structure

Each staff member and student are responsible for cleaning specific areas of the laboratory. A monthly cleaning schedule is posted on a spreadsheet located at the laboratory entryway. All laboratory personnel are expected to participate in monthly cleanings.

Maintenance

Any facility maintenance issues must be reported immediately to the Laboratory Manager or Principal Investigators (PIs). It is the responsibility of the Laboratory Manager to contact the building manager or maintenance engineer to resolve the issue.

9.3.16 Biosafety and Chemical Hygiene

Laboratory personnel must be aware that biological and chemical hazards are present in EOHML. Detailed safety practices and responsibilities are outlined in the **Laboratory Safety Manual** and the **Biosafety Manual**; both located on the shelves above the flammable storage cabinet with the most current editions pinned to the desktops of the shared computers located in the clean bay and found in the EOHML SharePoint.

These manuals align with the principles established in the CDC/NIH publication, *Biosafety in Microbiological and Biomedical Laboratories*, 4th edition (CDC BMBL).

All laboratory personnel are required to be familiar with the Biosafety Level 2 (BSL-2) guidelines.

Chemical-specific safety information is provided in the Material Safety Data Sheets (MSDS). An MSDS is maintained for each chemical used in the laboratory and is stored in the MSDS folder, located next to the Laboratory Safety and Biosafety Manuals. Additionally, all MSDSs are linked in the labs MyChem inventory site. All laboratory personnel must review and understand the hazards associated with any chemical they handle.

All staff are required to:

- Be familiar with the contents of the Laboratory Safety and Biosafety Manuals
- Complete initial and annual safety (re)certification training
- Have training records maintained on file

9.3.17 Signage, Equipment, and Access Control

- Appropriate signage identifying hazardous and biohazardous materials is posted at all lab entrances and in conspicuous locations.
- Access to laboratories is restricted to authorized personnel only.
- Safety equipment is tested regularly:
    - Safety showers: tested annually
    - Eyewash stations: tested and flushed weekly
    - Fire extinguishers: tested annually
- Chemical and biological spill kits are available in each lab. Supplies must be replenished after each use.

Live cultures must not be transported **outside** of the EOHML unless they are properly packaged according to shipping regulations. Guidelines for shipping infectious or hazardous agents are available in the Shipping and Transport of Hazardous Materials Manual, stored next to the other safety manuals above the entryway filing cabinet.

Strict adherence to biosafety practices is mandatory. Noncompliance will result in notification, retraining, or disciplinary action**.** Repeated violations of biosafety practices will result in termination of employment**.**

9.3.18 Gowning and Personal Protective Equipment (PPE)

Appropriate PPE, including nitrile gloves, surgical masks, N95 masks, PAPRs, safety glasses, face shields**,** lab coats**,** and disposable laboratory garments**,** are available in the lab.

Laboratory personnel must:

- Wear disposable gloves and lab coats when performing procedures involving biological agents or chemicals
- Use safety glasses or face shields when there is a risk of droplet, aerosol, or particulate exposure to the eyes

- Conduct all aerosol-generating procedures (e.g., vortexing, sonicating, transferring cultures, counting/examining agar plates) inside a Biological Safety Cabinet (BSC)
- Wear face protection when splash or spray risks are present outside the BSC

Glove and Lab Coat Protocol:

- Replace gloves immediately if visibly contaminated. Dispose of contaminated gloves in a biohazard bin**.**
- Remove lab coats and gloves before exiting the Tissue Culture laboratory **and** replace them with clean PPE for material transport.
- Lab coats must be removed before entering non-laboratory areas such as offices, restrooms, the cafeteria, and library.
- Either reusable cotton lab coats or disposable lab coats are acceptable.
- Lab coats are not required when entering the lab briefly for non-laboratory tasks (e.g., retrieving documents) or working at computers in the clean bay**,** provided no active culture manipulation is in progress**.**

Biohazardous waste bags must be taped shut prior to transport and disposed of according to autoclaving procedures.

9.3.19 Emergencies

In the event of a medical emergency, immediately contact emergency services (911)**.**

Additionally, report all laboratory-related emergencies (e.g., injuries, spills, exposures) to the:

- Laboratory Manager
- Biosafety/Chemical Hygiene Officer
- Principal Investigators

The Laboratory Manager is responsible for documenting all medical incidents, spills, injuries, or accidents in the University's OARS system.

Personnel must be familiar with the biosafety spill clean-up procedures**,** which are posted in each laboratory.

9.2.20 Guidance for Spills of Biohazardous Organisms Requiring Biosafety Level 2 Containment

General Spill Response

a) **Alert Others**
   Immediately notify all personnel in the laboratory of the spill.
b) If Injury Occurs
   - In the event of a human injury (e.g., cut from broken glass), request assistance from a co-worker and address the injury *before* initiating cleanup.

- Once the injury is treated, proceed with decontamination and cleanup.

c) Remove Contaminated Clothing
   - Disposable lab coat**:** Discard in an appropriate biohazard waste bin**.**
   - Reusable cotton lab coat**:** Remove and place in an autoclavable container**.**
   - Street clothing/footwear**:** Inspect for contamination. If contaminated, remove and place in an autoclavable container.
   - Skin exposure**:** If liquid has soaked through to the skin, wash thoroughly with soap and water.

d) Retrieve Clean Clothing
   - Have a co-worker retrieve temporary clothing from the locker area.
   - If alone, remove contaminated clothing and footwear as much as possible, put on shoe covers (from the biosafety spill kit), and retrieve clean clothing.

e) Preparing for Cleanup
   - Retrieve the biosafety spill kit and open it.
   - Don appropriate PPE**,** including:
     - Clean lab coat
     - Nitrile gloves
     - Safety glasses
     - Shoe covers (if material spilled on floor)
     - Face mask (if spill occurred *outside* a BSC)

Spill Cleanup Procedure

1. Assess for Broken Glass
   - Take special care to avoid injury.
   - Do not use gloved hands to pick up broken glass.
2. Unplug Contaminated Equipment
   - Disconnect any small equipment (e.g., vortexer, timer) that may be contaminated.
3. Decontaminate Horizontal Surfaces
   - Cover the entire affected area (including broken glass) with paper towels from the spill kit.
   - Do not use plastic-backed paper or absorbent wipers.
   - Saturate towels with 10% bleach solution (1:10 dilution of household bleach) or another suitable disinfectant.
   - Start at the outer edges and work inward.
   - Let stand for 20–30 minutes.
4. Decontaminate Vertical Surfaces
   - Apply disinfectant directly to the area.
   - Let stand for 20–30 minutes.
   - Wipe with absorbent material.
5. Disposal of Waste
   - Place all absorbent material in an autoclave bag from the spill kit.
   - If broken glass is present:
   - Use designated cut-resistant gloves from the kit to handle paper.

- Use brush and scoop to collect broken glass and place it in the autoclave bag.

WARNING: Under no circumstances should an analyst attempt to pick up broken glass with a latex-gloved hand.

6. Other Contaminated Items
   - Place contaminated small items (e.g., pens, markers) in the autoclave bag.
7. Final Steps
   - Autoclave and properly dispose of the autoclave bag contents.
   - Decontaminate tools and PPE used during cleanup (e.g., gloves, scoop, brush, spill kit handle/lid) with disinfectant.
   - Treat and launder contaminated reusable lab coats and clothing per standard protocol.
   - Replenish spill kit supplies after use.

Spills Inside a Biological Safety Cabinet (BSC)

1. Alert Personnel
   - Inform others of the spill.
   - Do not turn off the BSC blower - airflow will help contain bioaerosols.
2. Injury Protocol
   - Treat any injuries immediately (as outlined above).
3. Remove Contaminated Clothing
   - Follow the same protocol for removing and replacing contaminated garments and footwear.
4. PPE Requirements
   - Don PPE from the spill kit:
     - Lab coat
     - Gloves
     - Safety glasses
5. Cleanup Procedure
   - Follow the same spill cleanup procedure detailed above, beginning with assessing broken glass and proceeding through decontamination and disposal.

Important Notes

- Always have the biosafety spill kit fully stocked and easily accessible.
- Training in spill response procedures should be reviewed annually or as part of routine biosafety certification.
- Post biosafety spill clean-up instructions in all labs using BSL-2 materials.

Decontamination of Cotton Lab Coats

1. **Initial Decontamination Method**
   Cotton lab coats may be decontaminated using:
   - An appropriate disinfectant, or
   - Autoclaving in accordance with standard biosafety practices.

2. If Using Disinfectant:
    - Retrieve an appropriate EPA-registered disinfectant.
    - Apply the disinfectant to the contaminated area and surrounding region.
    - Allow contact time per the manufacturer's label.
    - After disinfection, immerse the lab coat in water containing laboratory-grade detergent to aid in the physical removal of biohazardous material.
3. If Autoclaving:
    - Place the lab coat in a tray or biohazard bag to minimize fabric damage.
    - Do not add water directly to the tray containing the lab coat.
    - Autoclave on liquid cycle to maintain humidity.
    - After autoclaving, immerse the lab coat in water containing detergent**.**
    - Rinse thoroughly**.**
4. Post-Decontamination Handling:
    - Set the lab coat aside to be included in the monthly lab coat laundry service**.**

Decontamination of Street Clothing and Footwear

1. **Initial Decontamination Method**
   Contaminated street clothing and footwear may be decontaminated using:
    - An appropriate disinfectant**,** or
    - Autoclaving**,** when material and equipment allow.
2. If Using Disinfectant:
    - Apply disinfectant thoroughly to the contaminated areas.
    - Allow it to sit for the label-specified contact time**.**
    - After disinfection, immerse the item in water with detergent to assist in removal of decontaminated material.
3. If Autoclaving:
    - Place clothing or footwear in a tray**,** not in a bag.
    - Do not add water to the tray with the item.
    - Instead, place a **second tray** with water in the autoclave to provide humidity or autoclave on liquid cycle.
    - Once autoclaved, immerse the item in detergent solution and rinse thoroughly.
4. Post-Decontamination Handling:
    - Take decontaminated clothing and footwear home for laundering, following regular washing instructions.

9.3.20 Equipment: Autoclaves

Overview

Sterilization is the process of eliminating all living microorganisms from substances or objects. The Environmental and Occupational Health Microbiology Laboratory (EOHML) is equipped with three dedicated autoclaves**,** one large-capacity and two small-capacity units for the sterilization of:

- Glassware and plasticware

- Prepared reagents and media
- Laboratory disposables
- Biohazardous and non-biohazardous waste

Autoclaving and Waste

Autoclaves:

There are 3 autoclaves in the EOHML. One in the clean media prep room, 2323C (used for media and clean glassware), one in the cell culture anti- room, 2323B, (used for cell culture waste and overflow if both others are in use) and one in 2325 (used for waste, dirty and clean labware, and media as needed).

The large Primus autoclave (2325) is kept off when not in use (Note: recent policy change). Allow it to preheat for ~20-30 minutes until the ready light turns on. It should be used to maximize loads and prevent excessive wear on the valves by leaving it on for when not in use.

Small Autoclaves:

- **Brand**: VWR Accusterilizer, Non-recirculating water system
- Model Number: AS12
- **Locations**: Room 2323A
- **Use**: Sterilization of media, reagents, labware, and disposables
- **Brand**: Heildolf/ Tuttnauer
- Model Number: 2840ELP
- **Locations**: Room 2323C
- **Use**: Sterilization of clean items including media, reagents, labware, and disposables

Large Autoclave

- **Model**: Primus
- **Location**: Room 2325
- **Use**: Sterilization and **decontamination** of waste materials, glassware, media making when large amounts are needed

Autoclave Bins:

- Bins are in each lab and/or bay.
- Use two bags to prevent punctures when replacing bags. Place closed bags in the red can and ensure they are autoclaved within 7 days.
- Replacement bags are in the labeled drawer under the centrifuge counter.

Autoclaving Schedule:

- Autoclave full bags the day they are replaced if possible.
- If autoclaving immediately is not possible, place closed bags in the large red garbage can in the water lab. The red can is ONLY for closed bags – no loose items please.

- Waste bags must be autoclaved within 7 days of replacement.

Preparation for Sterilization

- Labware should be wrapped in aluminum foil or brown kraft paper prior to autoclaving.
- Sterilized labware should be stored in designated clean storage areas until use.

Autoclave Operation:

- All laboratory personnel must be trained and familiar with the manufacturer's operating instructions**.**
- The Laboratory Manager is responsible for ensuring that staff are properly trained in autoclave operation
- Ensure you or someone else designated by you is available to empty the autoclave immediately after a run.
- Do not leave autoclaves pressurized overnight.
- Check the red bin on arrival; if the Primus autoclave is available, use it for large and small waste bags, optimizing for full loads.

Autoclave Parameters / Settings:

- Autoclaves operate at 15 psi steam pressure, achieving a temperature of 121–124°C, in accordance with APHA guidelines (1998, Section 9020B).
- All dirty items (waste bags and glass or plastic lab ware) must be autoclaved for 60 minutes on setting #4.
- All loads must include a chemical indicator sterigage strip and color changing autoclave tape to confirm successful sterilization.
- ⚠ **Do not overload the autoclave.** Adequate space must be maintained to ensure even steam penetration.

Material / Volume	Sterilization Time
Glassware or ≤ 250 mL liquid	15 minutes
500 – 2,000 mL liquid	30 minutes
> 2,000 mL – 6,000 mL liquid	15 minutes per 1,000 mL
> 6,000 mL liquid	90 minutes
Carbohydrate-containing media (≤ 250 mL)	15 minutes
Contaminated materials and discarded cultures	45–90 minutes

Disposing of Autoclaved Waste:

- Dispose of autoclaved biohazard bags in the large trash bin in the autoclave room and empty the bin into the trash compactor in the loading dock when full.

Recordkeeping:

- Records must be completed promptly, legibly, and with indelible ink.

- For daily autoclave use, record the following on the Daily Sterilization Record Information in the binder in 2323's entryway Form:
  - Date
  - Name/Initials of lab personnel and PI
  - Load contents/ Cycle type
  - Sterilization time and Temperature
  - Pass/Fail of internal indicators
- There are 3 sections in the binder, one for the record keeping of each autoclave.
- For monthly and quarterly QC runs, use the Monthly/Quarterly Sterilization Record Information Form located in the master EOHML autoclave logbook.
- Autoclave maintenance records are also maintained in the master logbook.
- All completed forms and logs are archived in file cabinets in Room 2323 and retained on-site for a minimum of 6 years.

Maintenance of EOHML Autoclaves

- The Primus autoclave and associated generator is maintained under a service contract with Omega Medical and tasks listed in Table 21.

Table 21. Routine Autoclave Maintenance Procedures

Task	Frequency
Use autoclave distilled water only	Ongoing
Empty non-recirculating assembly	End of each week or when full
Clean with mild soap, rinse, and drain	Twice monthly
Record cleaning dates on the posted lab task sheet	With each cleaning
Full inspection and calibration by Omega Medical	Annually for small autoclaves, quarterly for Primus

9.3.21 Equipment: Centrifuges

Overview

The Environmental and Occupational Health Microbiology Laboratory (EOHML) is equipped with:

- Four microcentrifuges
- Model: Beckman-Coulter Microfuge 18
- Location Use Restrictions:
- PCR product area
- Two designated for the BSL-2 area in 2323
- One located in the water lab 2323 D
- One large-capacity, high-speed refrigerated centrifuge
- Model: Beckman-Coulter Avanti J-20 XPI
- Location: General lab floor
- Use: High-speed, high-volume applications

Microcentrifuges: Beckman-Coulter Microfuge 18

- **Rotor**: 24-place rotor
- **Tube Capacity**: Up to 2.0 mL
- **Max Speed**: 14,000 rpm (18,000 × g)
- **Temperature**: Operates at ambient temperature
- **Run Time**: 0–30 minutes

Each microcentrifuge must be used only in its assigned area to prevent cross-contamination.

Large-Capacity Centrifuge: Beckman-Coulter Avanti J-20 XPI

- **Max Speed**: 26,000 rpm
- **Max Capacity:** 6 liters
- **Temperature Range**: -10°C to +40°C ± 2°C
- **Refrigeration**: Programmable and actively monitored
- **Rotor Compatibility**: Multiple rotor types supported (Table 22)
- **Service**: Professional service (cleaning, calibration, preventive maintenance) by Beckman Coulter Service completed annually

Table 22. Available Rotors and Centrifuge Maintenance for Large-Capacity Centrifuge

Rotor Model	Capacity & Type	Max Speed / Force
JA 25.50	8 × 50 mL, fixed angle	75,600 × g
JA 25.15	24 × 15 mL, fixed angle	74,200 × g
JLA 8.1000	6 × 1000 mL, fixed angle	15,910 × g
JS 7.5	4 × 250 mL, swinging bucket	10,390 × g
JS 5.3	Swinging bucket (various volumes)	5,300 rpm

Table 23. Centrifuge Maintenance

Task	Frequency
Clean rotors and surrounding areas	Quarterly or as needed

Operation of Centrifuges

- **Balancing**: All centrifuge loads must be balanced prior to each run to reduce vibrations and extend rotor lifespan.
- **Training**: All laboratory staff must be trained and familiar with the manufacturer's **operating instructions** for each centrifuge model.
- **Responsibility**: The Laboratory Manager is responsible for ensuring proper training and adherence to operating procedures.

Recordkeeping

Each centrifuge run must be documented in the **individual lab staff's notebook**:

- Number of samples
- Speed (rpm)
- Duration of run

Avanti J-20XPI Logbook

- Date and time of run
- Duration of run
- Rotor used
- Set and actual run temperature
- Sample type
- Volume per tube or bottle
- Operator's initials
- Confirmation that the centrifuge was properly balanced

All records must be completed promptly, legibly, and in indelible ink. Accurate documentation is essential for rotor life tracking, maintenance, and biosafety compliance. Completed logbooks are archived in file cabinets in Room 2323 and maintained on-site for a minimum of 2 years.

9.3.22 Temperature-Dependent Equipment

Routine temperature monitoring is required for any equipment where temperature is a critical operational parameter. All temperature-dependent equipment must be monitored using properly calibrated thermometers or continuous monitoring systems.

Monitoring Requirements

- Manual Monitoring: Temperatures must be checked and recorded at least once weekly during the weeks the equipment is in use.
- Continuous Monitoring: Acceptable as an alternative; systems must include an audible or visual alarm in the event of temperature deviation.

All readings must be recorded promptly, legibly, and in indelible ink in the designated temperature record document. Records retained in accordance with the EOHML Record Retention Schedule.

Deviation and Corrective Action

Any deviation from standard temperature ranges must be:

- Documented in the appropriate record book.
- Investigated immediately by laboratory personnel.
- If the issue cannot be resolved internally, a qualified service technician will be contacted to diagnose and repair the equipment.

Refrigerators (Bacteria sample storage)

- Kenmore 27 cu. ft. – 2323 General use (clean items)

- Avantco 46.5 cu. ft. –2323D, General use (dirty items)
- Kenmore 2.4 cu. ft. – Dedicated to PCR product area
- Kenmore – Dedicated to Field Samples

Temperature Range: 4°C ± 4°C

Monitoring Frequency: Weekly

Maintenance:

- Clean quarterly using:
  - A warm baking soda solution (2 tbsp/L of water)
  - Followed by 10% bleach disinfection
- Filters and fans: Cleaned quarterly

Freezers (Virus sample storage)

- Thermo Scientific Revco UXF – 2323D, Ultra-low (-80°C)
- Thermo Scientific TDE series – 2323, Ultra-low (-80°C)
- Three Kenmore Elite Freezers (-20°C)
- One Insignia Freezer (-20°C)

-80°C Freezers used for storage of nucleic acids:

- Set Point: -80°C
- Operating Range: -65°C to -86°C
- Temperature Stability: ±0.5°C
- Temperature Homogeneity: ±4.0°C
  - Equipped with continuous monitoring and audible alarms for deviations >10°C above set point

Maintenance:

- Front filter cleaned quarterly.
- Fans checked quarterly.
- Condenser dusted/vacuumed every 6 months.
- Ice buildup physically removed as necessary.
- Annual inventory to discard expired reagents and unnecessary archived samples.
- Defrosting & Cleaning as needed, using:
  - Baking soda solution (2 tbsp/L of water)
  - Followed by 10% bleach disinfection
- Cleaning activities must be recorded.

-20°C Freezers (Kenmore):

- Set Point: -20°C
- Monitoring: Weekly, using a dedicated thermometer.
- Data Entry: Recorded promptly in the logbook (Room 2323).

Incubators

The EOHML is equipped with the following incubators:

- Four temperature-only incubators (Fisher Isotemp, 5 cu. ft.).
- One shaking incubator (Lab-Line SHKA 4000).
- One incubated/ refrigerated bench shaker (Thermo Sci).
- Three CO_2 incubators (Thermo Scientific HeraCell 150i (2 in cell culture 2323B, 1 in water lab 2323D).
- All incubators are equipped with built-in digital thermometers**.**

Temperature Monitoring

- Temperature is recorded once daily on each working day (Monday through Friday, excluding holidays or facility closures).
- Data is recorded promptly, legibly, and in indelible ink on the designated Incubator Temperature Record Form.
- Completed forms are stored in the appropriate temperature logbook located in the file cabinets in Room 2323.
- All data is archived in accordance with the EOHML Record Retention Schedule.

Cleaning and Maintenance

- Bi-monthly, or more frequently as needed:
  - Clean with a warm baking soda solution (2 tablespoons per liter of water).
  - Decontaminate with 10% bleach or a less-corrosive disinfectant.
- Cleaning date and any notes should be recorded in the appropriate log**.**

Waterbaths / Bead Baths

The EOHML maintains the following waterbath equipment:

- Three dual-chambered 12-liter baths (Precision Scientific, Model 188).
- One single-chambered 33-liter bath (Lab-Line, Model 18900).
- One bead bath (Lab Armor, Model 74309706).

Each waterbath chamber is equipped with a dedicated partial-immersion thermometer for monitoring.

Temperature and Water Level Monitoring

- Temperature is recorded weekly or on each working day when the equipment is in use.
- The starting and ending temperature for each procedure must be recorded in the user's laboratory notebook.
- Note: When placing hot autoclaved media into the bath, allow 30–60 minutes or longer for temperature equilibration. Record temperature after equilibration.

- Water level is checked daily and replenished as needed using distilled water only.

Recordkeeping

- Data is recorded promptly, legibly, and in indelible ink on the appropriate Waterbath Temperature Record Form.
- Completed forms are maintained in the waterbath Log.
- All data is archived according to the EOHML Record Retention Schedule.

Cleaning and Maintenance

- Bi-monthly, or more often as needed:
  - Drain chambers
  - Clean with mild soap solution
  - Refill with distilled water
  - Cleaning dates must be recorded in the appropriate waterbath log.

Thermocyclers

The EOHML is equipped with two dedicated real time PCR machines

- Biorad CFX deep well
- Biorad CFX standard well

The EOHML shares access to three digital PCR systems

- Two Thermo Scientific Absolute Q systems
- One Qiagen QiaCuity system

Dry Bath/Hot Block

The EOHML is equipped with dry baths featuring exchangeable blocks. The temperature of each dry bath block is checked in two locations prior to use. All temperature readings are recorded in the laboratory notebook of the individual performing the procedure.

Ice Machine

The EOHML shares access to an ice machine located in room 2298.

9.3.23 Liquid Handling Devices

Drummond Pipet-Aids

The EOHML is equipped with Drummond Portable Pipet-Aids for handling liquids with serological pipettes. These devices operate using rechargeable nickel–metal hydride (Ni-MH) batteries and should be placed on charge when not in use. When fully charged, the batteries are expected to support a full day of routine pipetting activities.

If a battery, despite being fully charged, exhibits a noticeable decline in pipetting capacity, it must be replaced with an approved Drummond replacement battery.

Each unit is equipped with a self-locking filter located in the nosepiece to protect against over-pipetting and contamination. A single drop of liquid is sufficient to block the filter. If blockage occurs, the filter must be replaced immediately using an approved Drummond replacement filter. Substitution with non-approved filters is prohibited, as equivalent protection cannot be assured.

During operation, users must ensure that the pipette tip remains well below the liquid surface when aspirating to prevent bubbling and aerosol generation. Likewise, when dispensing, users must avoid expelling air through an emptied pipette, as this may generate aerosols.

Automatic Pipettes

The EOHML is equipped with two types of automatic pipettes: Rainin Pipet-Lite and Gilson Microman. The Pipet-Lite series consists of adjustable air-displacement pipettes and serves as the primary pipetting system used in the laboratory.

The volume ranges, increments, and recommended immersion depths for Pipet-Lite pipettes are summarized in Table 23.

Table 24. Pipet-Lite pipette volume ranges, adjustment increments, and immersion depths.

Pipette Model	Volume Range (µL)	Adjustment Increment (µL)	Recommended Immersion Depth (mm)
L-20	2 – 20	0.1	1 – 2
L-200	20 – 200	1	2 – 3
L-1000	100 – 1000	5	3 – 6

Complete pipette sets, consisting of one L-20, one L-200, and one L-1000, are assigned to specific workspaces within the laboratory. Each set is clearly labeled according to its designated location Table 24. Pipettes must remain in their assigned workspace and may only be relocated for cleaning, sterilization, or maintenance purposes.

Table 25. Dedicated Pipette Locations.

Pipette Set ID	L-20, L-200, L-1000	Assigned Workspace/Location	Notes
1	Complete	Middle Bay- Bench	-
2	Complete	Middle Bay- BSC	-
3	Complete	Bay 3- Bench	-
4	Complete	Bay 3- BSC	-
5	Complete	Molecular Lab- Bench	-
6	Complete	Molecular Lab- PCR Station	Includes Gilson Microman (M-10)
7	Complete	Clean Bay- Bench	Extra set for clean activities
8	Complete	Clean Bay- PCR Station	Includes multichannel pipette (L8-50)
9	Complete	Clean Room- Bench	-
10	Complete	Water Lab-Bench	-
11	Complete	Water Lab- BSC	Includes multichannel pipette (L8-50)
12	Complete	Cell Culture Room	-
13	Complete	Field Lab- BSC	-
14	Complete	Field Lab- Bench	-
15	-	NanoDrop Station	Single pipette only (L-2)

The Gilson Microman pipettes are adjustable-volume, positive-displacement pipettes and are designated exclusively for transferring first-round amplification products into nested PCR reactions. The M-10 model has a volume range of 1-10 µL.

Only manufacturer-recommended tips are used with all pipettes. Filter tips must be used whenever there is a risk of microbial contamination. Each pipette is cleaned and sterilized on a quarterly basis in accordance with the manufacturer's instructions. However, if contamination is suspected pipettes must be immediately cleaned and sterilized following manufacturer recommendations. All maintenance actions and corresponding dates shall be documented in the Pipette QA file.

If a calibration issue is suspected, the pipette shall first be cleaned and sterilized. The laboratory manager shall then evaluate performance using an analytical balance by taring an empty weigh boat and dispensing reagent water at the following volumes: 100%, 50%, and 10% of the pipette's maximum capacity. Ten replicate measurements shall be performed at each volume. The weight of dispensed water shall be recorded, assuming a density of 1.00 g/mL, and the relative standard deviation (RSD) shall be calculated for each set of measurements.

If measured values fall within manufacturer-specified limits listed above the pipette is acceptable for continued use. If results fall outside acceptable limits, the pipette shall be adjusted according to the manufacturer's instructions and the evaluation repeated. If performance remains outside acceptable limits, the pipette shall be sent to the manufacturer for professional recalibration.

Pipettes are calibrated and receive preventative maintenance annually. They are either sent to the manufacturer or a technician from the manufacturer preforms onsite PM and calibration Table 25. All calibration documentation and certificates are filed (before 2022) or stored in the EOHML maintenance folder on the lab's SharePoint drive. Preventive maintenance includes annual replacement of seals and piston cleaning, as well as replacement of the shaft and reconditioning of the piston every three years.

Table 26. Pipette calibration, accuracy and precision.

Pipette Model	Test Volume (% of Max)	Nominal Volume (µL)	Accuracy (± %)	Precision (RSD %, ≤)
L-20	100%	20	1.0	0.5
L-20	50%	10	1.2	0.8
L-20	10%	2	2.0	1.5
L-200	100%	200	0.8	0.3
L-200	50%	100	1.0	0.5
L-200	10%	20	1.5	0.8
L-1000	100%	1000	0.8	0.3
L-1000	50%	500	1.0	0.4
L-1000	10%	100	1.5	0.6

Use of automatic pipettes with acidic or corrosive solutions should be minimized. When such use is unavoidable, filter tips must be used. Preferably, acidic or corrosive solutions shall be handled using dedicated pipettes or Pasteur pipettes. If a standard pipette must be used, it shall be disassembled immediately after use, and the piston assembly, shaft, and seal shall be inspected and cleaned with deionized water. All components must be thoroughly dried prior to reassembly.

9.3.24 Microscopes

The EOHML is equipped with two inverted microscopes and one binocular stereomicroscope. All microscopes are fitted with digital camera attachments to enable image capture and documentation. The inverted microscopes are in the Tissue Culture Laboratory and the Water Lab, while the stereomicroscope is in the Lab.

Following use of any microscope, users are responsible for cleaning all objectives that were utilized during observation. The lens cleaning fluid provided by the laboratory shall be used, along with lens paper only. Kimwipes, paper towels, or other non-lens-grade materials shall not be used, as they may scratch optical surfaces. Removal of immersion oil from objectives is critical; residual oil left on objectives will degrade optical performance and may permanently damage the lens.

Microscopes are routinely dusted and must remain covered when not in use to prevent contamination and optical degradation. Each microscope shall undergo annual professional cleaning, alignment, and preventive maintenance in accordance with manufacturer recommendations.

9.3.25 Electrochemistry Multimeters

Beckman Coulter Φ45 pH meters

The EOHML maintains two Beckman Coulter Φ45 pH/mV Meter units for electrochemical analysis. One meter is designated for general sample processing in the main laboratory, and the second is dedicated to media preparation activities. Each instrument shall remain in its assigned location except when removed for maintenance or service.

Each Φ45 meter is equipped with temperature measurement capability to allow thermal correction of pH readings.

Use and Calibration of Electrochemistry Meters

All personnel must be trained and familiar with the manufacturer's operating procedures prior to use. Instruments shall be operated in accordance with manufacturer instructions and EOHML QA/QC requirements.

Calibration Requirements

- Meters **must be calibrated at least once per day of use**, and prior to sample measurement.
- Calibration shall be performed using standard buffers that bracket the expected sample pH.
- Standard buffers (pH 4.0, 7.0, and 10.0) shall be:
    - Dated upon receipt and opening
    - Discarded on or before expiration
- Calibration activities shall be recorded on the **Electrochemistry Meter Calibration Record Form**.

Calibration Procedure

- Perform calibration at room temperature.
- For two-point calibration:
    - Always use **pH 7.0 as the first buffer**
    - Use:
        - pH 4.0 for samples <7
        - pH 10.0 for samples >7

Steps:

1. Rinse electrode with deionized (DI) water and blot dry with Kimwipes
2. Place electrode in pH 7.0 buffer and press "cal."
3. Allow meter to reach endpoint (stable reading).
4. Rinse and blot electrode.

5. Place electrode in second buffer (pH 4.0 or 10.0) and press “cal.”
6. Allow endpoint stabilization.
1. Record electrode slope on the Calibration Record Form.
2. Acceptable slope: **≥95%**
    - If <95%, troubleshoot per manufacturer guidance.

Calibration Verification

- Verify calibration by measuring a pH 7.0 buffer after calibration.
- Results must fall within acceptable tolerance (per manufacturer or lab criteria).

Conductivity Calibration

- Conductivity meters shall be calibrated **monthly** using 0.01 M KCl (or appropriate alternative).
- Follow applicable methods such as:
    - United States Environmental Protection Agency Method 120.1
    - American Public Health Association Standard Methods Section 2510

Documentation and Records

- All calibration data shall be:
    - Recorded promptly, legibly, and in indelible ink
    - Maintained in the instrument logbook
- Records shall include:
    - Calibration date
    - Buffers used and expiration dates
    - Electrode slope
    - Analyst initials
    - Notes (e.g., buffer changes)
- Completed records are archived in Room 2323 or electronically on the EOHML SharePoint drive and maintained per EOHML data retention policies. Access is restricted to authorized personnel.

Measurement Procedure

- Rinse electrode with DI water and blot dry between samples.
- Place electrode in sample and press “read.”
- When stable, record pH.

Elevated Temperature Measurements

- For heated samples (e.g., agar media):
    - Allow cooling to **45–55°C** prior to measurement.
    - Rinse electrode with **warmed DI water** after use.
- Record:
    - Initial pH
    - Final adjusted pH

- Temperature
- Volume of acid/base added

Electrode Handling

- Do not wipe electrodes (prevents static interference), blot only.
- Rinse thoroughly between solutions.
- Do not allow electrodes to dry out.

Electrode Maintenance and Cleaning

Junction Flow Check

- Suspend electrode in air for 1–2 hours.
- Proper function is indicated by formation of KCl crystals.

Cleaning Procedures

- **Protein contamination:**
  - Soak in deproteinizing solution (1–2 hours)
  - Rinse and equilibrate in pH 7 buffer
- **Oil contamination:**
  - Clean with alcohol or acetone using a cotton swab
  - Rinse and equilibrate in pH 7 buffer
- If performance does not improve:
  - Replace junction
  - Rinse electrode body and refill with appropriate solution

Electrode Filling Solution

- Maintain 3M KCl fill solution above minimum level (≤25 mm below fill hole).
- Refill as needed and **replaced at least every two months**.

Storage and Handling Precautions

- Remove the fill hole plug during calibration and measurement; replace after use.
- Do not expose epoxy electrodes to organic solvents.
- Store electrodes according to manufacturer recommendations.

3.26 Ultraviolet Lamps

All ultraviolet (UV) lamps within the EOHML are tested on a bi-annual basis using either a UV radiometer or a bacterial challenge assay. Lamps shall be replaced if UV output is measured at less than 70% of the initial output or if performance fails the bacterial reduction criterion.

For bacterial challenge testing, agar spread plates containing 200–250 CFU of *Escherichia coli* is exposed to UV light for two minutes. A minimum reduction of 99% in viable counts is required for acceptable performance.

The UV radiometer shall be sent to the manufacturer or a qualified service provider for recalibration every three years. Certificates of calibration shall be retained in the UV logbook.

UV irradiance measurements or bacterial reduction results for each lamp shall be recorded promptly and legibly in indelible ink on the UV Lamp Monitoring Form within the UV logbook. Completed records shall be maintained and archived in accordance with the standard EOHML record retention schedule.

9.4 Special method requirements

The development of special methods is not expected to be applicable to this project. If special methods are required, the process for preparing a standard operating procedure is described in Appendix E-14.

9.5 Laboratories accredited for methods

9.5.1 Protists

Analytical Services, Inc. (ASI) Laboratory (https://analyticalservices.com/) is accredited for *Cryptosporidium* and Giardia Services using EPA Method 162 and 163 (See Appendix E: Standard Operating Procedures (SOP)ASI provides comprehensive environmental microbiological services to clients throughout the United States and abroad.

ASI Contact information:

130 Allen Brook Lane
Williston, VT 05495 USA
Toll Free: 800-723-4432
Fax: 802-878-6765

Paul Warden
Vice President & Director of Operations
800-723-4432 x15
pwarden@analyticalservices.com

9.5.2 Virus and Bacteria

The project 'Characterization of in situ virus transport and inactivation in the groundwater of Columbia River basalt aquifers' and the UW Environmental and Occupational Health Microbiology Lab (EOMHL) have a waiver for the following analytical methods (See Appendix E: Standard Operating Procedures (SOP).

Table 27. Waiver of analytical methods

Analytical Method	Analyte	Matrix
SM 9230 D Enterolert®	Enterococci	Water
SM 9223 B Colilert 24 Qtray	Total Coliform	Water
Qiagen methods at UW EOMHL	Virus DNA	Water
Qiagen methods at UW EOMHL	Virus RNA	Water
Life Technologies methods at UW EOMHL	Virus DNA	Water
Life Technologies methods at UW EOMHL	Virus RNA	Water
Illumina methods at methods at UW EOMHL	Virus DNA	Water

EOMHL Contact information:

Nicola Beck, EOMHL Laboratory Manager
Phone: 206-616-1171
Email: nkj2@uw.edu

10.0 Quality Control Procedures

Describe the quality control procedures that will help identify problems or issues associated with data collection, data analysis, or modeling while the project is underway (e.g., before it is too late to address them). These may include having experts accompany field staff on sampling campaigns, holding weekly staff meetings, or reviewing interim work products or model outputs.

10.1 Laboratory quality control procedures

Each type of QC sample listed above will have MQOs associated with it (Section 6.2) that will be used to evaluate the quality and usability of the results.

10.1.1 QA/QC: PCR

All BSCs have automated audible alarms which will sound if the appropriate pressure differential is not maintained. Additionally, the Class II B2 BSCs are tied to the building alarm system and building maintenance will be immediately notified in the case of hood failure. The laminar flow clean bench has a magnetic pressure gauges (MAG) that are used to monitor the air flow. When using the clean bench, check to make sure the pressure gauge is reading at a level approximately equal to the annually recorded MAG level on the calibration sticker. A significant increase in pressure indicates that the filters are dirty whereas a significant decrease in pressure indicates an electrical problem.

10.1.2 QA/QC: Autoclaves

Autoclave performance will be verified by examining the autoclave printout and using heat-sensitive tape, maximum registering thermometers, chemical indicator strips and biological ampules. Specifically, heat-sensitive tape and a chemical strip will be used with each daily sterilization run. The printout, thermometers, chemical strips, and spore ampules will be used concurrently for the performance of monthly verification.

Heat-Sensitive tape

Heat-sensitive tape is used with each run to identify supplies that have been properly sterilized and to check the performance of the autoclave. Tape is removed immediately upon use of the sterilized item.

Spore Ampules

Spore ampules (10^6 spores) are run monthly to verify wet, dry, and waste loads. After completion of the cycle, recover and label the ampule and incubate for 48 hours at 55-60°C along with a control ampule that has not been autoclaved. Record the results in the appropriate Autoclave QA/QC form.

Table 28. Manufacturer's Claims on built-in calibration system for Sartorius balance.

Readability, g	Capacity, g	Reproducibility (Std. Dev.), g	Linearity, g	Response Time, s	Sensitivity Drift, 10-30°C	Pan Size, cm (in.)
0.001/0.002/0.005	120/240/620	<=±0.001/0.001/0.003	<=±0.002/0.002/0.005	1.5	2 x 10	13 (5 1/8) diameter

If a processed biological indicator ampule fails (i.e., growth after incubation at 55°C for 48 hours), another ampule should be processed at the same parameters. If the nonconformance persists, service should be scheduled, and the autoclave should not be used.

Spore ampules (sealed spore ampules containing spores in liquid culture media) must be stored according to manufacturer's specifications to insure shelf life. Care must be taken to ensure that they are unpacked immediately upon arrival and placed in the refrigerator.

Chemical Indicator Strip

For short liquid runs, place a strip within a rack of media between tubes. For verifying short gravity cycles and kill load liquid cycles, place strip flat on top (along the lip) of each beaker that contains a maximum registering thermometer. Do not place the strip upright within the beaker that contains the maximum registering thermometer. Record the results from the chemical indicator strips on the appropriate form.

10.1.3 QA/QC: Balances

Analytical balances are used for accurate weighing of reagents and media. The EOHML has two dedicated top-loading balances and a Harvard trip balance. Balances must be leveled prior to use. Once leveled, balances should be moved as infrequently as possible to maintain calibration.

The main top-loading balance is a Sartorius MasterPro Series Model LP620P (Serial Number 14302862) (See Table for Manufacturer's Claims). The balance has a built-in calibration system. This balance is to remain in the media/reagent preparation room only.

The lab also has an Ohaus Scout II top-loading balance (model number SC2020, serial number BJ431540). This balance weighs up to 200g with a readability of 0.01g. The balance is limited to use within the PCR product laboratory only.

The Harvard trip balance is a double beam model (Ohaus model number 1312; serial number 1560SD) with 225 g tare and stainless-steel plates. This balance is dedicated to balancing centrifuge buckets for the high-speed centrifuge.

10.1.4 QA/QC: Centrifuges

Separate centrifuges are used for pre- and post-PCR use. Centrifuge calibration records will be maintained for the life of centrifuge.

10.1.5 Operation

Balances must rest on a firm, level surface and the balance must be levelled prior to operation. Prior to use, each balance must be tared with an appropriate size weigh boat or weigh paper in place. Weights of samples measured must be recorded legibly in laboratory notebooks. All significant figures should be included and balanced used should be indicated. Each balance will be cleaned after each use with a soft brush, if necessary; the balance pans will be cleaned of any debris with a damp towel after each use. Balance trays are wiped off daily with water or a surface disinfectant, such 70 percent ethanol.

10.1.6 Maintenance

Calibration of balances is checked quarterly in house using a minimum of three NIST-traceable weights. Additionally, balances are checked and calibrated annually by a qualified service technician using ASTM class 2 reference weights.

The Sartorius Model LP 620P balance is checked quarterly for accuracy using NIST reference weights. Eight ASTM class II weights (with NIST certification) ranging from 10 mg to 500 g (10 mg, 100 mg, 1 g, 5 g, 10 g, 50 g, 100 g, and 500 g) will be used to check the instrument. The results are recorded on the Verification of Weigh Balance Calibration Record Form.

The Ohaus SC2020 balance is checked annually for accuracy using NIST reference weights. Four ASTM class II weights ranging from 100mg to 100g (100mg, 1g, 10g, 100g) will be used to check the instrument. The results are recorded on the Verification of Weigh Balance Calibration Record Form.

10.1.7 Record Keeping

Data will be recorded promptly, legibly and in indelible ink on the Verification of Weigh Balance Calibration Record Form. Completed forms and the NIST-certificates for ASTM Class II reference weights are archived in notebooks kept in file cabinets in room 2323.

10.2 Corrective action processes

10.2.1 Corrective Actions: PCR

When laboratory staff believe that service is necessary for the BSCs (e.g., alarms are sounding, the BSC fails to advance past the warm-up mode, the BSC is not functioning as it usually does, etc.), they will immediately notify the Laboratory Manager and principal investigator. The BSC will be removed from use and the Laboratory Manager, or his designees will investigate and make a service call if necessary and any corrective action will be taken.

10.2.2 Corrective Actions: Autoclaves

If the autoclave does not reach the specified temperature or fails the spore indicator test, the autoclave will be immediately removed from use, the autoclave will be serviced, and all glassware and reagents that were insufficiently sterilized will be discarded or re-sterilized.

10.2.3 Corrective Actions: Balances

Any discrepancies in weight measurements during quarterly or annual checks will be confirmed by repeating the operation three times. A service representative will be notified, and if the calibration check shows that the balance is out of tolerance, the representative will re-calibrate the instrument. Details of all non-compliance and the corrective action taken will be recorded in the EOHML balance logbook.

10.2.4 Corrective Actions: Control Sample Location Change

If the control sample well, Othello 9, is not operational or accessible for water sampling, a second alternative has been identified as Port of Othello well no. 3. Both well are located to the East of the injection well, upgradient of any flow transport or impacts or physical process relationships with the other well and surface water samples. Port of Othello well 3 is the most eastern well shown in the horizontal cross sectional map Figure 15. Port of Othello well 3 is approximately 4 miles to the east of Othello well 3R (Figure 15) and distinct from Othello wells 3 and 3R shown in Figure 14.

10.2.5 Corrective Actions: Sample does not meet MQO

Virus Sample: We have allocated five additional contingency samples to the sampling plan and may add an additional duplicate field sample during the following field visit. If no samples meet MQO, we will schedule an additional field visit and/or expand the sampling plan.

Environmental Sample: We will have real time access to the sampling results and be able to assess and adjust collection in the field.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

11.1.1 Field Notebook

Procedures for recording field data in a field notebook intended for transfer to EPA's Water Quality Exchange (WQX):

11.1.1.1 Recording Field Data

- **Detailed and Legible Notes:** Record all sampling activities, including date, time, location (latitude/longitude), sample ID, field measurements, and environmental conditions. Use waterproof field notebooks or digital devices with backup.
- **Standardized Data Entry:** Use standardized formats and codes consistent with WQX schema requirements to ease later data transfer. Include metadata such as sampler name, equipment used, and preservation methods.
- **Data Verification:** Immediately review entries in the field to identify missing or suspicious values. Cross-check measurements with duplicate or replicate samples where applicable.

11.1.1.2 Transfer to WQX or Database

- **Data Transcription:** Transcribe field notebook data into digital templates aligned with WQX formats (e.g., Excel or CSV with specific headers).
- **Data Validation:** Use validation rules embedded in the WQX template or software tools to check for completeness, allowable domain values, and format consistency.
- **Metadata Documentation:** Include project, monitoring location, and activity metadata as required by WQX.

11.1.1.3 Detection and Correction of Data Entry Errors

- **Automated Validation:** Use WQX validation services and domain value lookups to flag errors such as incorrect coordinates, invalid codes, or out-of-range measurements.
- **Manual Review:** Compare digital entries against original field notes to identify transcription and logical errors.
- **Error Logging and Correction:** Document detected errors, their corrections, and revisits in data records for audit trails.
- **Training and QA/QC:** Ensure field and QA/QC staff are trained on data collection and entry protocols. Perform periodic quality audits and inter-operator comparisons to reduce errors.

11.1.1.4 Training Resources:

https://www.epa.gov/system/files/documents/2023-08/wqx_web_user_guide_v3.0.1.pdf

https://www.epa.gov/sites/default/files/2020-08/documents/wqx_web_template_user_guide.pdf

11.1.2 Laboratory Notebook

Each laboratory staff member must maintain separate 8-1/2 x 11 bound laboratory notebooks with pre-numbered pages for each project to which they are assigned. All calculations, observations, experimental procedures, and raw data must be recorded in the laboratory notebook. Each page should be dated appropriately. If the results from an experiment are to be recorded on a later date, such as Heterotrophic Plate Counts seven days later, indicate on the page a continuation note, such as *continued on page XX* and on the page the results are logged indicate with the note *continued from* page *XX* .

When pre-printed forms are used to log routine data, the forms will be taped, stapled, or otherwise permanently affixed into lab notebooks. Computer-generated tables, text protocols, or figures must be similarly affixed into lab notebooks. Manufacturer's instruction manuals, specification sheets, etc. should be affixed to laboratory notebooks so that if necessary both sides of a page may be read. Storage of these items in an attached envelope is acceptable. If the original copy of the manufacturer's instructions, specification sheets, etc. is not available, a photocopy may be substituted. Instruction manuals, specification sheets, etc. must be legibly dated and filed accordingly within the laboratory manual. Only one copy of an instruction or specification sheet is necessary in a laboratory notebook. Instead of including a duplicate copy later, refer in the notebook to the earlier date of entry.

Use ink only when recording information in the notebook. If a mistake is made it should be crossed out with a single line, and the corrections made on the sheet with the original information. Distinct color ink can help denote corrections. Do not leave empty sheets or spaces. If an empty sheet or space is desired, put a large X across the space and mark the space as intentionally left blank.

An up-to-date table of contents should be maintained in front of the notebook (10-15 empty pages should be allowed for this purpose). Keep recipes for all reagents and solutions in the back of the notebook and refer in the daily text of the notebook to the appropriate page number.

Standardized methods may be referenced in the laboratory notebooks by citing a particular SOP. When referencing a method by SOP, laboratory staff must record the version and date of the SOP. Any modification or deviation from an SOP must be detailed in the notebook.

Alternatively, photocopies of standardized methods may be taped into the laboratory notebook.

Notebooks will be kept in the lab unless a researcher is using the notebook at his/her office. Notebooks and their contents are the property of the PI and should not be taken from the University. Any modifications of protocols should be dated and initialed by the person making the changes. Discuss any deviation from the protocols with the principal investigator listed on the project before implementing them. Changes to an SOP require consideration of the principal investigators and senior lab staff.

Data transformation and analysis will be performed using Microsoft Excel and Statistica. Data files should be named to include date, e.g., FILENAME-MMDDYY. Older electronic versions should not be deleted, rather they should be maintained as archive copies. A straightforward way to accomplish this is to do save-as FILENAME-MMDDYY, changing the date on each day of modification. Data files are to be backed up on the archive hard drive weekly, and a backup CDRW or Zip disk made after each day of modification.

Copies of the raw data worksheets and transformed data are included in the back of a completed notebook for QA/QC purposes. Electronic copies of the data files must be burned to CD and stored with a complete notebook. Worksheets are initially checked by comparing manual calculations to the worksheet results.

Data transfer from laboratory notebooks to data reduction worksheets shall be checked by a second person for errors in data transfer, prior to audit by QAPO. For example, the date, sample type, dilution, sample volume and colony count recorded in the lab notebook should be verified to be the same as that entered in the worksheet.

Data in the worksheets are used to generate graphs, tables, and statistics for comparison purposes. Resulting graphs, tables, and statistics should be printed and affixed to the laboratory notebook.

It is the responsibility of the principal investigator listed on a project (or his senior staff designee in the case of his extended absence) to review and give signatory approval for each lab notebook assigned to that project on a biweekly basis, or more frequently as questions arise. The listed PI must initial each newly completed page, since the last review, and sign and date the last completed page. Notebook review and sign off should occur at weekly meetings with individual staff members. Documented deviations from general laboratory or project specific SOPs should be clearly acknowledged by the Principal Investigator with his initials.

11.1.3 Storage and Retention of Records and Materials

Only personnel authorized by principal investigators shall have access to the archived files. Any material retrieved from the archives shall be properly logged out by dated signature, and then similarly logged back in upon its return to the archive.

The general EOHML schedule for record retention is as follows: records shall be kept on-site for at least 3 years; after 3 years, record copies may be retired to an off-site storage facility if volume warrants. After 10 years, the records may be destroyed. Specific types of records may have different retention schedules. Retention schedules for these items accompanies their description within this manual.

Any instances of non-compliance with the EOHML record retention schedule will be corrected, to the extent possible, upon discovery.

11.1.4 General Laboratory Records

The Lab Manager shall be responsible for retaining all general laboratory records received or generated by the EOHML according to the records retention schedule.

General Laboratory records will be maintained in four drawer lateral file cabinet in room 2223. General laboratory records include but are not limited to the following:

- Media/reagent preparation records, including EOHML Media/Reagent Preparation Manual and MPRS sheets
- Media and chemical control number records
- Supply control number and procurement records
- Chain-of-custody records for organisms, environmental or clinical samples and test chemicals
- Raw data, including laboratory notebooks and electronic copies
- B/F and sterility test data
- Environmental monitoring data
- Organism control records
- Maintenance and calibration records
- Facility maintenance records
- Laboratory personnel files, including CV, job description and training records
- Audit files, including both internal and external audit files
- Historical file of all SOPs, including general laboratory and project specific SOPS

Materials retained in the archives shall be indexed to facilitate orderly storage and retrieval.

11.1.5 Project-Specific Records

Only personnel authorized by the principal investigator listed on the project shall have access to the project specific archives. Any material retrieved from the archives must be properly logged out by dated signature, and then similarly logged back in on its return to the archive.

The following project-specific materials shall be retained in the archives according to the EOHML schedule for records retention, or for the period specified by the funding/regulatory agency, or sponsor of the project:

- Overall project plan (OPP),
- List of personnel assigned to project, including description of duties,
- Raw and converted data,
- Interim reports (quarterly, annual, etc.)
- QA/QC documents,
- Final report of each study,
- Any other documentary materials with informational value related to the project.

Samples of test and reference items and specimens used in the project should be retained only if the preparation quality permits evaluation.

11.1.6 Financial Transaction Records

A record of all EOHML financial transactions including purchase orders, procurement requests, reimbursements, travel authorizations, shipping bills (e.g., Federal Express Air Bills, etc.) and other files documenting the acquisition of goods and non-personnel services shall be maintained for each budget number utilized by the EOHML. Principal investigators will be responsible for monitoring all expenditures on grants or contracts they oversee. Monitoring will be by monthly budget activity reports (BARs; issued by the University of Washington Financial Accounting System). BARs shall be maintained and archived for at least 3 years after the budget expires. Payroll and Personnel financial records will be monitored and maintained outside the EOHML by the Department of Environmental and Occupational Health Sciences at the University of Washington.

11.2 Laboratory data package requirements

The laboratory will provide a cover narrative along with detailed results presented in a standard package along with all relevant quality control data. See Section 4.5 and Section 12.3.

11.3 Electronic transfer requirements

The laboratory will submit data electronically, in a readily usable format (e.g. Microsoft Excel, text, or CSV files), to minimize data entry problems and facilitate data analysis.

11.4 Data upload procedures

See section 11.1. We will upload environmental and water level data collected from groundwater and surface water. There are currently no standards for uploading virus data.

11.5 Model information management

Not applicable. Please see QAPP “Characterization of in situ virus transport and inactivation in the groundwater of Columbia River basalt aquifers: Modeling”.

12.0 Audits and Reports

12.1 Audits

This study will be audited at quarterly intervals to ensure the integrity of the results. Written records of each audit show the following information: names and signatures of auditors, date of audit, title of function audited, scope of audit, findings, actions recommended and taken to resolve issues, and schedule for any follow-up audit.

The Quality Assurance Project Officer (QAPO) will maintain copies of all SOPs for all projects the QAPO has responsibility to monitor. An overall project protocol (OPP) must also be maintained by the QA project officer. The OPP for each study is assigned a unique OPP number. OPP numbers are assigned in numerical order during the calendar year; therefore, it is practical to index the master schedule by the OPP number. The OPP shall contain, but shall not necessarily be limited to, the following: a descriptive title and statement of the purpose of the study; identification of tests to be performed, including a listing of control and reference substances; name and address of sponsor, if applicable; description of EOHML facility usage, and of any external testing facility; proposed experimental start and termination dates; justification for test system; records to be maintained; the procedure for ID of the test system; description of experimental design; date of approval of the protocol by the sponsor and the dated signature of the principal investigator; statement of any proposed statistical method(s) to be used; and changes or revisions of an approved protocol and the reasons therefore with the dated signature of the principal investigator.

The QAPO shall determine that no deviations from approved protocols and SOPs were made without proper authorization and documentation. The QAPO shall audit the performance of all methods to ensure that all methods are followed as written. All deviations from approved protocols or SOPs must be approved and documented by the principal investigator, or his designee. All major revisions of SOPs shall follow established EOHML practices for the preparation and revision of SOPs.

If a deviation is made that will require a change in the SOP, such as a permanent change in incubation time, the principal investigator, or his designee, shall initiate an addendum to the SOP. The addendum is circulated for review by the senior laboratory staff and approval by the QAPO. Once the addendum is approved, the QAPO shall distribute controlled copies which are appended to the existing SOPs. The addendum shall be filed with the appropriate SOP in the QAPO's controlled copy of the current SOPs and verified at the next audit. The addendum shall be incorporated into the SOP during the annual SOP revision process.

The QAPO's and the Laboratory manager shall prepare an annual list of the internal systems audits to be performed during that calendar year at the Laboratory. The list will include technical audits of general laboratory functions. The list will also include the test methods conducted by the laboratory. The proposed list will be subject to modification from the samples collected, actual tests conducted, and other factors affecting laboratory scheduling. All audits

will use laboratory SOPs and/or protocols as the audit standard. In addition, for the audit of general laboratory functions, a checklist will be used for guidance.

The annual technical audit of general laboratory operations will include a review of the systems in place for quality assurance, sample handling, preparation, analysis, and data reduction. Adherence to guidelines and procedures stipulated in laboratory quality control, equipment calibration and maintenance, and test method SOPs will be audited during these reviews.

Specific test methods employed by the laboratory will be audited at the beginning of their use and every other year thereafter in which the methods are performed.

The audit of each test method or protocol will be based on the individual test methods. The laboratory's SOPs for these test methods will be the documents consulted during these audits. Apparatus and supplies will be reviewed for conformance to SOP specifications. A sampling of calculations will be verified, and documentation will be examined for accuracy and completeness.

SOPs will be used as the audit standard against which operations and procedures will be evaluated. A checklist will also be used as guidance during the audit of general laboratory operations. The QAPO or Invited Peer Investigator may probe related areas in depth, as necessary, to satisfy the objective of the audit.

The laboratory manager will facilitate internal audits by providing any necessary assistance, such as making personnel available, locating records, etc.

During the audit, if applicable, previous corrective action plans shall be verified.

At the completion of the audit, all observations and findings shall be reported to the principal investigators and laboratory staff responsible for resolving the findings and initiating correction action.

After the audit is complete, the QAPO or Invited Peer Investigator shall issue an audit report documenting observations/findings and conclusions/recommendations. The principal investigator or his designate will then submit corrective action plans for approval by the QAPO or Invited Peer Investigator in response to the audit report. When corrective actions have been completed, the QAPO or Invited Peer Investigator will prepare a close-out memorandum indicating that no more action is necessary.

12.1.1 Audit Reporting

Internal audit reports will be provided on the EOHML Internal Audit Report (IAR) form. The following information must be included in the form. Electronic and hard copies of the IAR form will be provided to auditors.

12.1.1.1 Audit Identification

An audit report shall be identified with the following information:

Audit Title: The audit title should detail whether the audit was project-specific or general laboratory.

Audit Number: The audit number will consist of the text "EOHML AUDIT" followed by the two digits of the fiscal year and the sequential number of the audit performed that year. For example, the first audit performed in the lab in Calendar Year 2005 would be coded "EOHML AUDIT 05-01".

Audit Date: The audit date is the date the audit was performed, not the date of the submission of the audit report.

Performed by: The full name, title, address, and signature of the QAPO or Invited Peer Investigator.

Report Content

Objective: Short paragraph(s) that outlines the objectives of the audit.

Scope: A brief description of when the audit was performed, what areas were reviewed and the names of key people contacted.

Findings/Observations: Each finding or observation is listed. When used, a complete checklist shall be included.

Previous Audits Status: A short summary detailing the status of corrective action of previous audits.

Conclusions/Recommendations: An overall summary of the audit with recommendations for a timeframe for corrective action.

Checklists: Checklists that are used during the audit will be completed and attached to the report.

Signature(s): Signature(s) of each person performing the audit.

IARs shall be issued within 30 working days of the audit's conclusion. Copies of audit reports shall be directed to the Principal Investigators, the Laboratory Manager, and the Sponsor of the project, if applicable.

12.2 Responsible personnel

The QA project officer (QAPO; Kethanh Duong) shall determine that no deviations from approved protocols and SOPs were made without proper authorization and documentation. The QAPO shall audit the performance of all methods to ensure that all methods are followed as written. All deviations from approved protocols or SOPs must be approved and documented by the principal investigator, or their designee. All major revisions of SOPs shall follow established EOHML practices for the preparation and revision of SOPs.

If a deviation is made that will require a change in the SOP, such as a permanent change in incubation time, the principal investigator, or his designee, shall initiate an addendum to the SOP. The addendum is circulated for review by the senior laboratory staff and approval by the QAPO. Once the addendum is approved, the QAPO shall distribute controlled copies which are appended to the existing SOPs. The addendum shall be filed with the appropriate SOP in the QAPO's controlled copy of the current SOPs and verified at the next audit. The addendum shall be incorporated into the SOP during the annual SOP revision process.

12.2.1 Audit Follow-up

Audit report responses shall be returned to the QAPO or Invited Peer Investigator, and Laboratory Manager within 30 working days from the date the IAR was issued, or a schedule for completion of corrective actions must be prepared that would have all corrective actions scheduled to be completed within 60 working days of the date of the IAR. The principal investigator(s) is responsible for addressing each finding or observation. A reason for the noncompliance, as well as a plan for corrective action, is required. If the QAPO or Invited Peer

The investigator finds the plan of corrective action deficient, the QAPO or Invited Peer Investigator will discuss the situation with the principal investigator and the Laboratory Manager towards the resolution of the deficiency. Once corrective actions are taken, a close-out memorandum will be prepared by the QAPO or Invited Peer Investigator indicating that no further follow-up is required.

Results of reviews of data and reports, findings from audits, audit responses, and other documentation associated with project specific audit activities will be filed in the Principal investigator's project files. Results of data reviews and reports, findings from audits, audit responses, and other documentation associated with general laboratory audits will be in the lateral file cabinets in room 2223. These documents are subject to EOHML's records retention schedule.

12.3 Frequency and distribution of reports

The QAPO will prepare annual written reports (one in this project timeline) for principal investigators and the study sponsor on the status of each month's data collection and lab analysis, noting any problems and actions taken to eliminate the problems. All study reports are reviewed by the QAPO, and findings are reported to the principal investigator listed on the project. Likewise, results of methods audits are sent to the Team Leader (Christina Norton) with a copy sent to the Laboratory Director (Scott Meschke). The principal investigator (Elaine Faustman), or their designee, is responsible for a follow-up report addressing the findings of the QAPO and the corrective actions taken, when necessary.

12.3.1 Reporting on Study Results

12.3.1.1 General

A final report should be prepared for each project. Reports should be signed and dated by Principal Investigators and the scientists involved in the project. The final report should also be signed and dated by the QAPO to indicate acceptance of responsibility for the validity of the data. The extent of compliance with these Principles of Good Laboratory Practice should be indicated.

Corrections and additions to a final report should be in the form of amendments. Amendments should clearly specify the reason for the corrections or additions and should be signed and dated by the principal investigator.

Reformatting the final report to comply with the submission requirements of a funding agency or sponsor does not constitute a correction, addition, or amendment to the final report.

12.3.1.2 Format of the Reports

The format of the final and any quarterly reports is flexible and should conform to the requirements of the appropriate funding/regulatory agency, or sponsor of the project.

12.3.1.3 Content of the Final Report

The final report should include, but not be limited to, the following information:

Identification of the Study, the Test Item and Reference Item

a. A descriptive title.
b. Identification of the test item by code or name (IUPAC, CAS number, biological parameters, etc.).
c. Identification of the reference item by name.
d. Characterization of the test item including purity, stability, and homogeneity.

Information Concerning the Sponsor and the Test Facility

a. Name and address of the sponsor.

b. Name and address of any test facilities and test sites involved.
c. Name and address of the Study Director.
d. Name and address of the Principal Investigator(s) and the phase(s) of the study delegated, if applicable.
e. Name and address of scientists having contributed reports to the final report.

Dates

a. Experimental starting and completion dates.

Statement

A Quality Assurance statement listing the types of inspections made and their dates, including the phase(s) inspected, and the dates any inspection results were reported to management and to the Principal Investigator(s), if applicable. This statement would also confirm that the final report reflects the raw data.

Description of Materials and Test Methods

a. Description of methods and materials used.

b. Reference to OECD Test Guideline or other test guideline or method.

Results

a. A summary of results.
b. All information and data required by the study plan.
c. A presentation of the results, including calculations and determinations of statistical significance.
d. An evaluation and discussion of the results and, where appropriate, conclusions.

Storage

The location(s) where the study plan, samples of test and reference items, specimens, raw data, and the final report are to be stored.

12.4 Responsibility for reports

The QAPO will prepare and sign a statement included with the data report which specifies the audit dates and findings reported to the sponsor.

The QAPO will review the final study report to assure that the report accurately describes methods and SOPs, and the reported results accurately reflect raw data for the study. The final report and GLP compliance statement shall be signed and dated by the principal investigator.

Corrections or additions shall be amendments by the principal investigator. Compliance with GLPs, or any deviation there from, in the study's conduct will be evaluated by the QAPO. A copy of the final report and any amendment to it shall be maintained by the sponsor, if applicable, and the EOHML.

The EOHML shall maintain in writing the following: QA responsibilities, procedures, records maintained and indexing procedures. These documents and files shall be made available to authorized project sponsors and/or their representatives.

Results of data reviews and reports, findings from audits, and any other documentation of quality assurance activities, including those required by GLPs, will be filed in the files in Room 2249. These documents are subject to EOHML's established records retention schedule described herein.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

Field data collection (verification defined by QA sample analyses of duplicate samples measurements, and trip blanks and specified level to tolerance for deviations) by Chirstina Norton will be verified by Nicola Beck.

13.2 Laboratory data verification

Laboratory data verification will be overseen by Nicola Beck as described in Section 9.

13.3 Validation requirements, if necessary

Not applicable.

13.4 Model quality assessment

Not applicable. This is described in Phase 2 QAPP: Characterization of in situ virus transport and inactivation in the groundwater of Columbia River basalt aquifers: Modeling.

13.4.1 Calibration and validation

Not applicable. This is described in Phase 2 QAPP: Characterization of in situ virus transport and inactivation in the groundwater of Columbia River basalt aquifers: Modeling.

13.4.2 Analysis of sensitivity and uncertainty

Not applicable. This is described in Phase 2 QAPP: Characterization of in situ virus transport and inactivation in the groundwater of Columbia River basalt aquifers: Modeling.

14.0 Data Quality (Usability) Assessment

14.1 Risk Assessment: Process for determining project objectives were met

Goal: We will use the following framework for managing risks in water sampling to ensure data quality and safety for input to the groundwater fate and transport modeling (see descriptions in Modeling QAPP). The primary objective of this project is to understand if the methods and procedures can detect a log-4 removal of virus (99.99%). In the field study, we will have outcomes to provide information on sampling efficiency using the following data streams to develop a series of nested risk factors:

- Statistical analysis evaluating the validity of the sampling approach.
- Sensitivity of the experimental design.
- Biological and methodological variance.
- Accuracy of laboratory analytical results.
- Accounting for measurement errors.
- Lab result variability.

Risk assessments often inappropriately report and handle data near the limits of detection. Common errors include (1) omission of detection limits, (2) failure to define detection limits which are reported, and (3) unjustified treatment of non-detects as zero (EPA, 2015). For this reason, we are including bacteria sampling as positive control to provide a contextual comparison for our sampling techniques, since there is more bacterial data available than for viruses.

These factors do not include model sensitivity analysis (described in Phase 2 QAPP: modeling) but allow us to understand contributions to certainty and uncertainty of our total project risk values. We want to estimate risk on average, as well as the range of sensitivity to risk, although we are not assessing exposure to human populations (in Phases 1 and 2).

14.1.1 Risk Assessment Responsibilities

- **Quality Assurance (QA) Project Officer (QAPO)**: Ensure compliance with this QAPP and data integrity. Kethanh Duong
- **Principal Investigator**: Overall project oversight and risk mitigation approval. Elaine Faustman
- **Field Sampling**: Conduct sampling and initial risk identification. Christina Norton
- **Model Integration Review:** Verify sample data relevance and flag anomalies. Scott Meschke

14.1.2 Risk Identification

- **Site-Specific Risks:** Accessibility, contamination sources near sampling points, hydrological variability, weather effects (flooding, drought), institutional effects (irrigation water open/closing of canal).
- **Sampling Method Risks:** Cross-contamination, inadequate sample volume, improper preservation, equipment malfunction.
- **Transport/Storage Risks:** Delays impacting sample stability, temperature control failure.
- **Analytical Risks:** Laboratory error, inappropriate detection limits, data entry mistakes.

There are two types of analytical lower limits: detection limits (DLs) and quantitation limits (QLs). The DL is the lowest concentration that can reliably be distinguished from zero but is not quantifiable with acceptable precision. At the DL, the analyte is proven to be present, but its reported concentration is an estimate. The QL is the lowest concentration which can be not only detected but also quantified with a specified degree of precision. At the QL, the analyte is both proven present and measured reliably (EPA, 2015).

14.1.3 Risk Assessment Process

- Conduct preliminary site reconnaissance to evaluate physical and environmental conditions (completed June 9, 2025).
- Identify groundwater and surface water sources or hydrological features influencing sample representativeness (focus of November sampling plan).
- Document sampling procedures include sample type, containers, preservatives, frequency, and holding times (as described in QAPP).
- Evaluate possible failure points in sample collection, transport, and analysis.
- Assess potential impacts of identified risks on model input quality and interpretation.

14.1.4 Risk Mitigation Measures

- Use appropriate sampling protocols (e.g., field blanks, duplicates).
- Employ quality equipment calibrated and maintained regularly.
- Implement chain of custody and documentation rigorously.
- Train personnel on safety and sampling protocols.
- Use preservatives and adhere to sample holding times.
- Select laboratories with appropriate certifications and detection capabilities.

14.1.5 Documentation and Reporting

- Maintain a detailed sampling and risk assessment log including deviations and corrective actions.
- Report any unforeseen risks or incidents immediately to project management.
- Include a risk summary in the final modeling report noting any limitations affecting model outcomes.

14.1.6 Final Assessment of Usability and Applicability

EPA's Guidance for Data Useability in Risk Assessment (DURA) (October 1990), Section 3.3.4, subdivides generic DLs and QLs, describing six different lower analytical limits:

1. The instrument detection limit (IDL) is three times the standard deviation of seven replicate analyses at the lowest concentration of a laboratory standard that is statistically different from a blank.

2. The method detection limit (MDL) is three times the standard deviation of seven replicate spiked samples handled as environmental samples.

3. The sample quantitation limit (SQL) is the MDL corrected for sample dilution and other sample-specific adjustments.

4. The contract required detection limit (CRDL) is the SQL which CLP laboratories are required to maintain for inorganic analytes.

5. The contract required quantitation limit (CRQL) is the SQL which CLP laboratories must maintain for organic analytes.

6. The limit of quantitation (LOQ) is the level above which analytes may be quantified with a specified precision, often +/- 30%. This precision is usually assumed to occur at ten times the standard deviation measured for the IDL. (EPA, 2015). There is no specific guidance on reporting the precision or standard deviation of virus characterization nor virus transport and inactivation at the log-4 removal quantities. In our assessment we will assess the detection limits 1-6 and appropriateness of each for this project and virus applications.

14.1.7 EPA Risk Assessment SOP related references

- EPA. 1990. Guidance for Data Useability in Risk Assessment. EPA/540/G-90/008.
- EPA. 1989. Risk Assessment Guidance for Superfund. Volume I, Human Health Evaluation Manual (Part A). EPA/501/1-89/002.
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4.2 Treatment of non-detects

We will use the Decision Path method of handling Non-Detection at Detection Limit (DL) v. Zero Concentration, from EPA (2015):

1. Is the virus/protozoa/bacteria present at a hazardous concentration in any site-related sample? If not, assume non-detects are zero; if yes, continue. (EPA Note: if the compound is not present in any sample at a hazardous level (e.g., 10-6 risk or a hazard

quotient of 1), it probably should be dropped from the risk assessment. Project Note: hazardous levels are not anticipated; we are assessing whether the methods can detect log4 removal of any theoretical occurrence of a hazardous level.)

2. Was the sample taken down-gradient of (or, if no gradient exists, adjacent to) a detectable concentration of the chemical/pathogen? If not, assume non-detects are zero; if yes, continue.
3. Do the chemical/pathogens physical-chemical characteristics (e.g., water solubility, octanol-water partitioning, vapor pressure, Henry's law constant, biodegradability, etc.), permit it to reasonably be present in the sample? Are other site-related compounds with similar characteristics present in the sample? If no (to both questions), assume non-detects are zero; if yes (to either question), continue.
4. Does the assumption that non-detects equal DL/2 significantly impact route-specific quantitative risk estimates? If no, assume non-detects equal DL/2; if yes, consider using statistical methods to estimate concentrations below the DL for that exposure route, assuming data quality permits.

14.3 Data analysis and presentation methods

Sequencing data generated from DNA and RNA libraries using Illumina platforms will undergo a standardized bioinformatic workflow that includes sequence quality assessment, removal of low-quality reads and adapter sequences, assembly of sequence reads, and taxonomic assignment. Quality control metrics, including the total number of raw reads, filtered reads, and classified reads, will be documented for each sample to verify sequencing performance and data quality.

Following taxonomic assignment, viral community composition will be characterized by calculating taxonomic richness and diversity within individual samples (alpha diversity) and differences in community composition among samples (beta diversity). Relative abundances of detected viral taxa will also be determined based on normalized sequence read counts. Analyses will primarily be conducted at the viral family level unless sequence quality and database matches support more specific taxonomic classification.

Results will be summarized using tables and figures to facilitate comparison among samples, sampling locations, and study conditions. Planned data products may include:

- Tables listing the viral families detected in samples and their corresponding sequence read counts and relative abundances.
- Box-and-whisker plots summarize alpha diversity metrics (e.g., richness and Shannon diversity) among sampling groups.
- Ordination plots (e.g., Principal Coordinates Analysis [PCoA] or Non-metric Multidimensional Scaling [NMDS]) to visualize beta diversity and similarities or differences in viral community composition among samples.

- Stacked bar charts illustrate the relative abundance of viral families across samples or sampling locations.
- Sankey diagrams, where appropriate, illustrate taxonomic relationships and the distribution of sequence reads among viral taxa.
- Heat maps or other comparative visualizations may also be generated to display patterns in viral family occurrence and abundance across samples.

All bioinformatic analyses will be performed using validated and documented Illumina software tools and statistical packages appropriate for viral metagenomic data. The analytical workflow, software versions, reference databases, and processing parameters used during the study will be provided in reports to ensure reproducibility and traceability of the results.

14.4 Sampling design evaluation

The study has been designed to collect sufficient data to support statistical analyses from which to draw conclusions based on the number of samples and geospatial relationships (see Figure 18), using inverse distance weighting in various years. Preliminary sampling of groundwater wells to determine the most suitable wells for continuous sampling (those most likely to be downgradient of Othello Well 3R) will be conducted.

14.5 Documentation of assessment

The quarterly reports will include an evaluation of data quality parameters and their impact on the intended use of the data. We will discuss known limitations, uncertainties, or gaps in the data which may affect interpretations or model results. Each report will provide a clear statement about the fitness of the data for its intended use in ASR project development and specify any restrictions or caveats.

Key parameters to evaluate:

- Precision: variability among replicate measurements at each site (2), variability between monthly data sets, and variability between sites (13 in November, and 5 groundwater sites continuously measures, and 2 surface water sites).
- Accuracy/Bias: closeness to true values or known standards.
- Representativeness: degree to which samples reflect the conditions, esp. comparing surface and groundwater samples.
- Completeness: proportion of valid data against expected.
- Comparability: consistency with other data sets or methods focusing on basalt aquifer transport and virus inactivation in similar hydrogeological conditions.
- Sensitivity: ability to detect analytes at requisite levels (log-4 removal).

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16.0 Appendices

16.1 Appendix A: Outline for a Literature Review: Virus Transport and Inactivation in Basalt Aquifers

1. Introduction

- Importance of understanding virus contamination in groundwater.
- Unique features of basalt aquifers compared to other geological settings.
- Relevance for water safety, resource management, and public health.

2. Basalt Aquifer Characteristics

- Structure and hydraulic properties of basalt aquifers (fractures, rubble layers, porosity).
- Comparison of virus movement in basalt vs. other aquifer types (e.g., sand, gravel, limestone).

3. Mechanisms of Virus Transport

- Physical transport processes: advection, dispersion, preferential flow, matrix diffusion.
- Role of fractures and conduits in virus migration.
- Impact of specific aquifer features: transmissive layers, connectivity, flow rates

4. Factors Affecting Virus Mobility

- Influence of sediment mineralogy, clay content, and organic matter on virus adsorption and retention
- Water chemistry: pH, ionic strength, presence of divalent ions and organic contaminants
- Viral characteristics: size, isoelectric point, surface properties.

5. Virus Inactivation in Basalt Aquifers

- Inactivation kinetics of viruses during subsurface transport (temperature, time, chemical environment)
- Interaction with sediment surfaces and reversible/irreversible attachment.
- Modeling separation distances for safe groundwater use based on inactivation rates.

6. Case Studies and Field Experiments

- Key injection/recovery experiments in basalt aquifers (e.g., Oahu, Hawaii).
- Field studies measuring virus breakthrough, retention, and inactivation in fractured bedrock or weathered basalt.
- Comparison with studies in other aquifer types (Cape Cod, Florida, sand and gravel aquifers).

7. Implications for Groundwater Protection

- Risk assessment: viral outbreak association with basalt aquifers.
- Guidelines for setback distances from potential contamination sources.
- Water treatment, monitoring, and policy implications.

8. Knowledge Gaps and Future Research Directions

- Limitations in current field and laboratory data, especially for human viruses.
- Uncertainty in modeling due to heterogeneity and variable hydrogeologic conditions.
- Suggested avenues for future research: improved models, long-term studies, broader virus types.

9. Conclusion

- Summary of current understanding and areas needing further investigation.
- The importance of virus transport and inactivation knowledge for safeguarding groundwater in basalt aquifers.

16.2 Appendix B: Constant-Rate Test and Results for Othello Wells 3R and 3 (Aspect, 2019a)

The 24 hours constant-rate test was performed at an average rate of about 1,570 gpm, beginning on December 18, 2018. At the completion of the test the pump was shut-off and water level recovery was monitored for 24 hours. Recovery data at Well 3R was not analyzed in detail because the test pump assembly did not include a check valve.

Using the Cooper-Jacob Straight-Line Method the aquifer transmissivity (a quantitative measure of an aquifer's ability to transmit water) in the vicinity of Well No. 3R can be calculated based on the following equation (Fetter 2001):

$$T = \frac{264Q}{\Delta s}$$

Where:

T = Aquifer transmissivity (gpd/foot)
Q = Well discharge (gpm)
Δs = Change in drawdown over one log cycle during pumping (feet)

Figure 7 (Figure 22 in this QAPP) presents the Cooper-Jacob analysis for the drawdown data in Well No. 3R. Using data collected between about 100 and 1,000 minutes after the start of the test, we measured a drawdown of about 13.9 feet per log cycle. Combined with the average pumping rate of 1,570 gpm, this drawdown results in an estimated aquifer transmissivity of about 4,000 feet squared per day (ft^2/day).

Drawdown data from the observation well (Well No. 3) were also analyzed using the Cooper-Jacob method to estimate aquifer transmissivity and storativity. Transmissivity is calculated using the same approach and equation as for the pumping well. Once a transmissivity is estimated, storativity can be estimated based on the following equation (Fetter, 2001):

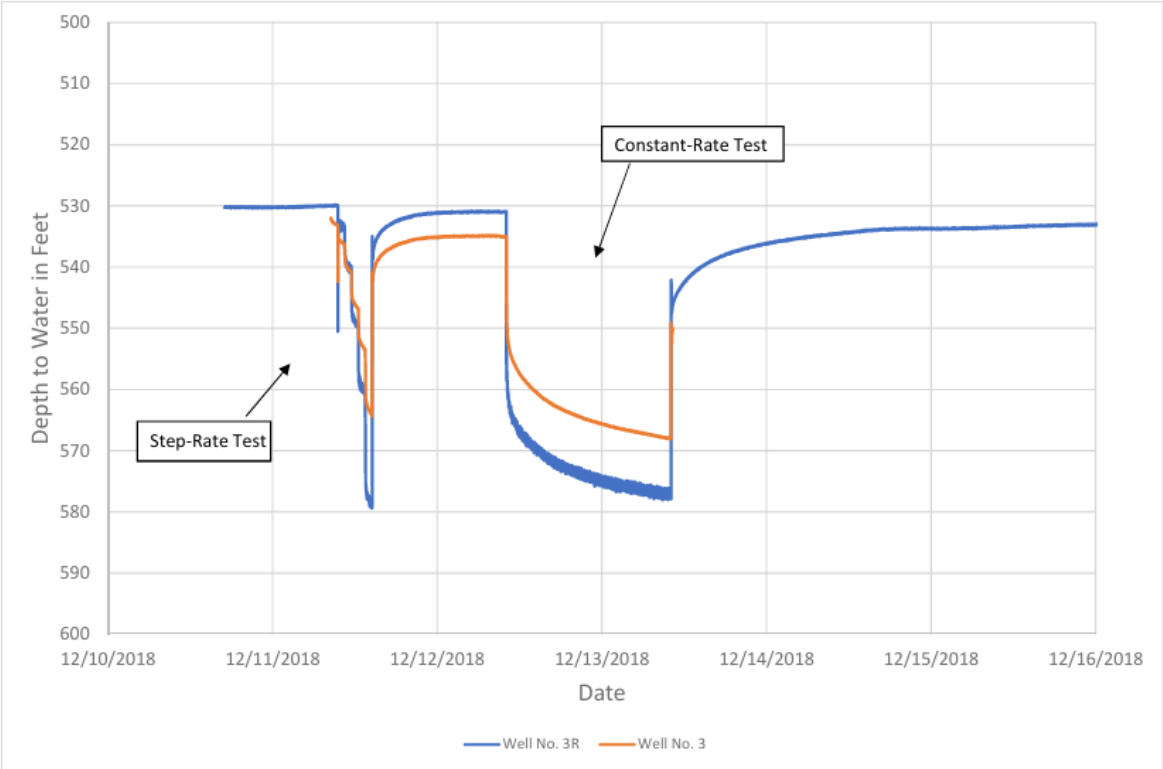
$$S = \frac{2.25Tt_0}{r^2}$$

Where:

S = Storativity (unitless)
t_0 = is the intercept of the drawdown with x-axis plotted on semi-log scale (days)
r = is radial distance from pumping well to observation well (feet)

Figure 8 (Figure 23 in this QAPP)presents the Cooper-Jacob analysis for drawdown data in observation Well No. 3. Using data collected between about 100 and 1,000 minutes after the start of the test, we measured a drawdown of about 10.2 feet per log cycle. Combined with the average pumping rate of 1,570 gpm, this drawdown results in an estimated aquifer transmissivity of about 5,470 ft^2/day.

The distance between the wells is about 30 feet. Projecting the drawdown curve to the point where drawdown equals zero results in a t_0 of 0.8 minutes (about 5.6 x 10^{-4} days). Using a transmissivity of 5,470 ft^2/day with these values results in an estimated storativity of 7.9 x 10^{-3}.



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V:\140207 City of Othello Strategic Planning\Deliverables\Well 3R\figure 5 _ Hydrograph

Figure 5
Well No. 3 and Well No. 3R Hydrographs
Project No. 140207
Well 3R, City of Othello

Figure B-1 Depth to groundwater during 2018 constant rate pump test for Othello Wells No. 3 and No. 3R.

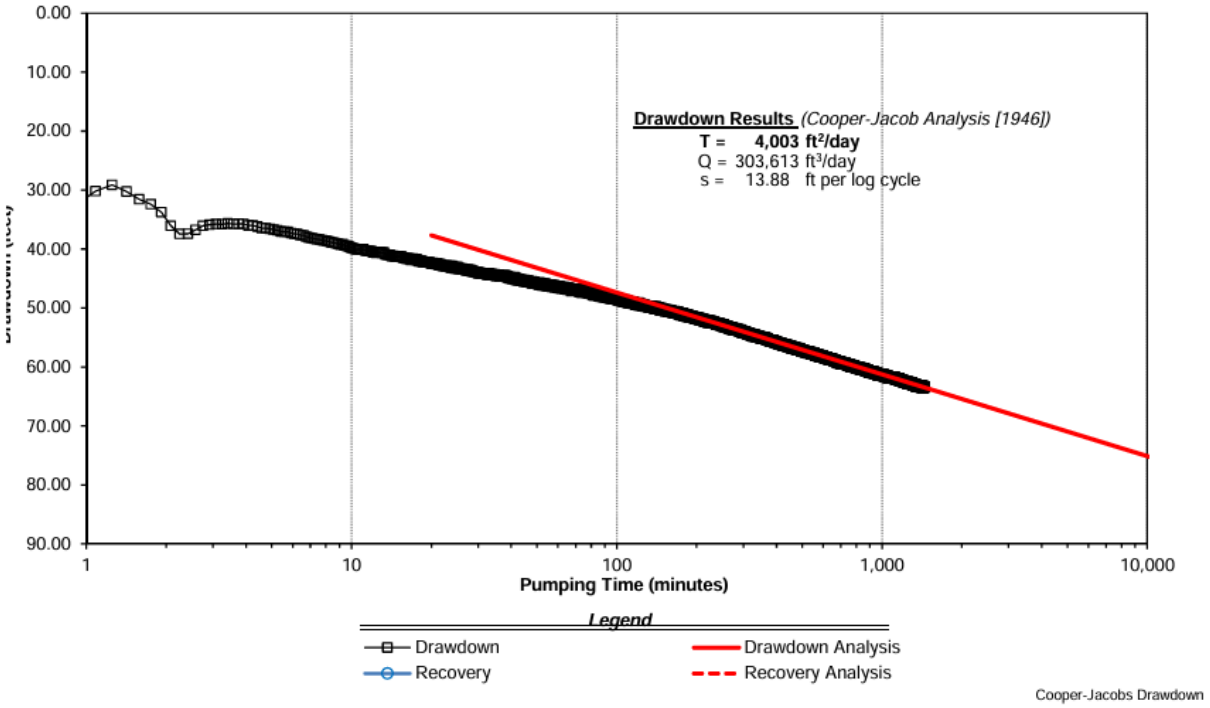
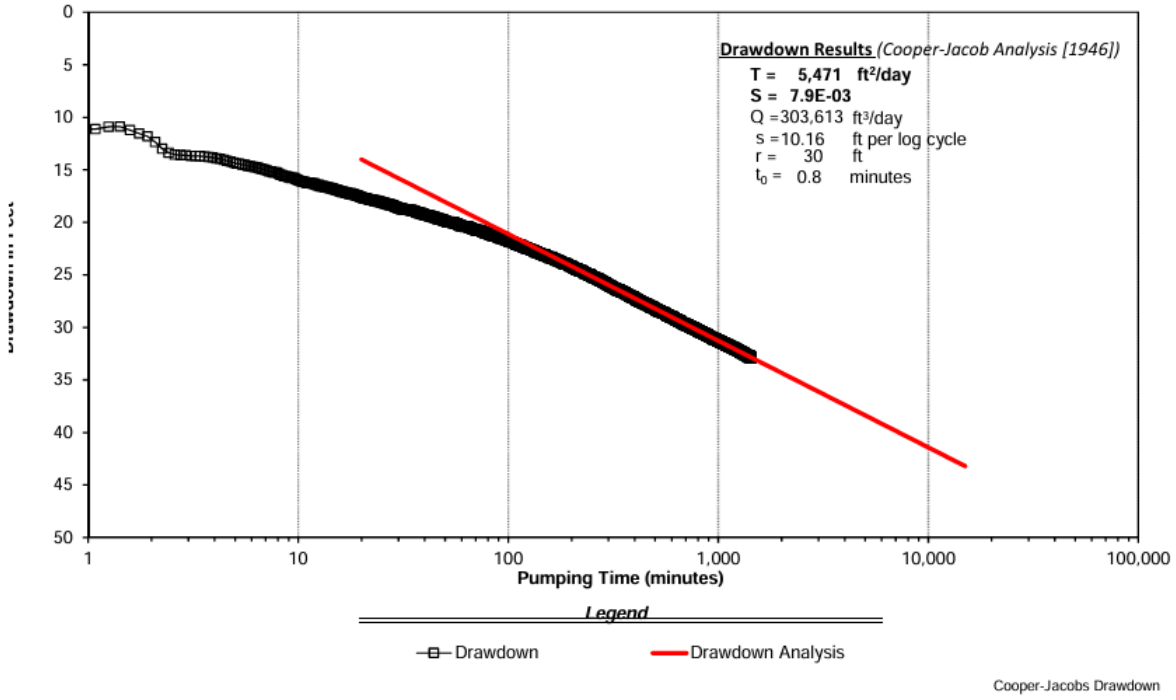


Figure 7
Well No. 3R - Cooper-Jacob Analysis
Well 3R Pump Test
Project No. 140207
Well 3R, Othello, WA

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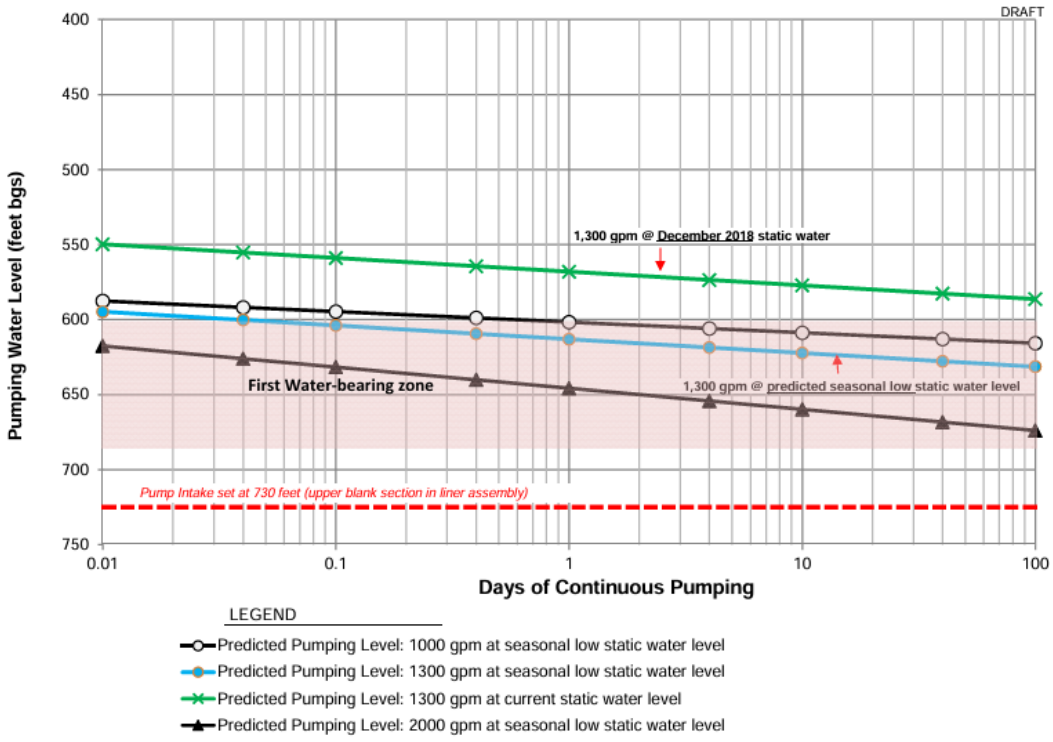
Figure B-2 Drawdown results using Cooper-Jacob Analysis for Othello Well No. 3R. (Aspect, 2019a).



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Figure 8
Observation Well No. 3 - Cooper-Jacob Analysis
Project No. 140207
Well 3R, Othello, WA

Figure B-3 Drawdown results using Cooper-Jacob Analysis for Othello Well No. 3 (Aspect, 2019a)



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V:\140207 City of Othello Strategic Planning\Deliverables\Well 3R\Figure 10 _ Predicted Ddn

Figure 10
Predicted Pumping Levels
Project No. 140207
City of Othello Well No. 3R, Othello, WA

Figure B-4 Predicted drawdown during different seasons and pumping rates at for Othello Well No. 3R. (Aspect, 2019a).

16.3 Appendix C: Well Logs, Well Reports and Available Information for Wells

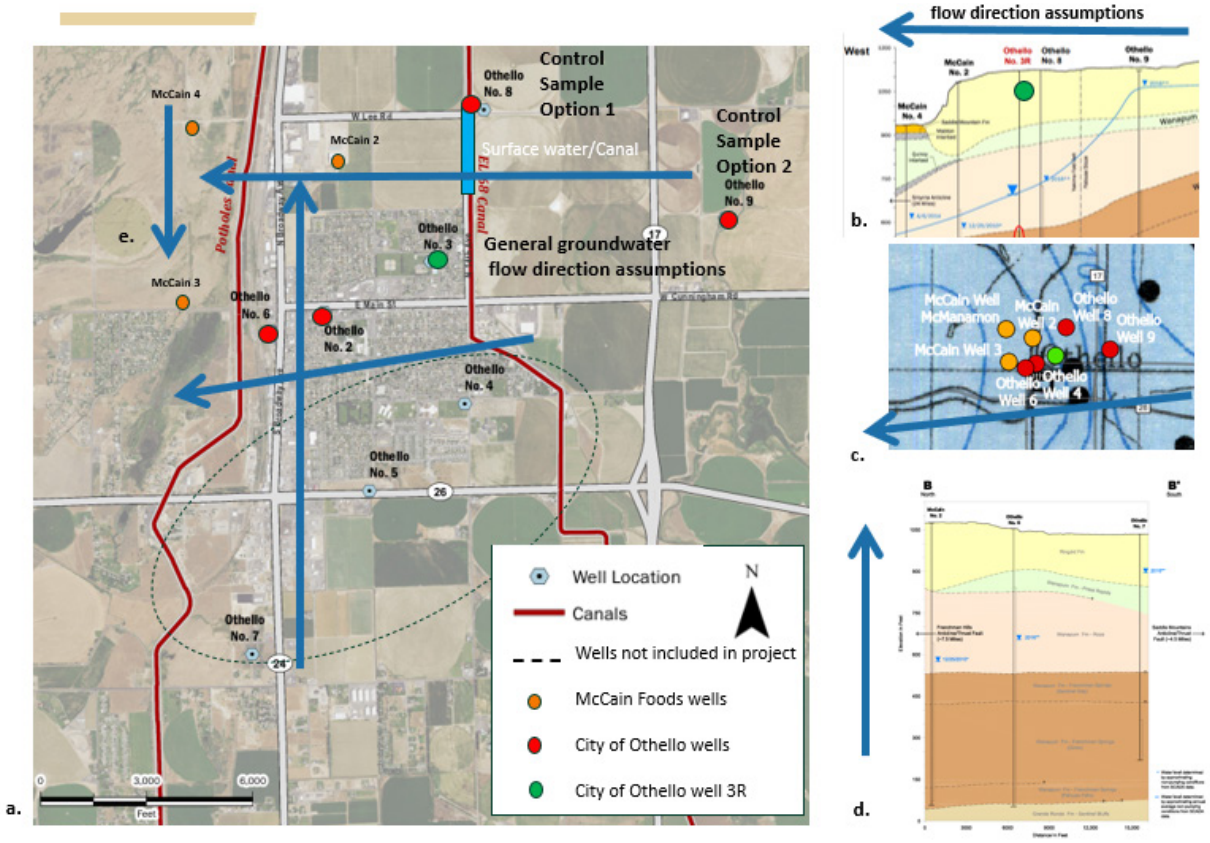


Figure C-1 Well locations

McCain Well #3 depth to water on 09/03/2021 is reported at 451 feet (see C-4 well log) and McCain Well #4 depth to water on 04/06/2014 is reported at 310 feet, which we interpret as a N-S downgradient in groundwater level (given surface elevation difference).

Table C-1 List of well logs and public information included in Appendix C.

Appendix C Section	ID	SWL [ft] (yr)	Geology Layer (Depth)	Owner-Usage (DOH)	Ecology Well ID	Site Address (Othello, WA)	TRS	Tax Parcel
C-1	Othello 3R Othello 3	537 (2018) 385 (1957) 515 (2018)	Wanapum Fm Frenchmen Springs- Gingko	Othello	AAS295 & AAS265	1130 E Fir St	SE ¼-¼ of SE ¼. S34. T16N. R29.	1529030680212
C-2	McCain Well #2	1032-1100 (2014) 353 (2003)	Wanapum Basalt	McCain Foods	BIN133 & AAS230 (no well reports online, 2025)	100 E Lee Rd	NW ¼-¼ of NW ¼. S34. T16N R29E.	1529030680269 & 1529030680289
C-3	McCain Well 3	402 (2021)	Wanapum Basalt	McCain Foods	BKL152	2136 Cunningham Rd	NW ¼-¼ of NW ¼. Section 34, T16N, R29E	2100490050200
C-4	McCain Well 4	310 (2014)	Wanapum Basalt	McCain Foods	no well reports online, 2025	2117 W McManamon Rd	NE1/4 NW1/4 Sect. 33 T16N R29EWM	-
C-5	Othello 2	No data (1940)	Wanapum Basalt at 557 ft	Othello	AFL224	Corner of S. 2nd and Larch Streets	NW ¼ of NW ¼. Section 03, T16N, R29E	-
C-6	Othello 4	396 ft (1994)	Wanapum Basalt at 904 ft (1970) & 1450 ft (1994)	Othello	AEL069	TBD	NE¼NE¼ NESE¼ S03 T15N R29E	-
C-7	Othello 5	277 ft (1987)	Wanapum Basalt 1007 ft (1974)	Othello	ABR235	TBD	SE-SW S03 T15N R29E	-
C-8	Othello Well 6	536 ft (2011)	Basalt	Othello	G3-25032P	S. Railroad Ave	NE ¼ NE ¼ Sec 4 T15N R29	-
C-9	Othello Well 7	125 ft (1998)	Wanapum Basalt (820 ft)	Othello	AAP562	1400 LF NO City Limits	SE-SE S09 T15N R29E	-
C-10	Othello Well 8	380 ft (2002)	Wanapum Basalt (951 ft)	Othello Permanent	AAS228	ENE of intersection	SW-SW S26 T16N R29E	-

Appendix C Section	ID	SWL [ft] (yr)	Geology Layer (Depth)	Owner-Usage (DOH)	Ecology Well ID	Site Address (Othello, WA)	TRS	Tax Parcel
						of Lee s/Reynolds		
C-11	Othello Well 9	51 (2015)	Wanapum Basalt (1115 ft)	Othello	AAR984	Cunningham Rd.	NE¼-¼ SW¼ S36 T16N R29	2100450780100
C-12	Port of Othello Well 3	57 (2008)	Wanapum Basalt (960 ft)	Port of Othello	ALF727	46.83681 119.05133	Sec33 T16N R30E	-

Table C-2. List of Othello wells with data from Department of Health (DOH).

Othello Wells	DOE Well Tag Numbers	Source Status	Effective Date	Usage	Capacity (gpm)	Treated	Metered	Well Depth (ft.)	T	R	S	Qtr/Qtr Section
2	AFL224	Active	10/1/1995	Emergency	260	No	Yes	588	15		3	NWNE
3	ABS088	Inactive	1/1/1970	Permanent	1,300	Yes	No	907	16		34	SESE
3R	AAS295	Active	3/19/2021	Permanent	1,570	Yes	Yes	979	16		34	SESE
4	AEL069	Active	1/1/1970	Permanent	450	Yes	Yes	904	15		3	NESE
5	AFL223	Active	1/1/1970	Permanent	1,200	Yes	Yes	1007	5		3	SESW
6	ABR235	Active	1/1/1970	Seasonal	2,000	Yes	Yes	1200	15		4	NENE
7	AAP562	Active	2/25/1999	Permanent	650	Yes	Yes	820	15		9	SESE
8	AAS228	Active	8/26/2003	Permanent	500	Yes	Yes	853	18		26	SWSW
9	AAR984	Active	6/30/2015	Permanent	1,000	Yes	Yes	1040	16		36	NESW

For all wells: Type: Groundwater well. Source Status: Active. WRIA: Esquatzel Coulee.

Table C-3. List of Othello & McCain wells ordered by Well Depth (ft).

Well	DOE Well Tag Number	SWL (ft.)	Year (SWL)	Well Depth (ft.)	Surface Elevation (ft.)
2	AFL224	No Data	1940	588	TBD
7	AAP562	125	1998	820	TBD
McCain 3	BKL152	402	2021	835	TBD
8	AAS228	380	2002	853	TBD
4	AEL069	396	1994	904	TBD
3	ABS088	385	1957	907	TBD
3	ABS088	515	2018	907	TBD
3R	AAS295	537	2018	979	TBD
5	AFL223	277	1987	1007	1055
McCain 2	BIN133	1100	2014	1010	TBD
McCain 2	AAS230	353	2003	1015	TBD
9	AAR984	51	2015	1040	TBD
6	ABR235	536	2011	1200	TBD
McCain 4	NA	310	2014	1250	940

Table C-4. List of Othello & McCain wells ordered by Surface Water Level (SWL, ft).

Well	DOE Well Tag Number	SWL (ft.)	Year (SWL)	Well Depth (ft.)	Surface Elevation (ft.)
9	AAR984	51	2015	1040	TBD
7	AAP562	125	1998	820	TBD
5	AFL223	277	1987	1007	1055
McCain 4	NA	310	2014	1250	940
McCain 2	AAS230	353	2003	1015	TBD
8	AAS228	380	2002	853	TBD
3	ABS088	385	1957	907	TBD
4	AEL069	396	1994	904	TBD
McCain 3	BKL152	402	2021	835	TBD
3	ABS088	515	2018	907	TBD
6	ABR235	536	2011	1200	TBD
3R	AAS295	537	2018	979	TBD
McCain 2	BIN133	1100	2014	1010	TBD
2	AFL224	No Data	1940	588	TBD

C-1 Othello Well 3R (AAS-295) & Othello Well 3 (AAS-265).



Figure C1-1 Site map for Othello Well 3 and 3R (Aspect, 2019a)

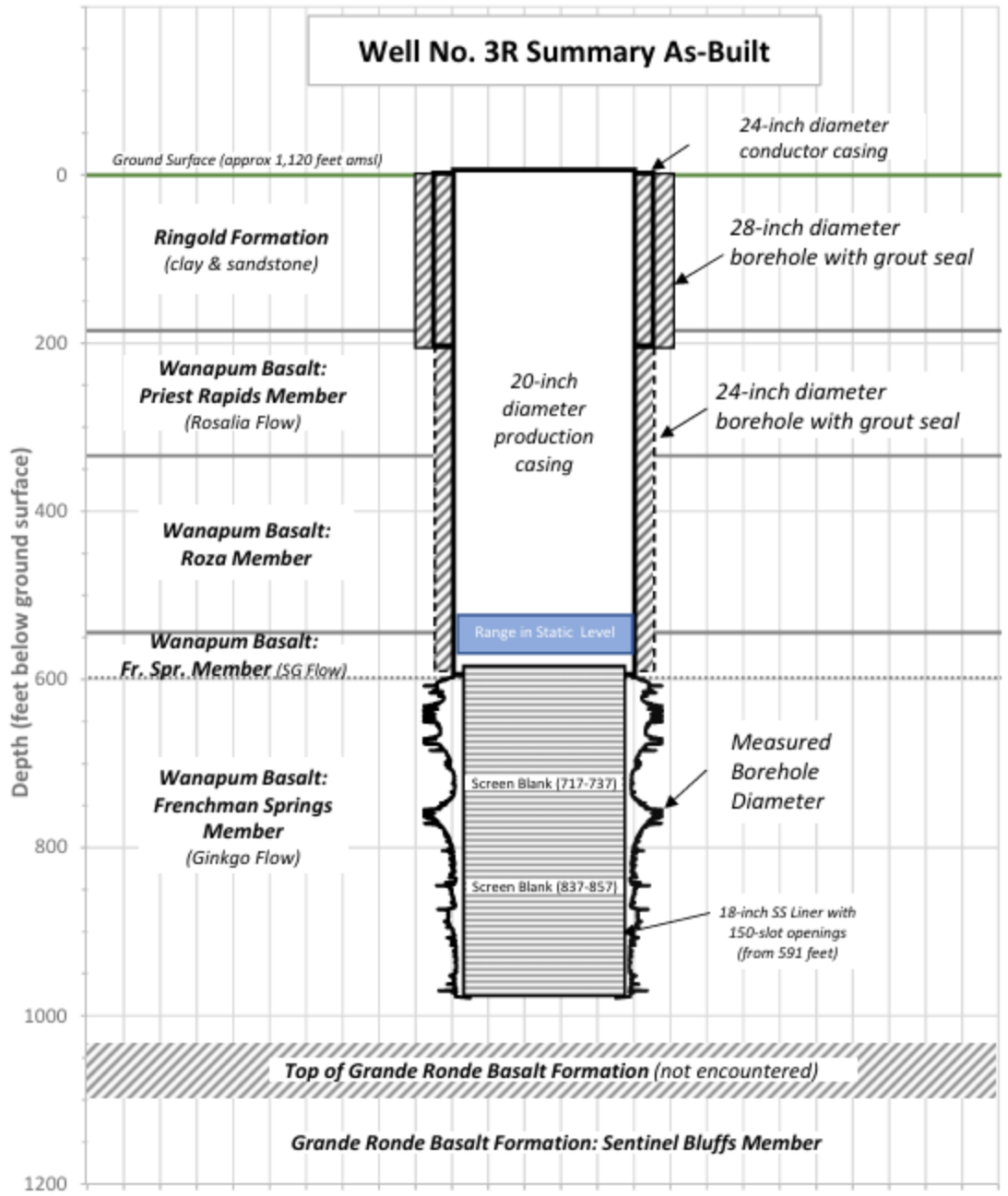


Figure 2
Well No. 3R Construction Log

Project No. 140207,
Well 3 Replacement Othello, WA

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V:\140207 City of Othello Strategic Planning\Deliverables\Well 3R\Figure 2_Well 3R Log

Figure C1-2 Summary of Othello Well 3R replacement of Well 3 (Aspect, 2019a)

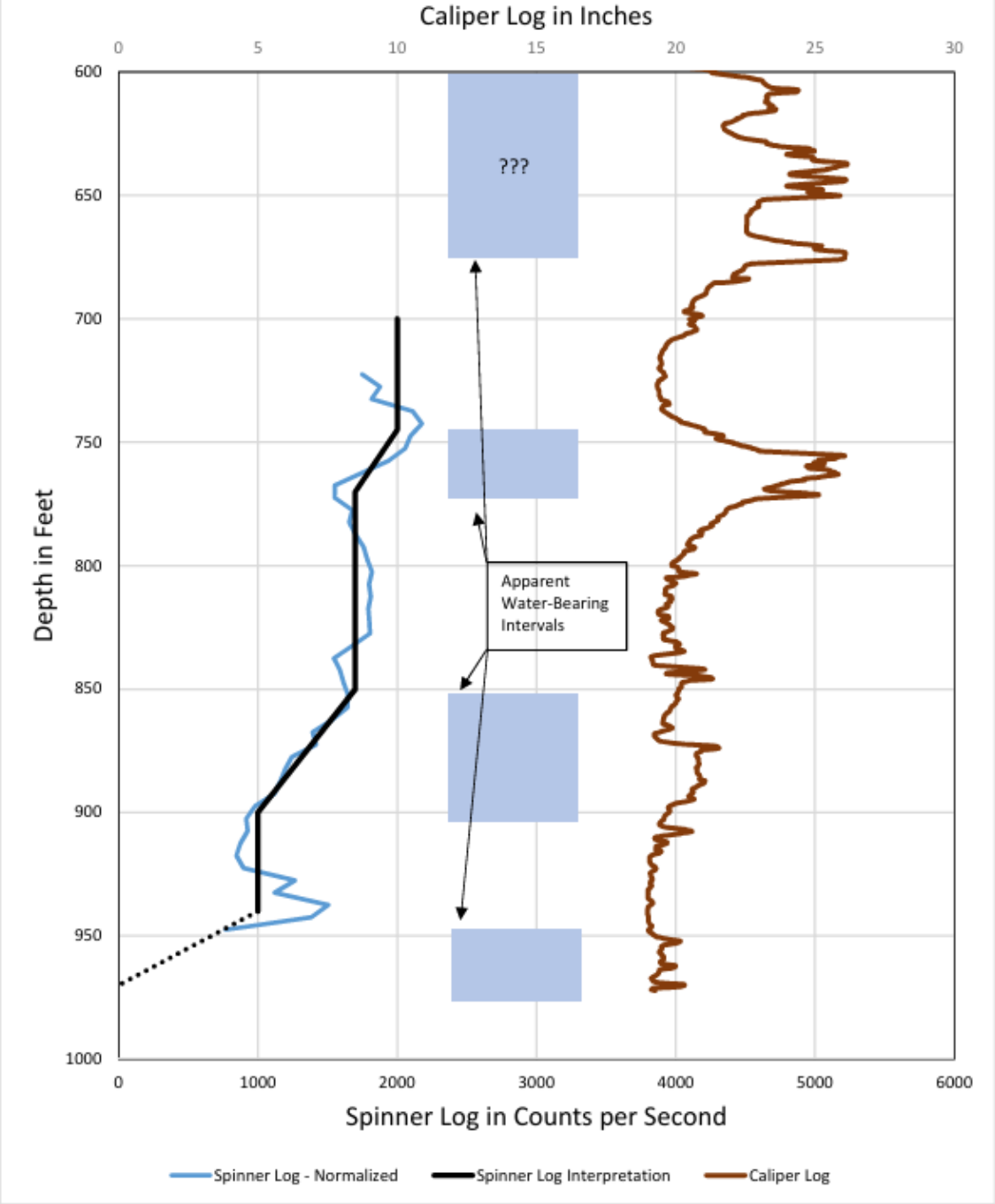


Figure 9
Spinner and Caliper Log Interpretation

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Well 3R
Project No. 140207
City of Othello

Figure C1-3 Othello Well 3R Spinner and Caliper Log interpretation from December 2018 constant-rate pump test (Aspect, 2019a)

WATER WELL REPORT

DEPARTMENT OF ECOLOGY State of Washington

Type of Work:
☑ Construction
☐ Decommission ⟹ Original installation NOI No. _____

Proposed Use: ☐ Domestic ☐ Industrial ☑ Municipal ☐ Dewatering ☐ Irrigation ☐ Test Well ☐ Other _____

Construction Type: ☑ New well ☐ Alteration ☐ Deepening ☐ Other _____

Method: ☐ Driven ☐ Jetted ☐ Cable Tool ☐ Dug ☑ Air- ☑ Mud-Rotary

Dimensions: Diameter of boring 28/24/20/16 in., to 205/624/977/979 ft.
Depth of completed well 979 ft.

Construction Details:

Casing	Liner	Diameter	From	To	Wall Thickness	Steel	PVC	Welded	Thread
☑	☐	24 in.	0.5	204	.375 in.	☑	☐	☑	☐
☑	☐	20 in.	+3	600	.375 in.	☑	☐	☑	☐
☐	☑	18 in.	591*	979*	.375 in.	☑	☐	☑	☐
☐	☐	____ in.	____	____	____ in.	☐	☐	☐	☐

Perforations: ☐ Yes ☑ No Type of perforator used _____
No. of perforations ____ Size of perforations ____ in. by ____ in.
Perforated from ____ ft. to ____ ft. below ground surface

Screens: ☑ Yes ☐ No ☐ K-Packer ⟹ Depth ____ ft.
Manufacturer's Name Alloy MFG
Type V-shaped wire wrap Model No. 304SS
Diameter 18 in. Slot size 0.150 in. from * ft. to * ft.
Diameter ____ in. Slot size ____ in. from ____ ft. to ____ ft.

Sand/Filter pack: ☐ Yes ☑ No Size of pack material ____ in.
Materials placed from ____ ft. to ____ ft.

Surface Seal: ☑ Yes ☐ No To what depth? 600 ft.
Material used in seal Neat cement & bentonite
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? _____ Depth of strata _____
Method of sealing strata off _____

Pump: Manufacturer's Name _____ Type: _____
H.P. ____ Pump intake depth: ____ ft. Designed flow rate: ____ gpm

Water Levels: Land-surface elevation above mean sea level ____ ft.
Stick-up of top of well casing 3 ft. above ground surface
Static water level 537 ft. below top of well casing Date 12-12-18
Artesian pressure ____ lbs. per square inch Date _____
Artesian water is controlled by _____ (cap, valve, etc.)

Well Tests:
Was a pumping test performed? ☐ No ☑ Yes ⟹ by whom? SWS
Yield 1570 gpm with 46 ft. drawdown after 24 hrs.
Yield ____ gpm with ____ ft. drawdown after ____ hrs.
Yield ____ gpm with ____ ft. drawdown after ____ hrs.
Recovery data (time = zero when pump is turned off - water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
____	____	____	____	____	____
____	____	____	____	____	____
____	____	____	____	____	____

Date of pumping test 12/12/18-12/13/18
Bailer test ____ gpm with ____ ft. drawdown after ____ hrs.
Air test ____ gpm with stem set at ____ ft. for ____ hrs. Date _____
Artesian flow ____ gpm
Temperature of water ~75 °F Was a chemical analysis made? ☑ Yes ☐ No

Notice of Intent No. WE30961
Unique Ecology Well ID Tag No. AAS-295
Site Well Name (if more than one well): Well 3R
Water Right Permit/Certificate No. G3-25032
Property Owner Name City of Othello
Well Street Address 1130 E Fir St
City Othello County Adams
Tax Parcel No. 1529030680212
Was a variance approved for this well? ☐ Yes ☑ No
If yes, what was the variance for? _____

Location (see instructions on page 2): ☐ WWM or ☑ EWM
SE ¼-¼ of the SE ¼ Section 34 Township 16N Range 29
Latitude (Example: 47.12345) _____
Longitude (Example: -120.12345) _____

Driller's Log/Construction or Decommission Procedure
Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each layer penetrated, with at least one entry for each change of information. Use additional sheets if necessary.

Material	From	To
See attached formation log		
*18" pipe size liner/screen assembly:		
J-receptor - low carbon steel	591	597
Screen	597	717
304SS blank pipe .375 wall	717	737
Screen	737	837
304SS blank pipe .375 wall	837	857
Screen	857	977
Low carbon steel fabricated cone bottom (18x~8)	977	979
Plate ring welded between 24" & 20" casings		
at top of 24" casing.		
12/11/18 Step test information:		
Step 1: 345 gpm with 3.6' DD after 1 hour		
Step 2: 707 gpm with 10.4' DD after 1 hour		
Step 3: 1053 gpm with 18.9' DD after 1 hour		
Step 4: 1382 gpm with 28.4' DD after 1 hour		
Step 5: 1900 gpm with 45.8' DD after 1 hour		

Start Date 5-3-18 Completed Date 12/20/18

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

☑ Driller ☐ Trainee ☐ PE Print Name Steve Schneider
Signature [signature]
License No. 0643
IF TRAINEE: Sponsor's License No.
Sponsor's Signature

Drilling Company Schneider Water Services
Address 21881 River Road NE
City, State, Zip St. Paul, OR, 97137
Contractor's Registration No. SCHNEEI940R8 Date 1/10/19

ECY 050-1-20 (Rev 11/18) *If you need this document in an alternate format, please call the Water Resources Program at 360-407-6872. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call*

Figure C1-4. Othello Well 3R Water Well Report (2018)

City of Othello
NOI #WE30961 - Well Tag ID #AAS-295
Well 3R Formation Log
by Schneider Water Services

FM	TO	DESCRIPTION
0	13	Clay, brown, dry, silty w/caliche
13	43	Caliche, medium
43	50	Clay, brown, medium-soft, sandy-silty
50	70	Clay, brown, medium, sandy-silty
70	110	Clay, tan, soft, silty
110	120	Shale, grey, medium-hard
120	138	Clay, brown, & grey, medium-soft w/claystone, brown & grey, soft
138	154	Clay, brown, & grey, medium-soft w/sand, multicolored, fine-medium
154	185	Siltstone, tan & white, hard w/clay, brown & tan, soft-medium
185	193	Basalt, brown & grey, medium, fractured
193	220	Basalt, grey, medium-hard, some fractures
220	225	Basalt, brown, soft-medium, fractured w/claystone, tan, med
225	232	Basalt, brown & grey, medium, fractured w/claystone, tan, medium
232	235	Basalt, brown & grey, medium
235	261	Basalt, grey, medium-hard, fractured
261	266	Basalt, grey & dark grey, medium, fractured, some vesicles
266	306	Basalt, grey, medium-hard, fractured
306	311	Claystone, orange & tan, medium w/basalt, brown & grey, vesicular
311	336	Basalt, grey & brown, medium, vesicular w/clayston, orange & tan
336	352	Basalt, grey & brown, medium-hard w/claystone, orange & tan
352	372	Basalt, grey & brown, medium-hard, fractured
372	391	Basalt, grey, hard, some fractures
391	413	Basalt, grey, medium-hard, fractured
413	428	Basalt, grey, hard, fractured
428	448	Basalt, grey & brown, hard, fractured w/claystone, greenish tan, soft
448	462	Basalt, grey & brown, hard, fractured w/claystone, black & green, medium-hard
462	468	Basalt, grey, hard, fractured w/claystone, black, hard
468	469	Basalt, grey & brown, medium-hard, fractured w/claystone, green & black, hard
469	497	Basalt, grey & brown, medium-hard, fractured, some vesicles w/claystone, green-tan-black, medium-hard
497	499	Basalt, grey, medium-hard, fractured, some vesicles
499	530	Basalt, grey, medium-hard, fractured, some vesicles w/claystone, green & blue, medium
530	559	Basalt, grey, hard, some fractures
559	571	Basalt, grey, medium, fractured w/claystone, black & grey, hard
571	653	Basalt, grey, medium-hard, fractured, vesicular

Figure C1-5. Othello Well 3R Formation Log Page 1 of 2

City of Othello
NOI #WE30961 - Well Tag ID #AAS-295
Well 3R Formation Log
by Schneider Water Services

FM	TO	DESCRIPTION
653	662	Basalt, grey, medium-hard, fractured, some vesicles w/claystone, green, medium
662	676	Basalt, grey, hard, some fracutres w/claystone, grey, med
676	681	Basalt, brown, soft-medium, fractured, vesicular
681	689	Basalt, grey, medium-hard, some fractures
689	720	Basalt, grey, hard, some fractures
720	725	Basalt, grey & brown, medium-hard, fractured, some vesicles
725	740	Basalt, grey, hard, some fractures
740	745	Basalt, grey & brown, medium, fractured, some vesicles
745	754	Basalt, grey, hard, fractured w/claystone, black, hard
754	759	Basalt, black, medium, fractured, some vesicles
759	761	Basalt, grey, hard, fractured
761	766	Basalt, grey, medium-hard, fractured
766	782	Basalt, grey, medium, fractured, vesicular
782	798	Basalt, grey, medium-hard, fractured
798	829	Basalt, grey, hard, fractured
829	847	Basalt, grey, hard, some fractures
847	860	Basalt, dark grey, medium, fractured, vesicular w/claystone, blue, medium
860	878	Basalt, dark grey, medium-hard, some fractures
878	896	Basalt, dark grey, medium, fractured, some vesicles w/claystone, blue & green, medium
896	900	Basalt, dark grey, medium-hard, some fractures
900	901	Clay, dark grey, medium, silty
901	916	Basalt, grey, hard, ssome fractures
916	954	Basalt, grey, hard, few fractures
954	957	Basalt, dark grey, medium, some fractures
957	967	Basalt, black, medium, fractured, vesicular w/clay, green, med
967	977	Basalt dark grey, medium, some vesicles & fractures
977	979	Basalt, dark grey, medium w/pyrite

Figure C1-6. Othello Well 3R Formation Log Page 2 of 2



Well 3R Housing and Sampling Spicket



Well 3 (not 3R) Well Tag



Well 3R Sampling Spicket

Figure C1-7. Othello Well 3R housing and sampling spicket. Well 3 well tag. Field Trip Photos taken June 9, 2025.

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

Original Log for Well No. 3

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
AND DEVELOPMENT

WELL LOG Well #3 No. Appli. #5002

Date February, 1957

Record by well driller

Source driller's record

Location: State of WASHINGTON

County Adams

Area

Map

NW¼SE¼ SE¼ sec 34 T. 16 N., R. 29 E. W.

Diagram of Section

Drilling Co. Gray & Osborne

Address Yakima, Washington

Method of Drilling Date , 19

Owner City of Othello, Wash.

Address

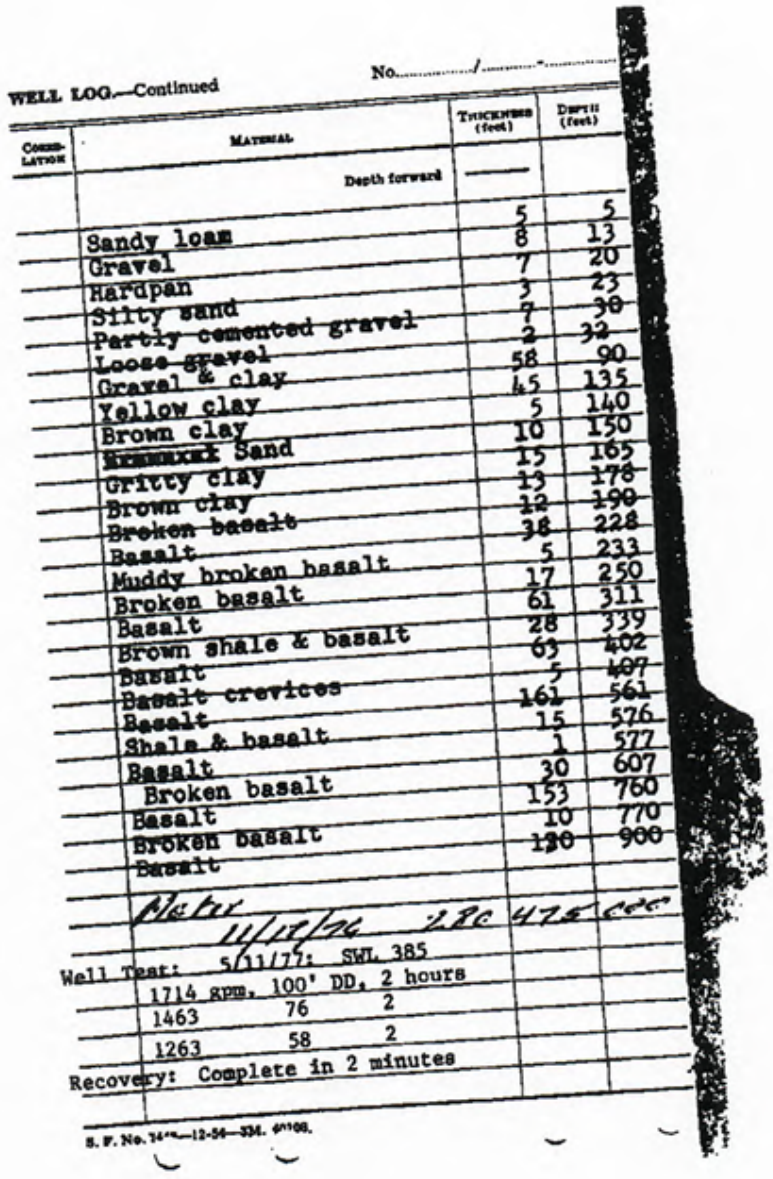
Land surface, datum ft above / below

Correlation	Material	Thickness (feet)	Depth (feet)
	(Transcribe driller's terminology literally but paraphrase as necessary, in parentheses. If material water-bearing, so state and record static level if reported. Give depths in feet below land-surface datum unless otherwise indicated. Correlate with stratigraphic column, if feasible. Following log of materials, list all casings, perforations, screens, etc.)		
	See drawing in file		
	PUMP TEST:		
	Dim. 900'x16"		
	SWL: 278 ft.		
	DD: 36 ft.		
	Yield: 1340 g.p.m.		
	Water Tem.p 75° F.		
	Type & size of pump: Turbine 1130 g.p		
	" " " " motor: elec. 150 h.p.		
	CASING:		
	16" diam. std. wt. from 0 to 197ft.		
	Metal 104612		

Turn up Sheet of sheets

Figure C1-8. Othello Well 3 Original Well Log (1957).

The Dep The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.



WELL LOG.—Continued No. ...../.....

Color-ation	Material	Thickness (feet)	Depth (feet)
	Depth forward	———	
	Sandy loam	5	5
	Gravel	8	13
	Hardpan	7	20
	Silty sand	3	23
	Partly cemented gravel	7	30
	Loose gravel	2	32
	Gravel & clay	58	90
	Yellow clay	45	135
	Brown clay	5	140
	Sand	10	150
	Gritty clay	15	165
	Brown clay	13	178
	Broken basalt	12	190
	Basalt	38	228
	Muddy broken basalt	5	233
	Broken basalt	17	250
	Basalt	61	311
	Brown shale & basalt	28	339
	Basalt	63	402
	Basalt crevices	5	407
	Basalt	161	561
	Shale & basalt	15	576
	Basalt	1	577
	Broken basalt	30	607
	Basalt	153	760
	Broken basalt	10	770
	Basalt	130	900
	Water 11/17/76 2BC 475 GPM		

Well Test: 5/11/77: SWL 385
1714 gpm, 100' DD, 2 hours
1463 76 2
1263 58 2

Recovery: Complete in 2 minutes

S. F. No. 74[illegible]—12-54—334. 6[illegible]08.

Figure C1-9. Othello Well 3 Well Log (1977).

Well No. 3
Modifications

WATER WELL REPORT

DEPARTMENT OF ECOLOGY State of Washington

Type of Work:
☒ Construction
☐ Decommission ⇨ Original installation NOI No. _____

Proposed Use: ☐ Domestic ☐ Industrial ☒ Municipal ☐ Dewatering ☐ Irrigation ☐ Test Well ☐ Other _____

Construction Type: ☐ New well ☒ Alteration ☐ Deepening ☐ Other _____
Method: ☐ Driven ☐ Jetted ☐ Cable Tool ☐ Dug ☐ Air- ☐ Mud-Rotary

Dimensions: Diameter of boring 16+/-(exist) in., to 853+? ft.
Depth of completed well 853 ft.

Construction Details:

Casing	Liner	Diameter	From	To	Wall Thickness	Steel	PVC	Welded	Thread
☒	☐	4 in.	+3'	853'	.237 in.	☒	☐	☒	☐
☐	☐	____ in.	____	____	____ in.	☐	☐	☐	☐
☐	☐	____ in.	____	____	____ in.	☐	☐	☐	☐
☐	☐	____ in.	____	____	____ in.	☐	☐	☐	☐

Perforations: ☒ Yes ☐ No Type of perforator used Mills Knife
No. of perforations 100 Size of perforations 3/8 in. by 2.5 in.
Perforated from 0 ft. to 20 ft. below ground surface

Screens: ☒ Yes ☐ No ☐ K-Packer ⇨ Depth ____ ft.
Manufacturer's Name Alloy
Type V-shaped wire wrap Model No. 304SS
Diameter 4 in. Slot size .100 in. from * ft. to * ft.
Diameter ____ in. Slot size ____ in. from ____ ft. to ____ ft.

Sand/Filter pack: ☐ Yes ☒ No Size of pack material ____ in.
Materials placed from ____ ft. to ____ ft.

Surface Seal: ☒ Yes ☐ No To what depth? 595** ft.
Material used in seal **Neat cement & bentonite chips
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? _____ Depth of strata _____
Method of sealing strata off _____

Pump: Manufacturer's Name _____ Type: _____
H.P. ____ Pump intake depth: ____ ft. Designed flow rate: ____ gpm

Water Levels: Land-surface elevation above mean sea level ____ ft.
Stick-up of top of well casing 3 ft. above ground surface
Static water level 515 ft. below top of well casing Date 11/26/18
Artesian pressure ____ lbs. per square inch Date ____
Artesian water is controlled by _____ (cap, valve, etc.)

Well Tests:
Was a pumping test performed? ☒ No ☐ Yes ⇨ by whom? _____
Yield ____ gpm with ____ ft. drawdown after ____ hrs.
Yield ____ gpm with ____ ft. drawdown after ____ hrs.
Yield ____ gpm with ____ ft. drawdown after ____ hrs.
Recovery data (time = zero when pump is turned off – water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
____	____	____	____	____	____
____	____	____	____	____	____
____	____	____	____	____	____

Date of pumping test _____
Bailer test ____ gpm with ____ ft. drawdown after ____ hrs.
Air test ____ gpm with stem set at ____ ft. for ____ hrs. Date _____
Artesian flow ____ gpm
Temperature of water ____ °F Was a chemical analysis made? ☐ Yes ☒ No

Notice of Intent No. WE33644
Unique Ecology Well ID Tag No. AAS 265 (found no previous tag)
Site Well Name (if more than one well): 3
Water Right Permit/Certificate No. G3-25032
Property Owner Name City of Othello
Well Street Address 1130 E Fir St
City Othello County Adams
Tax Parcel No. 1529030680212
Was a variance approved for this well? ☐ Yes ☒ No
If yes, what was the variance for? _____

Location (see instructions on page 2): ☐ WWM or ☒ EWM
SE ¼-¼ of the SE ¼ Section 34 Township 16N Range 29
Latitude (Example: 47.12345) _____
Longitude (Example: -120.12345) _____

Driller's Log/Construction or Decommission Procedure
Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each layer penetrated, with at least one entry for each change of information. Use additional sheets if necessary.

Material	From	To
Alteration Only - No Drilling. See attached log.		
Well is inside a masonry block building.		
Bailed well and removed:		
68' of PVC pipe & 63' of galvanized steel pipe		
Up to 10" size pieces of basalt (slough).		
Size of rocks prevented bailing hole below 853'.		
Received approval from Ecology to proceed.		
Perforated top 20' of existing 16" casing.		
*Installed 4" Casing & Screen Assembly:		
Casing	+3	605
Screen	605	625
Casing	625	675
Screen	675	695
Casing	695	755
Screen	755	775
Casing	775	830
Screen	830	850
Casing w/tapered bottom and plate	850	853
Placed following in annulus outside 4" Casing:		
**Neat cement (pumped 335 sacks)	0	198
**Bentonite chips (placed 1030 sacks)	198	595
Pea gravel (1/4-1/8)	595	853

Start Date 11/5/18 Completed Date 12-4-18

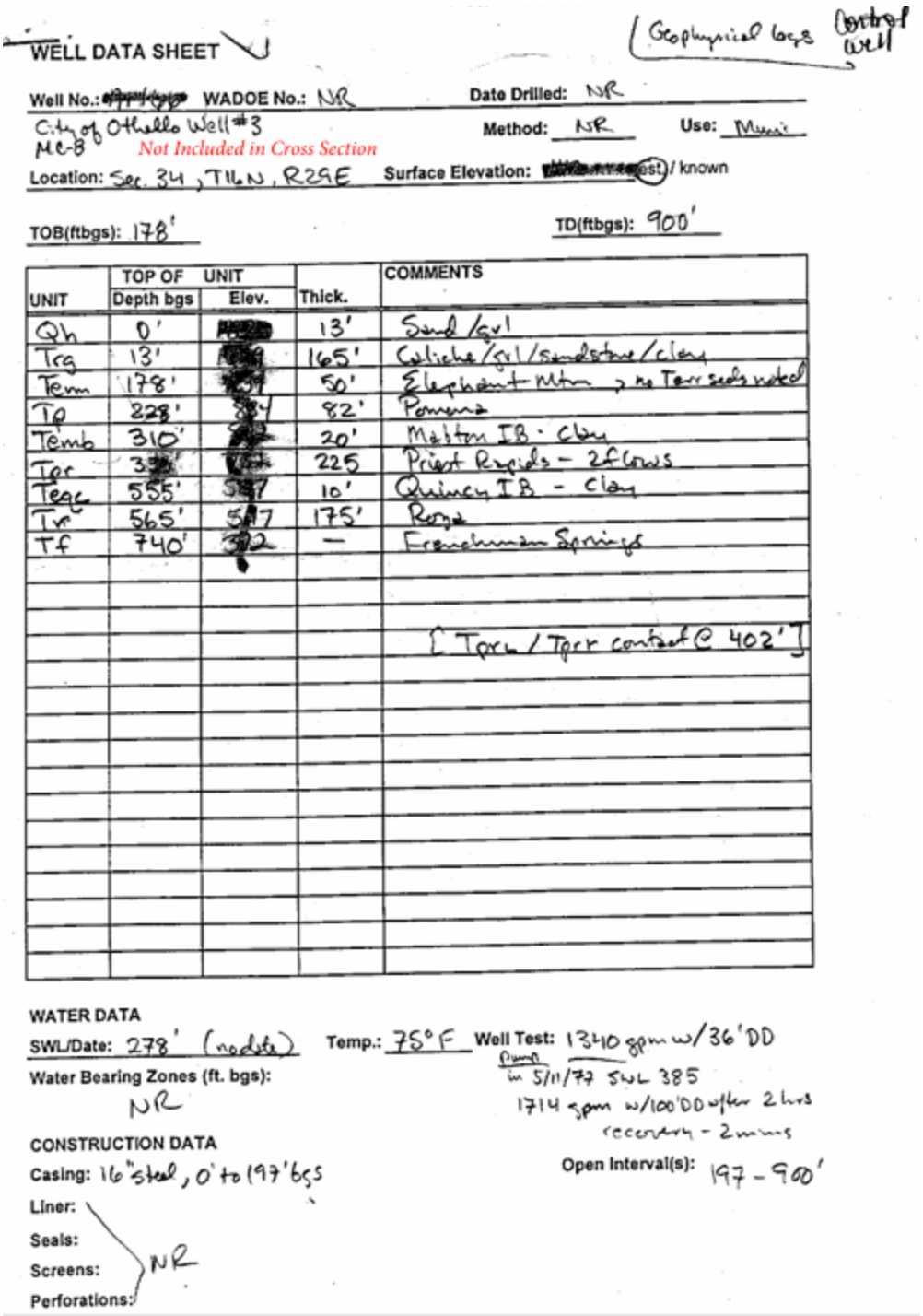
WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

☒ Driller ☐ Trainee ☐ PE – Print Name Steve Schneider
Signature Stephen Schneider
License No. 0643
IF TRAINEE: Sponsor's License No.
Sponsor's Signature

Drilling Company Schneider Water Services
Address 21881 River RD NE
City, State, Zip St. Paul OR 97137
Contractor's Registration No. SCHNEEI940R8 Date 12/31/18

ECY 050-1-20 (Rev 11/18) *If you need this document in an alternate format, please call the Water Resources Program at 360-407-6872. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call 877-833-6341.*

Figure C1-10. Othello Well 3 Well Modifications (2018).



WELL DATA SHEET

Geophysical logs (control well)

Well No.: [redacted] WADOE No.: NR Date Drilled: NR

City of Othello Well #3 Method: NR Use: Muni

MC-B Not Included in Cross Section

Location: Sec. 34, T16N, R29E Surface Elevation: [redacted] est. / known

TOB(ftbgs): 178' TD(ftbgs): 900'

UNIT	TOP OF UNIT Depth bgs	Elev.	Thick.	COMMENTS
Qh	0'	[redacted]	13'	Sand/gvl
Trg	13'	[redacted]	165'	Caliche/gvl/sandstone/clay
Tem	178'	[redacted]	50'	Elephant Mtn, no Terr seals noted
Tp	228'	[redacted]	82'	Pomona
Tcmb	310'	[redacted]	20'	Malaga IB · clay
Tgr	330'	[redacted]	225	Priest Rapids - 2 flows
Tcqc	555'	[redacted]	10'	Quincy IB - clay
Tr	565'	[redacted]	175'	Roza
Tf	740'	[redacted]	—	Frenchman Springs
				[Tgrw / Tgrr contact @ 402']

WATER DATA

SWL/Date: 278' (no date) Temp.: 75°F Well Test: 1340 gpm w/36'DD

Water Bearing Zones (ft. bgs): NR

Pump in 5/11/77 SWL 385

1714 gpm w/100'DD after 2 hrs

recovery - 2 mins

CONSTRUCTION DATA

Casing: 16" steel, 0' to 197' bgs Open Interval(s): 197 - 900'

Liner:

Seals:

Screens: NR

Perforations:

Figure C1-11. Othello Well 3 Well Data Sheet (1977).

Well #3 - ABS088

Source Status	Inactive	**Usage**	Permanent	**WRIA**	Esquatzel Coulee
Type	Groundwater Well	**Capacity (gpm)**	1,300	**Township**	16
Effective Date	1/1/1970	**Treated**	Yes	**Range**	29E
Inactive Date		**Metered**	No	**Section**	34
DOE Well Tag Number	**ABS088**	**Well Depth (ft)**	**907**	**Qtr/Qtr Section**	SESE

Well #3R - AAS295

Source Status	Active	**Usage**	Permanent	**WRIA**	Esquatzel Coulee
Type	Groundwater Well	**Capacity (gpm)**	1,570	**Township**	16
Effective Date	3/19/2021	**Treated**	Yes	**Range**	29E
Inactive Date		**Metered**	Yes	**Section**	34
DOE Well Tag Number	AAS295	**Well Depth (ft)**	979	**Qtr/Qtr Section**	SESE

C-2. McCain Well 2: Ecology Well ID Tag BIN-133 & AAS-230



Figure C2-1. McCain Well #2 at plant location 100 E Lee Road, Othello (NW ¼-¼ of NW ¼. Section 34, T16N, R29E). Photos taken during June 9, 2025, project field trip.

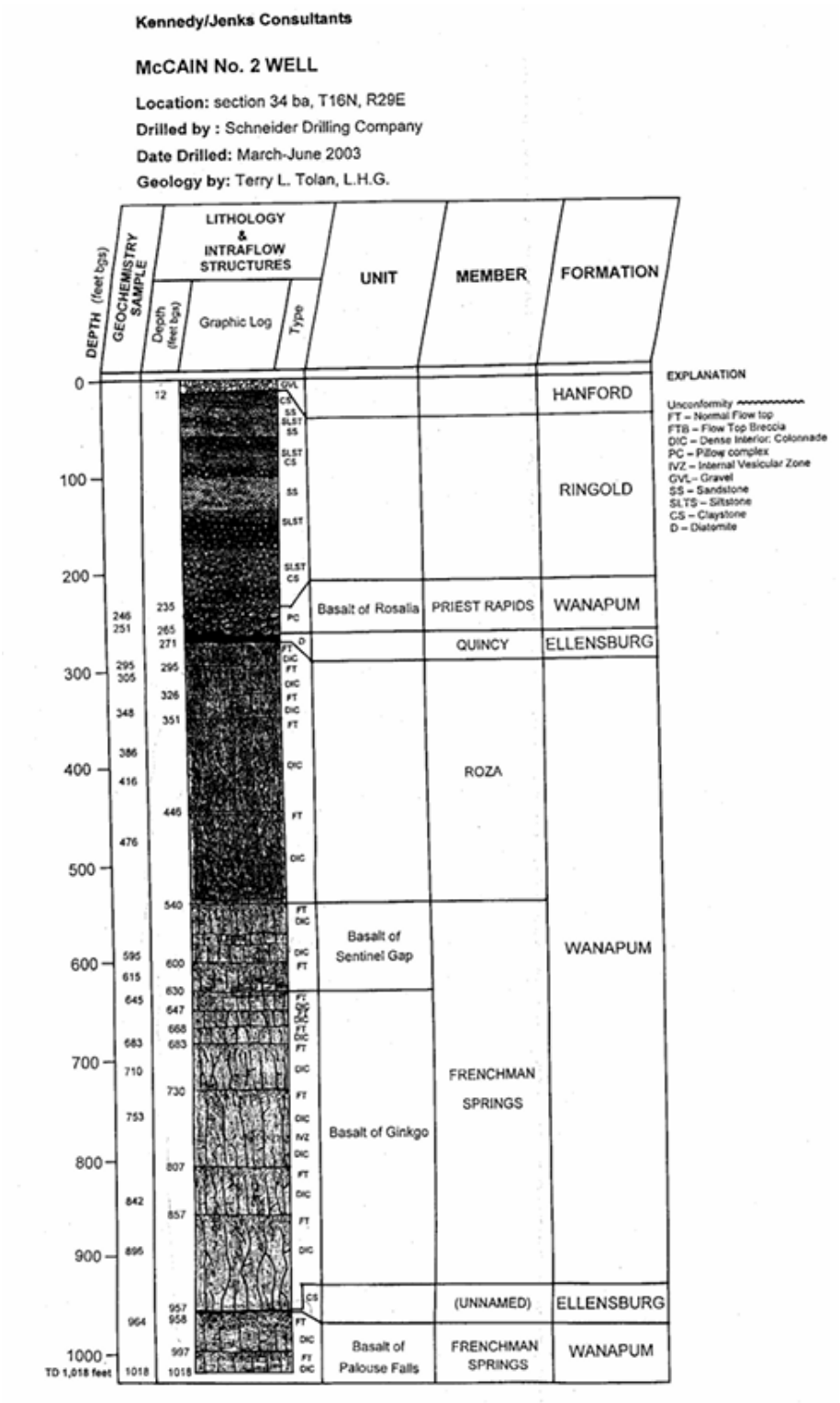
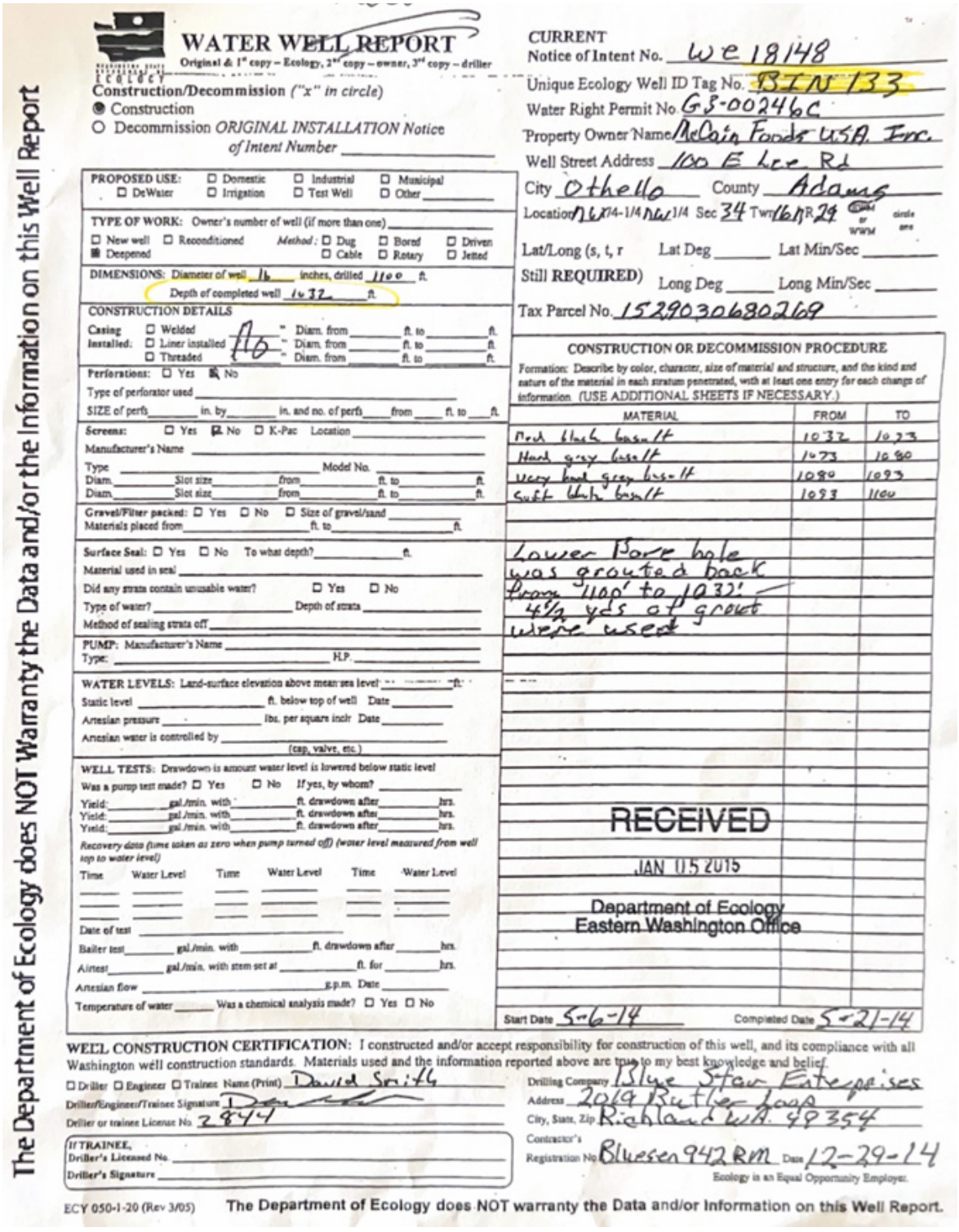


Figure C2-2. McCain Well #2 units, members, formations, lithology and interflow structures (2003).



WATER WELL REPORT
Original & 1st copy – Ecology, 2nd copy – owner, 3rd copy – driller

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report

Construction/Decommission ("x" in circle)
● Construction
○ Decommission ORIGINAL INSTALLATION Notice of Intent Number

CURRENT
Notice of Intent No. WE 18148
Unique Ecology Well ID Tag No. BIN 133
Water Right Permit No. G3-00246C
Property Owner Name McCain Foods USA Inc.
Well Street Address 100 E Lee Rd
City Othello County Adams
Location NE 1/4-1/4 NW 1/4 Sec 34 Twn 16N R 29 E or WWM
Lat/Long (s, t, r Still REQUIRED) Lat Deg ____ Lat Min/Sec ____ Long Deg ____ Long Min/Sec ____
Tax Parcel No. 152903068802 69

PROPOSED USE: ☐ Domestic ☐ Industrial ☐ Municipal ☐ DeWater ☐ Irrigation ☐ Test Well ☐ Other
TYPE OF WORK: Owner's number of well (if more than one)
☐ New well ☐ Reconditioned Method: ☐ Dug ☐ Bored ☐ Driven ■ Deepened ☐ Cable ☐ Rotary ☐ Jetted
DIMENSIONS: Diameter of well 16 inches, drilled 1100 ft. Depth of completed well 1032 ft.
CONSTRUCTION DETAILS
Casing Installed: ☐ Welded ☐ Liner installed 16 " Diam. from ____ ft. to ____ ft. ☐ Threaded " Diam. from ____ ft. to ____ ft.
Perforations: ☐ Yes ■ No
Type of perforator used
SIZE of perfs ____ in. by ____ in. and no. of perfs ____ from ____ ft. to ____ ft.
Screens: ☐ Yes ■ No ☐ K-Pac Location
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.
Gravel/Filter packed: ☐ Yes ☐ No ☐ Size of gravel/sand
Materials placed from ft. to ft.
Surface Seal: ☐ Yes ☐ No To what depth? ft.
Material used in seal
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? Depth of strata
Method of sealing strata off
PUMP: Manufacturer's Name
Type: H.P.
WATER LEVELS: Land-surface elevation above mean sea level ft.
Static level ft. below top of well Date
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (cap, valve, etc.)
WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☐ Yes ☐ No If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
Yield: gal./min. with ft. drawdown after hrs.
Yield: gal./min. with ft. drawdown after hrs.
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)
Time Water Level Time Water Level Time Water Level
Date of test
Bailer test gal./min. with ft. drawdown after hrs.
Airtest gal./min. with stem set at ft. for hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? ☐ Yes ☐ No

CONSTRUCTION OR DECOMMISSION PROCEDURE
Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. (USE ADDITIONAL SHEETS IF NECESSARY.)

MATERIAL	FROM	TO
Med black basalt	1032	1073
Hard gray basalt	1073	1080
Very hard gray basalt	1080	1093
Soft black basalt	1093	1100
Lower Bore hole was grouted back from 1100' to 1032' 4½ yds of grout were used		

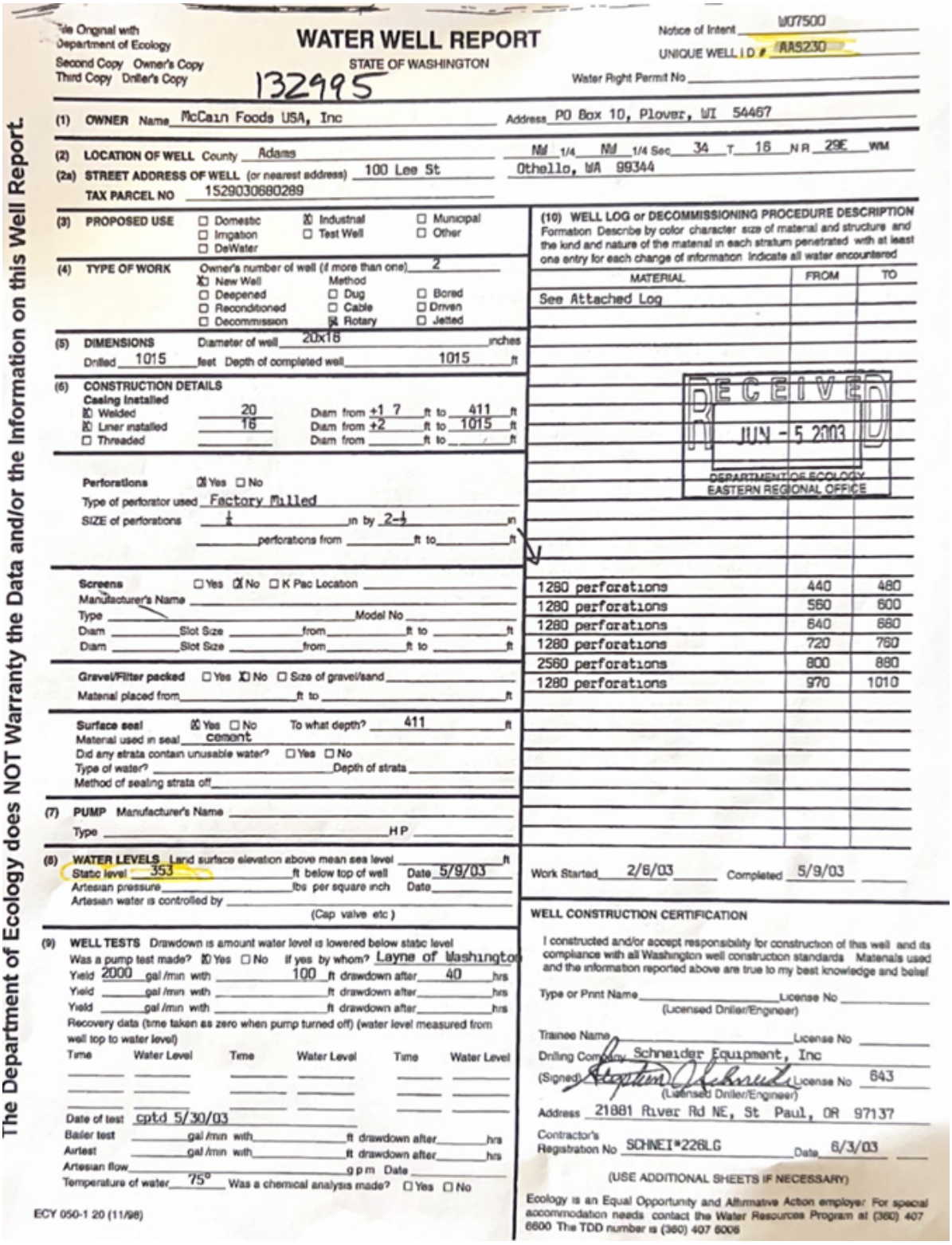
RECEIVED
JAN 05 2015
Department of Ecology
Eastern Washington Office

Start Date 5-6-14 Completed Date 5-21-14

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.
☐ Driller ☐ Engineer ☐ Trainee Name (Print) David Smith
Driller/Engineer/Trainee Signature
Driller or trainee License No. 2844
IF TRAINEE, Driller's Licensed No. Driller's Signature
Drilling Company Blue Star Enterprises
Address 2019 Rutler Loop
City, State, Zip Richland WA. 99354
Contractor's Registration No. Bluesen942RM Date 12-29-14

ECY 050-1-20 (Rev 3/05) The Department of Ecology does NOT warranty the Data and/or Information on this Well Report.
Ecology is an Equal Opportunity Employer.

Figure C2-3. McCain Well #2 water well report (2014).



The Original with Department of Ecology
Second Copy Owner's Copy
Third Copy Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

132995

Notice of Intent WO7500
UNIQUE WELL I.D. # AAS230
Water Right Permit No

(1) OWNER Name McCain Foods USA, Inc Address PO Box 10, Plover, WI 54467

(2) LOCATION OF WELL County Adams NW 1/4 NW 1/4 Sec 34 T 16 N R 29E WM
(2a) STREET ADDRESS OF WELL (or nearest address) 100 Lee St Othello, WA 99344
TAX PARCEL NO 1529030680289

(3) PROPOSED USE ☐ Domestic ☒ Industrial ☐ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐ DeWater

(4) TYPE OF WORK Owner's number of well (if more than one) 2
☒ New Well ☐ Deepened ☐ Reconditioned ☐ Decommission
Method ☐ Dug ☐ Cable ☒ Rotary ☐ Bored ☐ Driven ☐ Jetted

(5) DIMENSIONS Diameter of well 20x16 inches
Drilled 1015 feet Depth of completed well 1015 ft

(6) CONSTRUCTION DETAILS
Casing Installed
☒ Welded 20 Diam from +1 7 ft to 411 ft
☒ Liner installed 16 Diam from +2 ft to 1015 ft
☐ Threaded Diam from ft to ft

Perforations ☒ Yes ☐ No
Type of perforator used Factory Milled
SIZE of perforations ¼ in by 2-½ in
perforations from ft to ft

Screens ☐ Yes ☒ No ☐ K Pac Location
Manufacturer's Name
Type Model No
Diam Slot Size from ft to ft
Diam Slot Size from ft to ft

Gravel/Filter packed ☐ Yes ☒ No ☐ Size of gravel/sand
Material placed from ft to ft

Surface seal ☒ Yes ☐ No To what depth? 411 ft
Material used in seal cement
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP Manufacturer's Name
Type HP

(8) WATER LEVELS Land surface elevation above mean sea level ft
Static level 353 ft below top of well Date 5/9/03
Artesian pressure lbs per square inch Date
Artesian water is controlled by (Cap valve etc.)

(9) WELL TESTS Drawdown is amount water level is lowered below static level
Was a pump test made? ☒ Yes ☐ No If yes by whom? Layne of Washington
Yield 2000 gal/min with 100 ft drawdown after 40 hrs
Yield gal/min with ft drawdown after hrs
Yield gal/min with ft drawdown after hrs
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test cptd 5/30/03
Bailer test gal/min with ft drawdown after hrs
Airtest gal/min with ft drawdown after hrs
Artesian flow gpm Date
Temperature of water 75° Was a chemical analysis made? ☐ Yes ☐ No

ECY 050-1 20 (11/98)

(10) WELL LOG or DECOMMISSIONING PROCEDURE DESCRIPTION
Formation Describe by color character size of material and structure and the kind and nature of the material in each stratum penetrated with at least one entry for each change of information Indicate all water encountered

MATERIAL	FROM	TO
See Attached Log		
1280 perforations	440	480
1280 perforations	560	600
1280 perforations	640	680
1280 perforations	720	760
2560 perforations	800	880
1280 perforations	970	1010

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Work Started 2/6/03 Completed 5/9/03

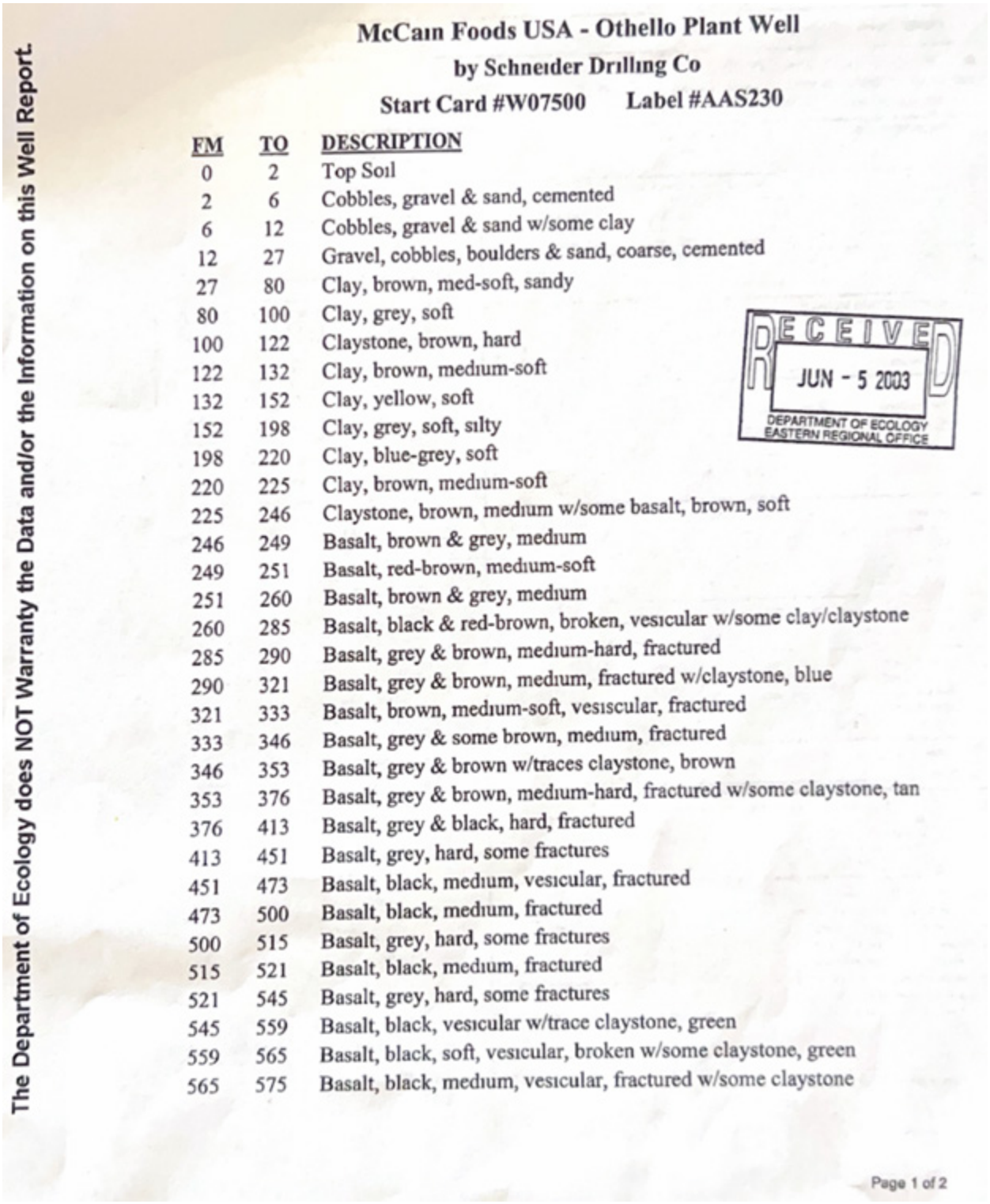
WELL CONSTRUCTION CERTIFICATION
I constructed and/or accept responsibility for construction of this well and its compliance with all Washington well construction standards Materials used and the information reported above are true to my best knowledge and belief
Type or Print Name License No
(Licensed Driller/Engineer)
Trainee Name License No
Drilling Company Schneider Equipment, Inc
(Signed) (Licensed Driller/Engineer) License No 843
Address 21881 River Rd NE, St Paul, OR 97137
Contractor's Registration No SCHNEI*226LG Date 6/3/03

(USE ADDITIONAL SHEETS IF NECESSARY)

Ecology is an Equal Opportunity and Affirmative Action employer For special accommodation needs contact the Water Resources Program at (360) 407 6600 The TDD number is (360) 407 6006

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

Figure C2-4. McCain Well at Othello Plant. Water Well Report (2003).



The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

McCain Foods USA - Othello Plant Well

by Schneider Drilling Co

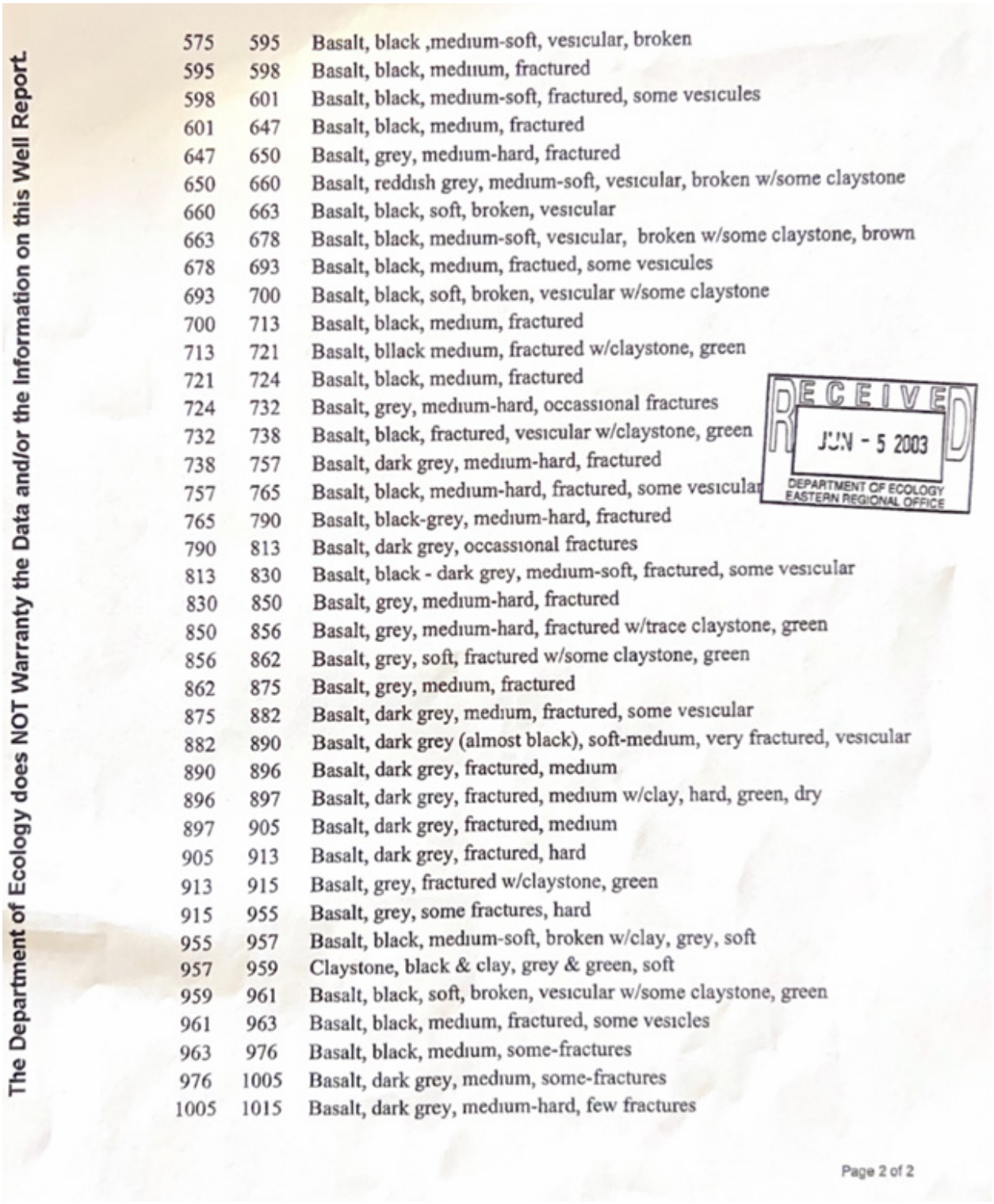
Start Card #W07500 Label #AAS230

FM	TO	DESCRIPTION
0	2	Top Soil
2	6	Cobbles, gravel & sand, cemented
6	12	Cobbles, gravel & sand w/some clay
12	27	Gravel, cobbles, boulders & sand, coarse, cemented
27	80	Clay, brown, med-soft, sandy
80	100	Clay, grey, soft
100	122	Claystone, brown, hard
122	132	Clay, brown, medium-soft
132	152	Clay, yellow, soft
152	198	Clay, grey, soft, silty
198	220	Clay, blue-grey, soft
220	225	Clay, brown, medium-soft
225	246	Claystone, brown, medium w/some basalt, brown, soft
246	249	Basalt, brown & grey, medium
249	251	Basalt, red-brown, medium-soft
251	260	Basalt, brown & grey, medium
260	285	Basalt, black & red-brown, broken, vesicular w/some clay/claystone
285	290	Basalt, grey & brown, medium-hard, fractured
290	321	Basalt, grey & brown, medium, fractured w/claystone, blue
321	333	Basalt, brown, medium-soft, vesiscular, fractured
333	346	Basalt, grey & some brown, medium, fractured
346	353	Basalt, grey & brown w/traces claystone, brown
353	376	Basalt, grey & brown, medium-hard, fractured w/some claystone, tan
376	413	Basalt, grey & black, hard, fractured
413	451	Basalt, grey, hard, some fractures
451	473	Basalt, black, medium, vesicular, fractured
473	500	Basalt, black, medium, fractured
500	515	Basalt, grey, hard, some fractures
515	521	Basalt, black, medium, fractured
521	545	Basalt, grey, hard, some fractures
545	559	Basalt, black, vesicular w/trace claystone, green
559	565	Basalt, black, soft, vesicular, broken w/some claystone, green
565	575	Basalt, black, medium, vesicular, fractured w/some claystone

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Page 1 of 2

Figure C2-5. McCain Well at Othello Plant. Formation Description Page 1 of 2 (2003).



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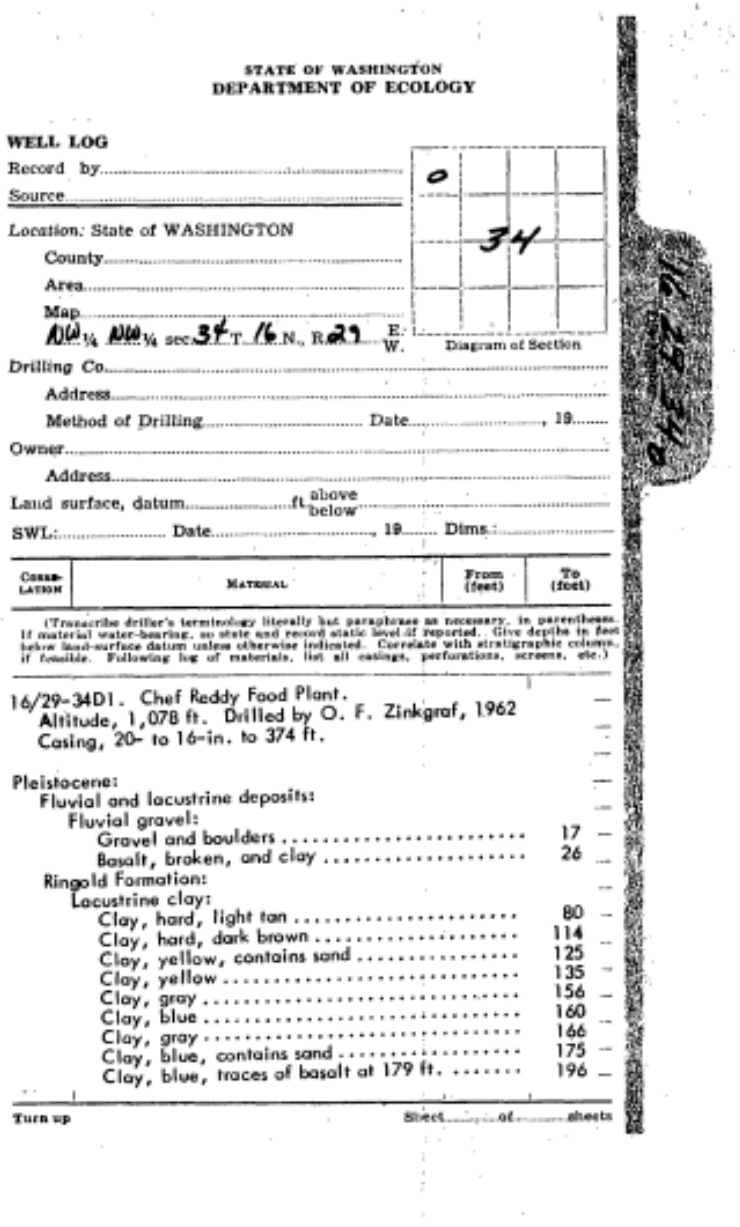
575	595	Basalt, black ,medium-soft, vesicular, broken
595	598	Basalt, black, medium, fractured
598	601	Basalt, black, medium-soft, fractured, some vesicules
601	647	Basalt, black, medium, fractured
647	650	Basalt, grey, medium-hard, fractured
650	660	Basalt, reddish grey, medium-soft, vesicular, broken w/some claystone
660	663	Basalt, black, soft, broken, vesicular
663	678	Basalt, black, medium-soft, vesicular, broken w/some claystone, brown
678	693	Basalt, black, medium, fractued, some vesicules
693	700	Basalt, black, soft, broken, vesicular w/some claystone
700	713	Basalt, black, medium, fractured
713	721	Basalt, bllack medium, fractured w/claystone, green
721	724	Basalt, black, medium, fractured
724	732	Basalt, grey, medium-hard, occassional fractures
732	738	Basalt, black, fractured, vesicular w/claystone, green
738	757	Basalt, dark grey, medium-hard, fractured
757	765	Basalt, black, medium-hard, fractured, some vesicular
765	790	Basalt, black-grey, medium-hard, fractured
790	813	Basalt, dark grey, occassional fractures
813	830	Basalt, black - dark grey, medium-soft, fractured, some vesicular
830	850	Basalt, grey, medium-hard, fractured
850	856	Basalt, grey, medium-hard, fractured w/trace claystone, green
856	862	Basalt, grey, soft, fractured w/some claystone, green
862	875	Basalt, grey, medium, fractured
875	882	Basalt, dark grey, medium, fractured, some vesicular
882	890	Basalt, dark grey (almost black), soft-medium, very fractured, vesicular
890	896	Basalt, dark grey, fractured, medium
896	897	Basalt, dark grey, fractured, medium w/clay, hard, green, dry
897	905	Basalt, dark grey, fractured, medium
905	913	Basalt, dark grey, fractured, hard
913	915	Basalt, grey, fractured w/claystone, green
915	955	Basalt, grey, some fractures, hard
955	957	Basalt, black, medium-soft, broken w/clay, grey, soft
957	959	Claystone, black & clay, grey & green, soft
959	961	Basalt, black, soft, broken, vesicular w/some claystone, green
961	963	Basalt, black, medium, fractured, some vesicles
963	976	Basalt, black, medium, some-fractures
976	1005	Basalt, dark grey, medium, some-fractures
1005	1015	Basalt, dark grey, medium-hard, few fractures

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Page 2 of 2

Figure C2-6. McCain Well at Othello Plant. Formation Description Page 2 of 2 (2003).

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STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

WELL LOG

Record by.....
Source.....

Location: State of WASHINGTON
County.....
Area.....
Map.....
NW¼ NW¼ sec. 34 T. 16 N., R. 29 E. W.

Diagram of Section

Drilling Co.....
Address.....
Method of Drilling..... Date....., 19.....
Owner.....
Address.....
Land surface, datum..... ft. above below
SWL:..... Date....., 19..... Dims.:.....

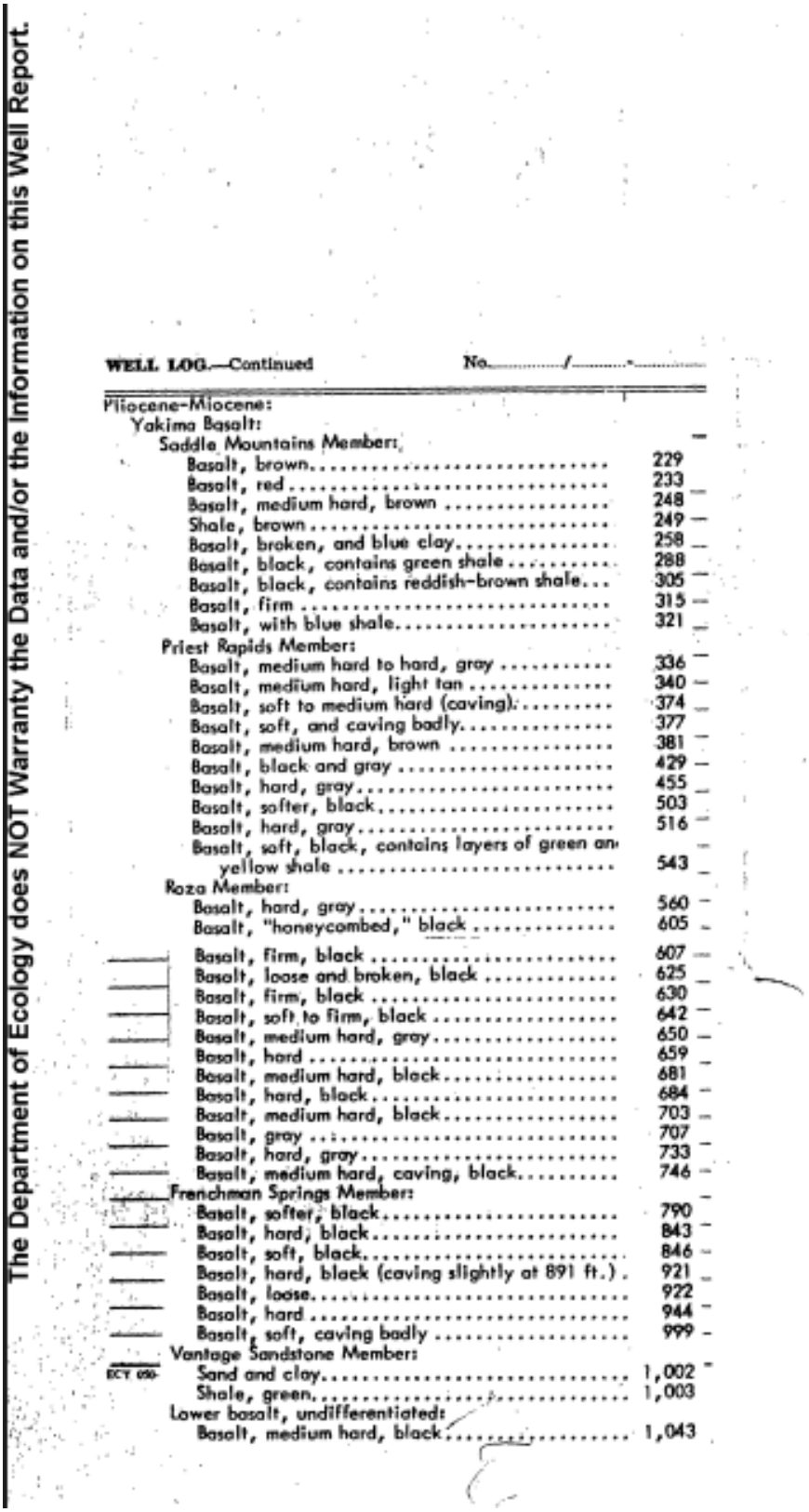
Consolidation	Material	From (feet)	To (feet)
	(Transcribe driller's terminology literally but paraphrase as necessary, in parentheses. If material water-bearing, so state and record static level if reported. Give depths in feet below land-surface datum unless otherwise indicated. Correlate with stratigraphic columns, if feasible. Following log of materials, list all casings, perforations, screens, etc.)		
	16/29-34D1. Chef Reddy Food Plant.		
	Altitude, 1,078 ft. Drilled by O. F. Zinkgraf, 1962		
	Casing, 20- to 16-in. to 374 ft.		
	Pleistocene:		
	Fluvial and lacustrine deposits:		
	Fluvial gravel:		
	Gravel and boulders		17
	Basalt, broken, and clay	17	26
	Ringold Formation:		
	Lacustrine clay:		
	Clay, hard, light tan	26	80
	Clay, hard, dark brown	80	114
	Clay, yellow, contains sand	114	125
	Clay, yellow	125	135
	Clay, gray	135	156
	Clay, blue	156	160
	Clay, gray	160	166
	Clay, blue, contains sand	166	175
	Clay, blue, traces of basalt at 179 ft.	175	196

Turn up

Sheet..... of..... sheets

Figure C2-7. Chef Reddy (1962) McCain Well 2 Well Log Page 1 of 5.

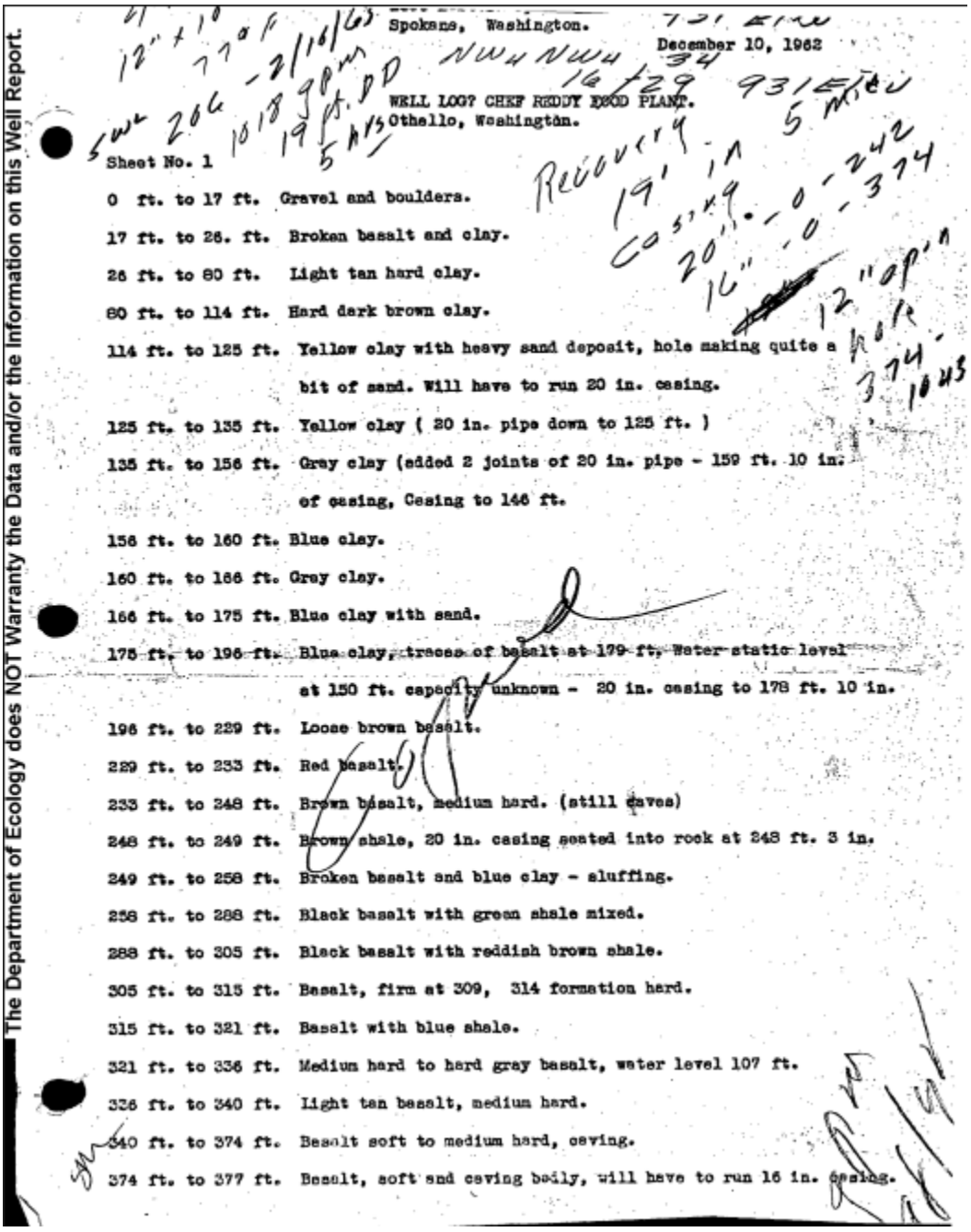
The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.



WELL LOG.—Continued No. ..../..../....

Pliocene-Miocene:		
Yakima Basalt:		
Saddle Mountains Member:		
Basalt, brown	229	
Basalt, red	233	
Basalt, medium hard, brown	248	
Shale, brown	249	
Basalt, broken, and blue clay	258	
Basalt, black, contains green shale	288	
Basalt, black, contains reddish-brown shale	305	
Basalt, firm	315	
Basalt, with blue shale	321	
Priest Rapids Member:		
Basalt, medium hard to hard, gray	336	
Basalt, medium hard, light tan	340	
Basalt, soft to medium hard (caving)	374	
Basalt, soft, and caving badly	377	
Basalt, medium hard, brown	381	
Basalt, black and gray	429	
Basalt, hard, gray	455	
Basalt, softer, black	503	
Basalt, hard, gray	516	
Basalt, soft, black, contains layers of green and yellow shale	543	
Roza Member:		
Basalt, hard, gray	560	
Basalt, "honeycombed," black	605	
Basalt, firm, black	607	
Basalt, loose and broken, black	625	
Basalt, firm, black	630	
Basalt, soft to firm, black	642	
Basalt, medium hard, gray	650	
Basalt, hard	659	
Basalt, medium hard, black	681	
Basalt, hard, black	684	
Basalt, medium hard, black	703	
Basalt, gray	707	
Basalt, hard, gray	733	
Basalt, medium hard, caving, black	746	
Frenchman Springs Member:		
Basalt, softer, black	790	
Basalt, hard, black	843	
Basalt, soft, black	846	
Basalt, hard, black (caving slightly at 891 ft.)	921	
Basalt, loose	922	
Basalt, hard	944	
Basalt, soft, caving badly	999	
Vantage Sandstone Member:		
ECY 050- Sand and clay	1,002	
Shale, green	1,003	
Lower basalt, undifferentiated:		
Basalt, medium hard, black	1,043	

Figure C2-8. Chef Reddy (1962) McCain Well 2 Well Log Page 2 of 5.



Spokane, Washington. December 10, 1962

WELL LOG? CHEF REDDY FOOD PLANT. Othello, Washington.

Sheet No. 1

0 ft. to 17 ft. Gravel and boulders.

17 ft. to 26. ft. Broken basalt and clay.

26 ft. to 80 ft. Light tan hard clay.

80 ft. to 114 ft. Hard dark brown clay.

114 ft. to 125 ft. Yellow clay with heavy sand deposit, hole making quite a bit of sand. Will have to run 20 in. casing.

125 ft. to 135 ft. Yellow clay (20 in. pipe down to 125 ft.)

135 ft. to 156 ft. Gray clay (added 2 joints of 20 in. pipe - 159 ft. 10 in. of casing, Casing to 146 ft.

156 ft. to 160 ft. Blue clay.

160 ft. to 166 ft. Gray clay.

166 ft. to 175 ft. Blue clay with sand.

175 ft. to 196 ft. Blue clay, traces of basalt at 179 ft. Water static level at 150 ft. capacity unknown - 20 in. casing to 178 ft. 10 in.

196 ft. to 229 ft. Loose brown basalt.

229 ft. to 233 ft. Red basalt.

233 ft. to 248 ft. Brown basalt, medium hard. (still caves)

248 ft. to 249 ft. Brown shale, 20 in. casing seated into rock at 248 ft. 3 in.

249 ft. to 258 ft. Broken basalt and blue clay - sluffing.

258 ft. to 288 ft. Black basalt with green shale mixed.

288 ft. to 305 ft. Black basalt with reddish brown shale.

305 ft. to 315 ft. Basalt, firm at 309, 314 formation hard.

315 ft. to 321 ft. Basalt with blue shale.

321 ft. to 336 ft. Medium hard to hard gray basalt, water level 107 ft.

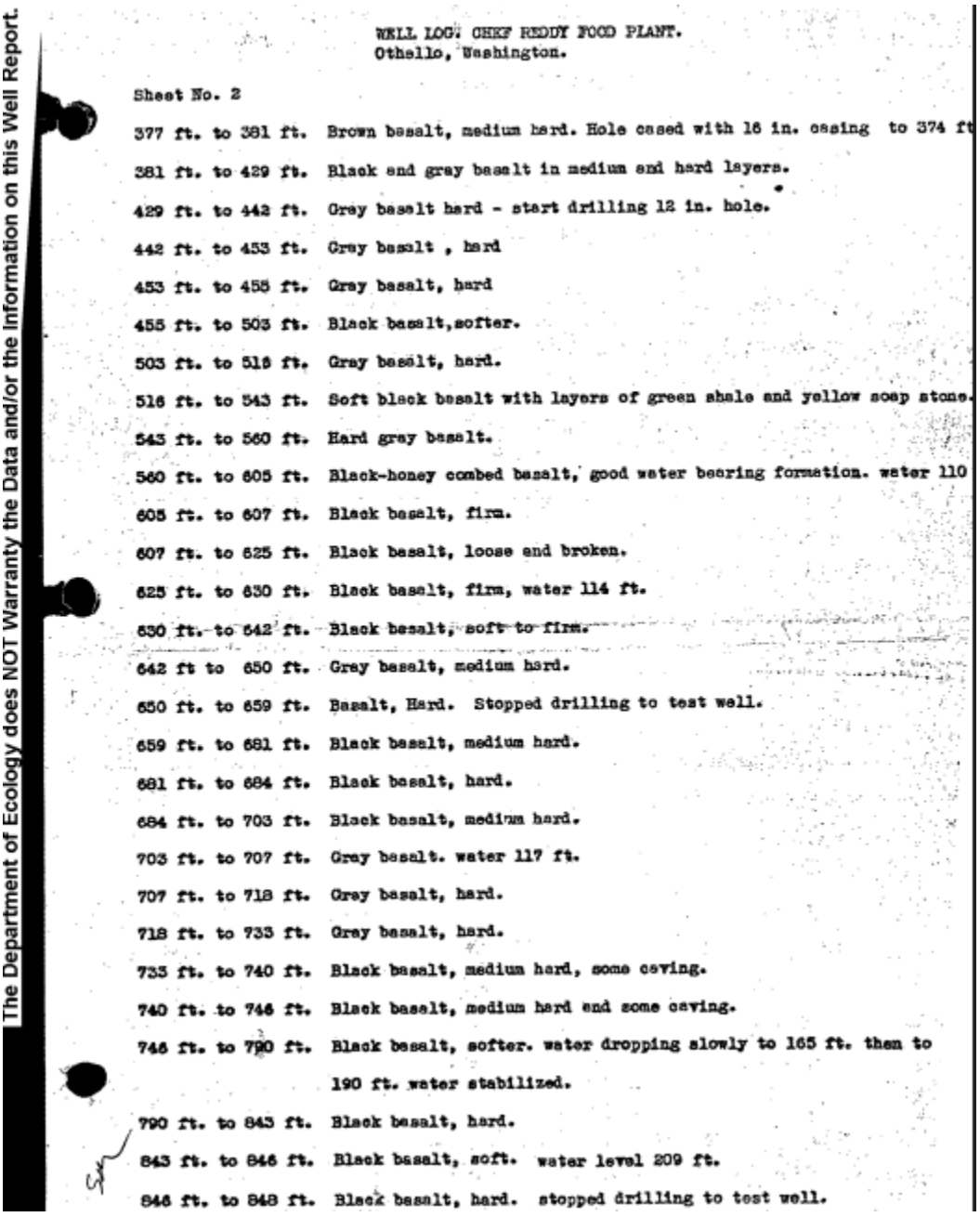
336 ft. to 340 ft. Light tan basalt, medium hard.

340 ft. to 374 ft. Basalt soft to medium hard, caving.

374 ft. to 377 ft. Basalt, soft and caving badly, will have to run 16 in. casing.

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

Figure C2-8. Chef Reddy (1962) McCain Well 2 Well Log Page 3 of 5.



WELL LOG: CHEF REDDY FOOD PLANT.
Othello, Washington.

Sheet No. 2

377 ft. to 381 ft. Brown basalt, medium hard. Hole cased with 16 in. casing to 374 ft

381 ft. to 429 ft. Black and gray basalt in medium and hard layers.

429 ft. to 442 ft. Grey basalt hard - start drilling 12 in. hole.

442 ft. to 453 ft. Grey basalt , hard

453 ft. to 455 ft. Grey basalt, hard

455 ft. to 503 ft. Black basalt,softer.

503 ft. to 516 ft. Gray basalt, hard.

516 ft. to 543 ft. Soft black basalt with layers of green shale and yellow soap stone.

543 ft. to 560 ft. Hard gray basalt.

560 ft. to 605 ft. Black-honey combed basalt, good water bearing formation. water 110

605 ft. to 607 ft. Black basalt, firm.

607 ft. to 625 ft. Black basalt, loose and broken.

625 ft. to 630 ft. Black basalt, firm, water 114 ft.

630 ft. to 642 ft. Black basalt, soft to firm.

642 ft to 650 ft. Gray basalt, medium hard.

650 ft. to 659 ft. Basalt, Hard. Stopped drilling to test well.

659 ft. to 681 ft. Black basalt, medium hard.

681 ft. to 684 ft. Black basalt, hard.

684 ft. to 703 ft. Black basalt, medium hard.

703 ft. to 707 ft. Gray basalt. water 117 ft.

707 ft. to 718 ft. Gray basalt, hard.

718 ft. to 735 ft. Gray basalt, hard.

735 ft. to 740 ft. Black basalt, medium hard, some caving.

740 ft. to 746 ft. Black basalt, medium hard and some caving.

746 ft. to 790 ft. Black basalt, softer. water dropping slowly to 165 ft. then to 190 ft. water stabilized.

790 ft. to 843 ft. Black basalt, hard.

843 ft. to 846 ft. Black basalt, soft. water level 209 ft.

846 ft. to 848 ft. Black basalt, hard. stopped drilling to test well.

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

Figure C2-9. Chef Reddy (1962) McCain Well 2 Well Log Page 4 of 5.

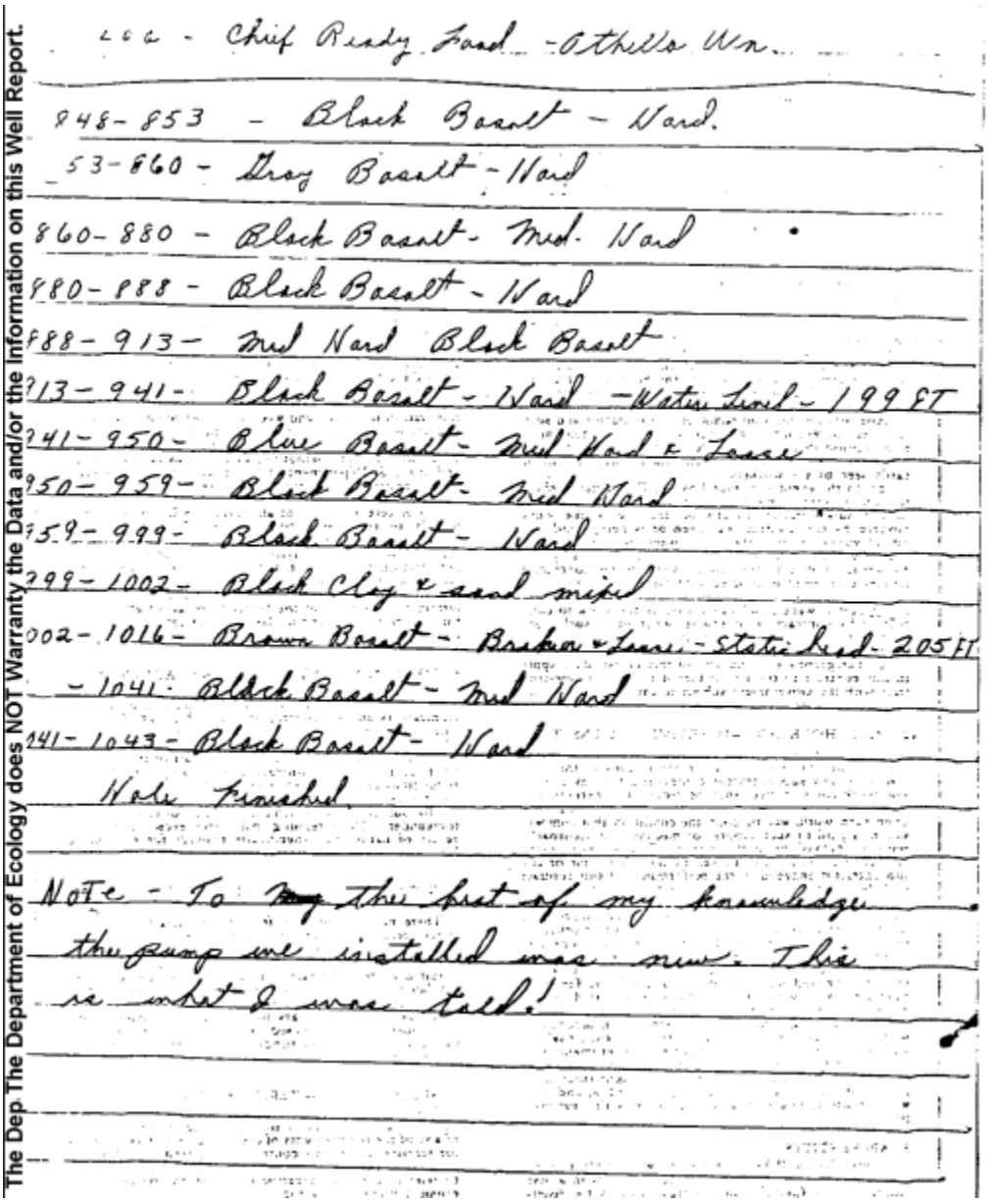


Figure C2-10. Chef Reddy (1962) McCain Well 2 Well Log Page 5 of 5.

C-3. McCain Well 3: Ecology Well ID Tag BKL-152

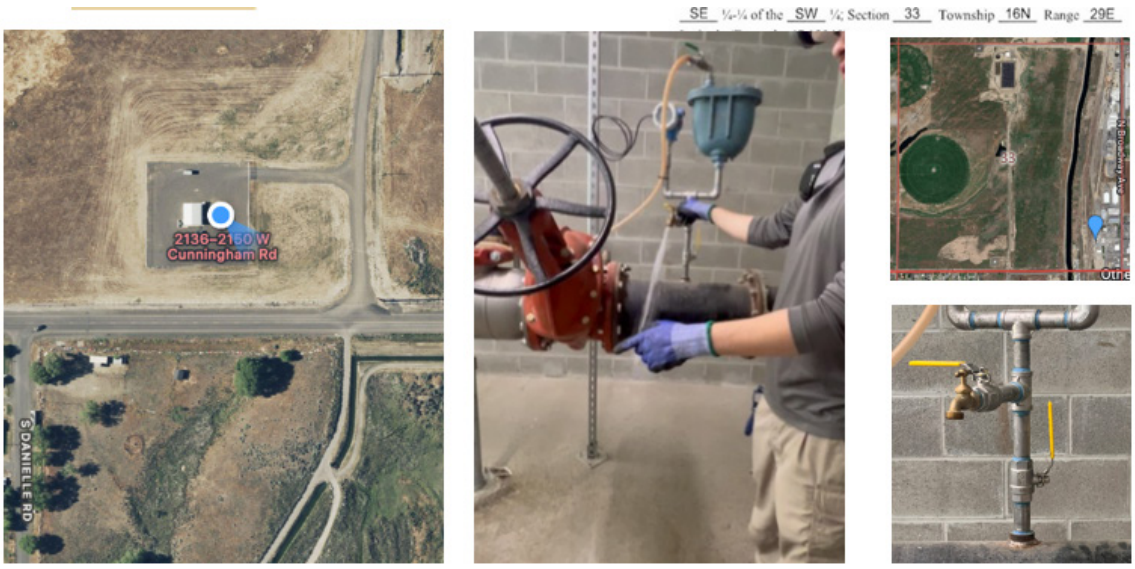


Figure C3-1. McCain Well 3 at Cunningham Road, Othello (NW ¼-¼ of NW ¼. Section 34, T16N, R29E). Photos taken during June 9, 2025, project field trip.



WATER WELL REPORT

DEPARTMENT OF ECOLOGY State of Washington

Type of Work:
☒ Construction
☐ Decommission ⟹ Original installation NOI No. WE43617

Proposed Use: ☐ Domestic ☒ Industrial ☐ Municipal ☐ Dewatering ☐ Irrigation ☐ Test Well ☐ Other

Construction Type: ☒ New well ☐ Alteration ☐ Deepening ☐ Other
Method: ☐ Driven ☐ Jetted ☐ Cable Tool ☐ Dug ☐ Air- ☐ Mud-Rotary

Dimensions: Diameter of boring 24 in., to 483 ft.
Depth of completed well 835 ft.

Construction Details:

Casing	Liner	Diameter	From	To	Wall Thickness	Steel	PVC	Welded	Thread
☒	☐	20 in.	+3	473	.375 in.	☒	☐	☒	☐
☐	☐	19 in.	473	835	____ in.	☐	☐	☐	☐
☐	☐	____ in.	____	____	____ in.	☐	☐	☐	☐
☐	☐	____ in.	____	____	____ in.	☐	☐	☐	☐

Perforations: ☐ Yes ☒ No Type of perforator used ____
No. of perforations ____ Size of perforations ____ in. by ____ in.
Perforated from ____ ft. to ____ ft. below ground surface

Screens: ☐ Yes ☒ No ☐ K-Packer ⟹ Depth ____ ft.
Manufacturer's Name ____
Type ____ Model No. ____
Diameter ____ in. Slot size ____ in. from ____ ft. to ____ ft.
Diameter ____ in. Slot size ____ in. from ____ ft. to ____ ft.

Sand/Filter pack: ☐ Yes ☒ No Size of pack material ____ in.
Materials placed from ____ ft. to ____ ft.

Surface Seal: ☒ Yes ☐ No To what depth? 483 ft.
Material used in seal Neat Cement w/5% bentonite
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? ____ Depth of strata ____
Method of sealing strata off ____

Pump: Manufacturer's Name ____ Type: ____
H.P. ____ Pump intake depth: ____ ft. Designed flow rate: ____ gpm

Water Levels: Land-surface elevation above mean sea level ____ ft.
Stick-up of top of well casing 3 ft. above ground surface
Static water level 402.7 ft. below top of well casing Date 09/02/2021
Artesian pressure ____ lbs. per square inch Date ____
Artesian water is controlled by ____ (cap, valve, etc.)

Well Tests:
Was a pumping test performed? ☐ No ☒ Yes ⟹ by whom? Holt
Yield 1000 gpm with 54.5 ft. drawdown after 24 hrs.
Yield ____ gpm with ____ ft. drawdown after ____ hrs.
Yield ____ gpm with ____ ft. drawdown after ____ hrs.
Recovery data (time = zero when pump is turned off – water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
1	451.6	45	413.0	____	____
15	416.7	60	412.1	____	____
30	414.6	____	____	____	____

Date of pumping test 09/03/2021
Bailer test ____ gpm with ____ ft. drawdown after ____ hrs.
Air test ____ gpm with stem set at ____ ft. for ____ hrs. Date ____
Artesian flow ____ gpm
Temperature of water 78.6 °F Was a chemical analysis made? ☐ Yes ☒ No

Notice of Intent No. WE 43617
Unique Ecology Well ID Tag No. BKL-152
Site Well Name (if more than one well): McCain Well 3
Water Right Permit/Certificate No. 4671A / G3-00246C
Property Owner Name McCain Foods
Well Street Address West Cunningham Rd.
City Othello, WA County Adams
Tax Parcel No. 2100490050200
Was a variance approved for this well? ☐ Yes ☒ No
If yes, what was the variance for? ____

Location (see instructions on page 2): ☐ WWM or ☐ EWM
SE ¼-¼ of the SW ¼, Section 33 Township 16N Range 29E
Latitude (Example: 47.12345) 46.826392
Longitude (Example: -120.12345) -119.186262

Driller's Log/Construction or Decommission Procedure
Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each layer penetrated, with at least one entry for each change of information. Use additional sheets if necessary.

Material	From	To
SEE ATTACHED		

RECEIVED
FEB 07 2022
Department of Ecology
Eastern Washington Office

Start Date 04/28/2021 Completed Date 01/14/2022

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

☒ Driller ☐ Trainee ☐ PE – Print Name David Sandy
Signature David Sandy
License No. 3217
IF TRAINEE: Sponsor's License No.
Sponsor's Signature

Drilling Company Holt Services Inc.
Address 10621 Todd Rd E
City, State, Zip Edgewood, WA 98372
Contractor's Registration No. HOLTSSI898JG Date 01/24/2022

ECY 050-1-20 (Rev 08/19) *If you need this document in an alternate format, please call the Water Resources Program at 360-407-6872. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call 877-833-6341.*

The Department of Ecology does NOT warranty the Data and/or information on this well report.

Figure C3-2. McCain Well 3 Water Well Report completed 01/14/2022.

The Department of Ecology does NOT warranty the Data and/or information on this well report.

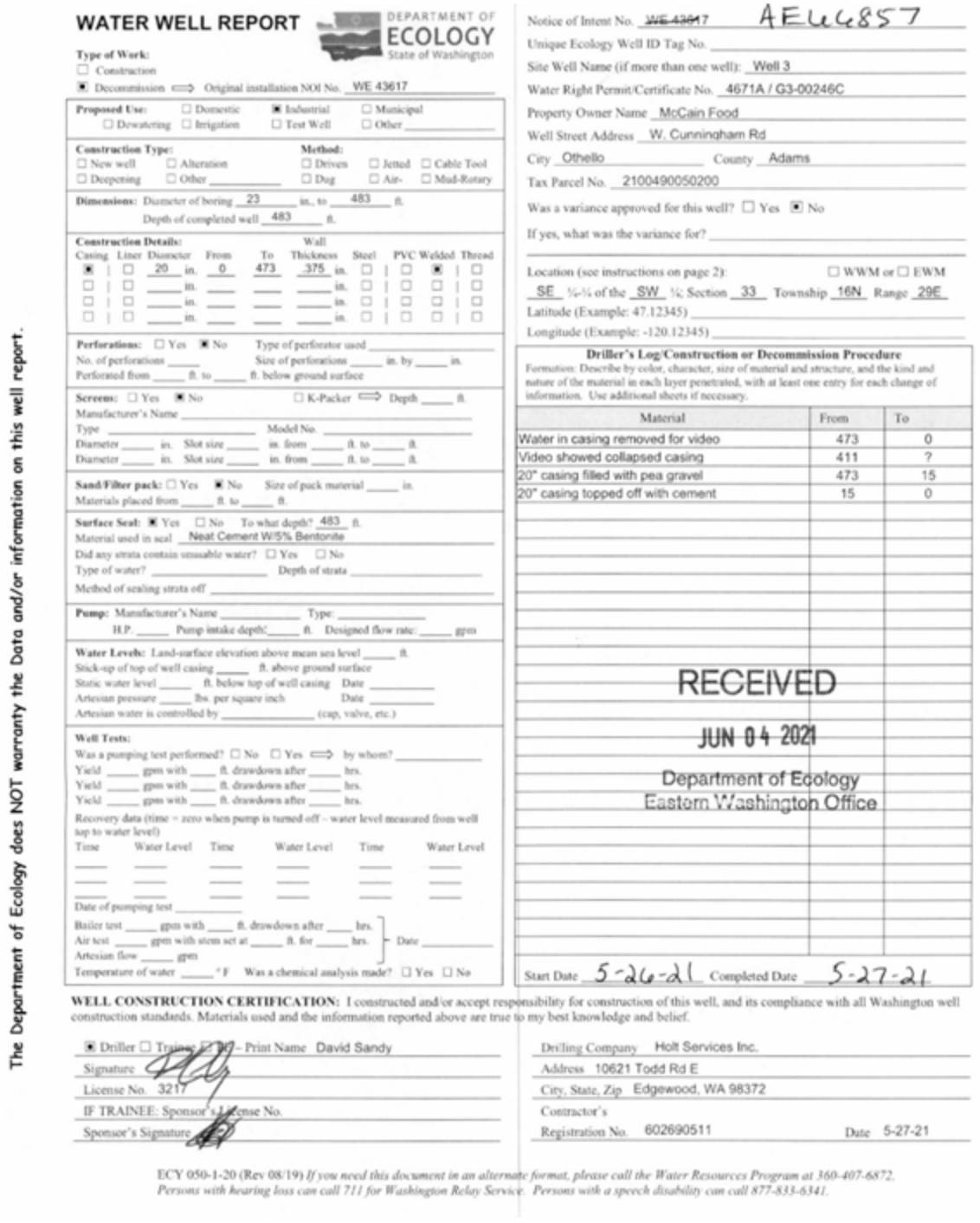
		Well Name: McCain Foods RD	
Depth From:	Depth To:	Formation Description	(WB)
0	10	Sand and clay	
10	15	Broken loose rock	
15	50	weathered Basalt	
50	77	Medium black basalt	
77	85	Broken basalt soft	
85	92	Hard fracture basalt	
92	120	Hard basalt Water at 101	yes
120	128	Soft loose Gravels	
128	134	Hard basalt	
134	141	Fractured basalt	
141	183	Hard black basalt water at 160	yes
183	195	Fractured basalt	
195	202	Hard black basalt	
202	212	Fractured basalt	
212	216	Red pumice, fractured	
216	225	Fractured basalt	
225	235	Loose fractured basalt	
235	255	Hard black basalt	
255	268	Hard fracture basalt water at 258	yes
268	325	Heavily fractured More water flow 500-600 gpm	yes
325	346	Hard basalt black	
346	365	Hard fractured basalt	
365	373	Medium fractured black basalt	
373	378	Hard fractured basalt	
378	410	Hard black basalt	
410	415	Loose fractured basalt heave	yes
415	425	Black hard basalt	
425	440	Black basalt some fractures water at 432	yes
440	476	Fractured black basalt more water at 460	yes
476	503	Medium hard black basalt	
503	513	Medium hard fractured basalt	
513	518	Medium hard black basalt more water at 517'	
518	555	Medium hard fractured basalt lots of water at 540	
555	588	Medium hard black basalt	
588	591	Medium hard black basalt	
591	629	Fractured basalt	
629	650	Medium hard black basalt	
650	656	Fractured basalt	
656	666	Medium hard fractured basalt	
666	672	Fractured basalt	
672	750	Medium soft basalt	
750	760	Medium hard black basalt	
760	762	Fractured basalt	
762	773	Medium hard fractured basalt	
773	779	Hard Basalt	

Figure C3-3. McCain Well 3 Formation Description Page 1 of 2; in Water Well Report completed 01/14/2022.

779	784	Medium hard black basalt	
784	789	Hard fractured basalt	
789	792	Hard fracture basalt	
792	799	Hard fractured basalt	
799	803	Hard medium basalt	
803	808	Fractured basalt Increased water at 804	
808	812	Large Fracture/ broken up basalt	
812	813	Hard Fractured basalt	
813	814	Medium hard black basalt	
814	815	Medium hard fractured basalt	
815	835	Hard black basalt	

The Department of Ecology does NOT warranty the Data and/or information on this well report.

Figure C3-4. McCain Well 3 Formation Description Page 2 of 2; in Water Well Report completed 01/14/2022.



WATER WELL REPORT

DEPARTMENT OF ECOLOGY State of Washington

Notice of Intent No. ~~WE 43617~~ AE46857

Unique Ecology Well ID Tag No.

Site Well Name (if more than one well): Well 3

Water Right Permit/Certificate No. 4671A / G3-00246C

Property Owner Name McCain Food

Well Street Address W. Cunningham Rd

City Othello County Adams

Tax Parcel No. 210490050200

Was a variance approved for this well? ☐ Yes ☒ No

If yes, what was the variance for?

Location (see instructions on page 2): ☐ WWM or ☐ EWM

SE ¼-¼ of the SW ¼ Section 33 Township 16N Range 29E

Latitude (Example: 47.12345)

Longitude (Example: -120.12345)

Type of Work:
☐ Construction
☒ Decommission ⟹ Original installation NOI No. WE 43617

Proposed Use: ☐ Domestic ☒ Industrial ☐ Municipal ☐ Dewatering ☐ Irrigation ☐ Test Well ☐ Other

Construction Type: ☐ New well ☐ Alteration ☐ Deepening ☐ Other
Method: ☐ Driven ☐ Jetted ☐ Cable Tool ☐ Dug ☐ Air- ☐ Mud-Rotary

Dimensions: Diameter of boring 23 in., to 483 ft.
Depth of completed well 483 ft.

Construction Details:

Casing	Liner	Diameter	From	To	Wall Thickness	Steel	PVC	Welded	Thread
☒	☐	20 in.	0	473	.375 in.	☐	☐	☒	☐
☐	☐	____ in.	____	____	____ in.	☐	☐	☐	☐
☐	☐	____ in.	____	____	____ in.	☐	☐	☐	☐
☐	☐	____ in.	____	____	____ in.	☐	☐	☐	☐

Perforations: ☐ Yes ☒ No Type of perforator used
No. of perforations ____ Size of perforations ____ in. by ____ in.
Perforated from ____ ft. to ____ ft. below ground surface

Screens: ☐ Yes ☒ No ☐ K-Packer ⟹ Depth ____ ft.
Manufacturer's Name
Type Model No.
Diameter ____ in. Slot size ____ in. from ____ ft. to ____ ft.
Diameter ____ in. Slot size ____ in. from ____ ft. to ____ ft.

Sand/Filter pack: ☐ Yes ☒ No Size of pack material ____ in.
Materials placed from ____ ft. to ____ ft.

Surface Seal: ☒ Yes ☐ No To what depth? 483 ft.
Material used in seal Neat Cement W/5% Bentonite
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? Depth of strata
Method of sealing strata off

Pump: Manufacturer's Name Type:
H.P. ____ Pump intake depth: ____ ft. Designed flow rate: ____ gpm

Water Levels: Land-surface elevation above mean sea level ____ ft.
Stick-up of top of well casing ____ ft. above ground surface
Static water level ____ ft. below top of well casing Date
Artesian pressure ____ lbs. per square inch Date
Artesian water is controlled by (cap, valve, etc.)

Well Tests:
Was a pumping test performed? ☐ No ☐ Yes ⟹ by whom?
Yield ____ gpm with ____ ft. drawdown after ____ hrs.
Yield ____ gpm with ____ ft. drawdown after ____ hrs.
Yield ____ gpm with ____ ft. drawdown after ____ hrs.
Recovery data (time = zero when pump is turned off – water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of pumping test
Bailer test ____ gpm with ____ ft. drawdown after ____ hrs.
Air test ____ gpm with stem set at ____ ft. for ____ hrs. Date
Artesian flow ____ gpm
Temperature of water ____ °F Was a chemical analysis made? ☐ Yes ☐ No

Driller's Log/Construction or Decommission Procedure
Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each layer penetrated, with at least one entry for each change of information. Use additional sheets if necessary.

Material	From	To
Water in casing removed for video	473	0
Video showed collapsed casing	411	?
20" casing filled with pea gravel	473	15
20" casing topped off with cement	15	0

RECEIVED
JUN 04 2021
Department of Ecology
Eastern Washington Office

Start Date 5-26-21 Completed Date 5-27-21

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

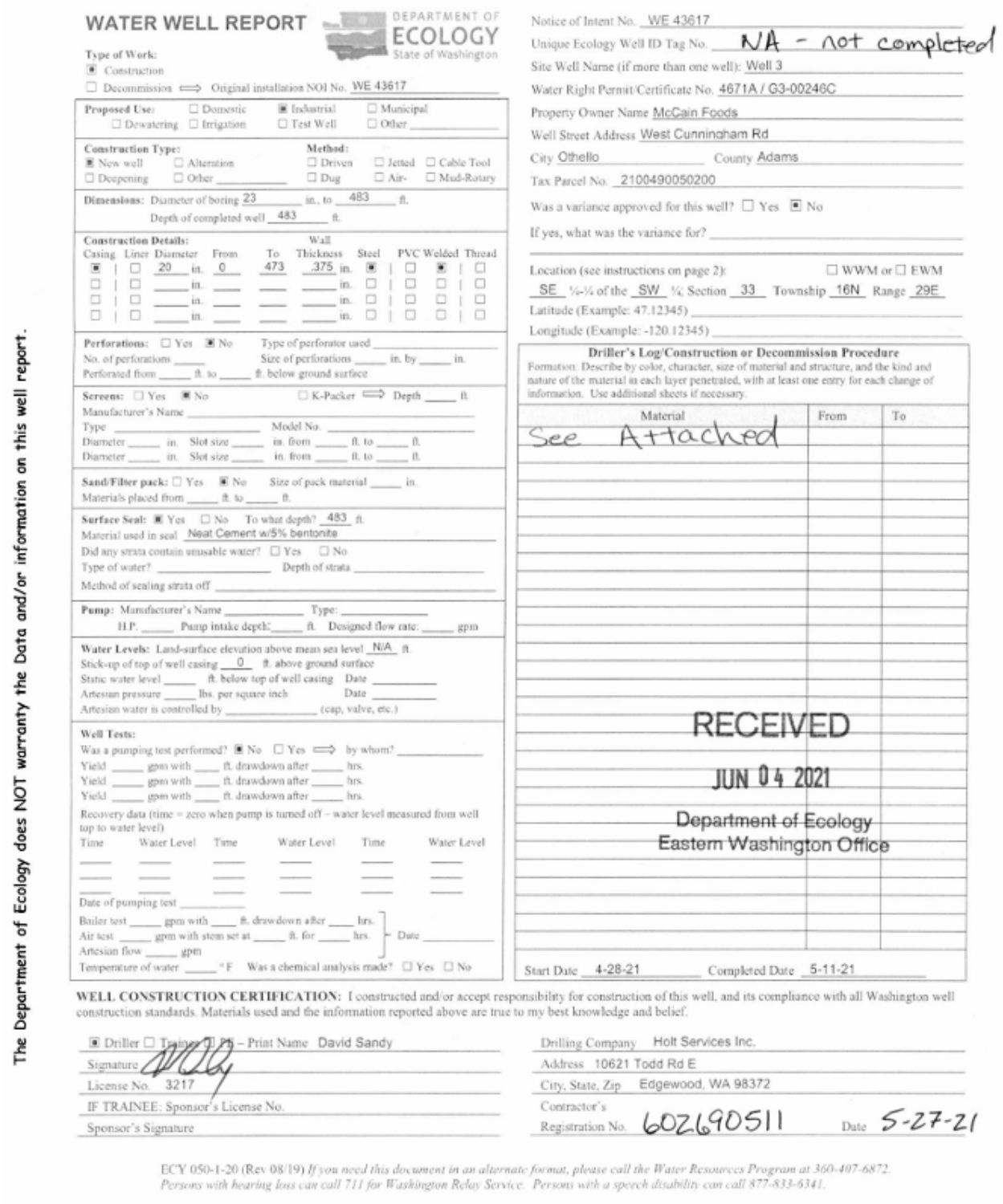
☒ Driller ☐ Trainee ☐ ____ – Print Name David Sandy
Signature
License No. 3217
IF TRAINEE: Sponsor's License No.
Sponsor's Signature

Drilling Company Holt Services Inc.
Address 10621 Todd Rd E
City, State, Zip Edgewood, WA 98372
Contractor's Registration No. 602690511 Date 5-27-21

ECY 050-1-20 (Rev 08/19) *If you need this document in an alternate format, please call the Water Resources Program at 360-407-6872. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call 877-833-6341.*

The Department of Ecology does NOT warranty the Data and/or information on this well report.

Figure C3-5. McCain Well 3 Water Well Report completed 05/27/2021.



WATER WELL REPORT

DEPARTMENT OF ECOLOGY State of Washington

Notice of Intent No. WE 43617

Unique Ecology Well ID Tag No. NA - not completed

Site Well Name (if more than one well): Well 3

Water Right Permit/Certificate No. 4671A / G3-00246C

Property Owner Name McCain Foods

Well Street Address West Cunningham Rd

City Othello County Adams

Tax Parcel No. 2100490050200

Was a variance approved for this well? ☐ Yes ☒ No

If yes, what was the variance for?

Location (see instructions on page 2): ☐ WWM or ☐ EWM

SE ¼-¼ of the SW ¼ Section 33 Township 16N Range 29E

Latitude (Example: 47.12345)

Longitude (Example: -120.12345)

Type of Work: ☒ Construction ☐ Decommission ⟹ Original installation NOI No. WE 43617

Proposed Use: ☐ Domestic ☒ Industrial ☐ Municipal ☐ Dewatering ☐ Irrigation ☐ Test Well ☐ Other

Construction Type: ☒ New well ☐ Alteration ☐ Deepening ☐ Other

Method: ☐ Driven ☐ Jetted ☐ Cable Tool ☐ Dug ☐ Air- ☐ Mud-Rotary

Dimensions: Diameter of boring 23 in., to 483 ft. Depth of completed well 483 ft.

Construction Details:

Casing	Liner	Diameter	From	To	Wall Thickness	Steel	PVC	Welded	Thread
☒	☐	20 in.	0	473	.375 in.	☒	☐	☒	☐
☐	☐	____ in.	____	____	____ in.	☐	☐	☐	☐
☐	☐	____ in.	____	____	____ in.	☐	☐	☐	☐
☐	☐	____ in.	____	____	____ in.	☐	☐	☐	☐

Perforations: ☐ Yes ☒ No Type of perforator used

No. of perforations ____ Size of perforations ____ in. by ____ in.

Perforated from ____ ft. to ____ ft. below ground surface

Screens: ☐ Yes ☒ No ☐ K-Packer ⟹ Depth ____ ft.

Manufacturer's Name

Type Model No.

Diameter ____ in. Slot size ____ in. from ____ ft. to ____ ft.

Diameter ____ in. Slot size ____ in. from ____ ft. to ____ ft.

Sand/Filter pack: ☐ Yes ☒ No Size of pack material ____ in.

Materials placed from ____ ft. to ____ ft.

Surface Seal: ☒ Yes ☐ No To what depth? 483 ft.

Material used in seal Neat Cement w/5% bentonite

Did any strata contain unusable water? ☐ Yes ☐ No

Type of water? Depth of strata

Method of sealing strata off

Pump: Manufacturer's Name Type:

H.P. ____ Pump intake depth: ____ ft. Designed flow rate: ____ gpm

Water Levels: Land-surface elevation above mean sea level N/A ft.

Stick-up of top of well casing 0 ft. above ground surface

Static water level ____ ft. below top of well casing Date

Artesian pressure ____ lbs. per square inch Date

Artesian water is controlled by (cap, valve, etc.)

Well Tests:

Was a pumping test performed? ☒ No ☐ Yes ⟹ by whom?

Yield ____ gpm with ____ ft. drawdown after ____ hrs.

Yield ____ gpm with ____ ft. drawdown after ____ hrs.

Yield ____ gpm with ____ ft. drawdown after ____ hrs.

Recovery data (time = zero when pump is turned off – water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of pumping test

Bailer test ____ gpm with ____ ft. drawdown after ____ hrs.

Air test ____ gpm with stem set at ____ ft. for ____ hrs. Date

Artesian flow ____ gpm

Temperature of water ____ °F Was a chemical analysis made? ☐ Yes ☐ No

Driller's Log/Construction or Decommission Procedure

Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each layer penetrated, with at least one entry for each change of information. Use additional sheets if necessary.

Material	From	To
See Attached		

RECEIVED

JUN 04 2021

Department of Ecology
Eastern Washington Office

Start Date 4-28-21 Completed Date 5-11-21

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

☒ Driller ☐ Trainee ☐ RS – Print Name David Sandy

Signature

License No. 3217

IF TRAINEE: Sponsor's License No.

Sponsor's Signature

Drilling Company Holt Services Inc.

Address 10621 Todd Rd E

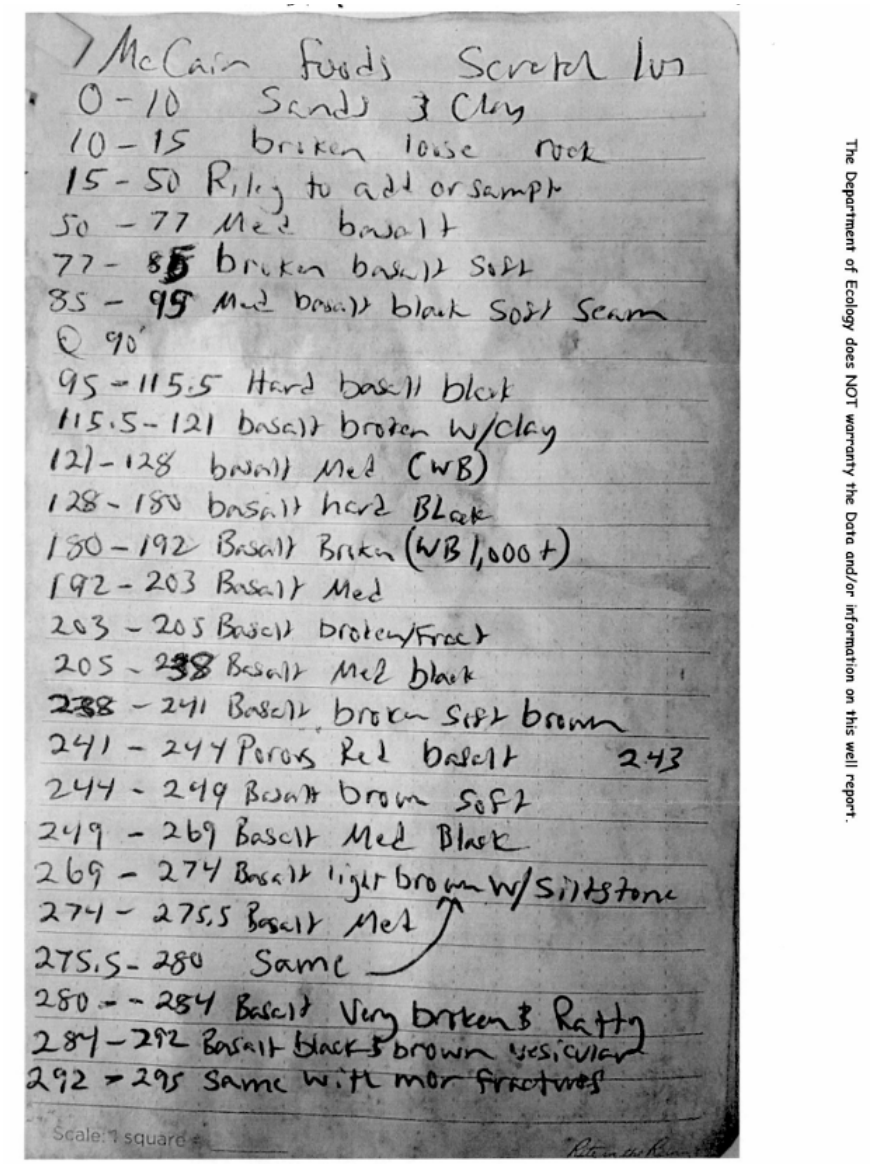
City, State, Zip Edgewood, WA 98372

Contractor's Registration No. 602690511 Date 5-27-21

ECY 050-1-20 (Rev 08/19) *If you need this document in an alternate format, please call the Water Resources Program at 360-407-6872. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call 877-833-6341.*

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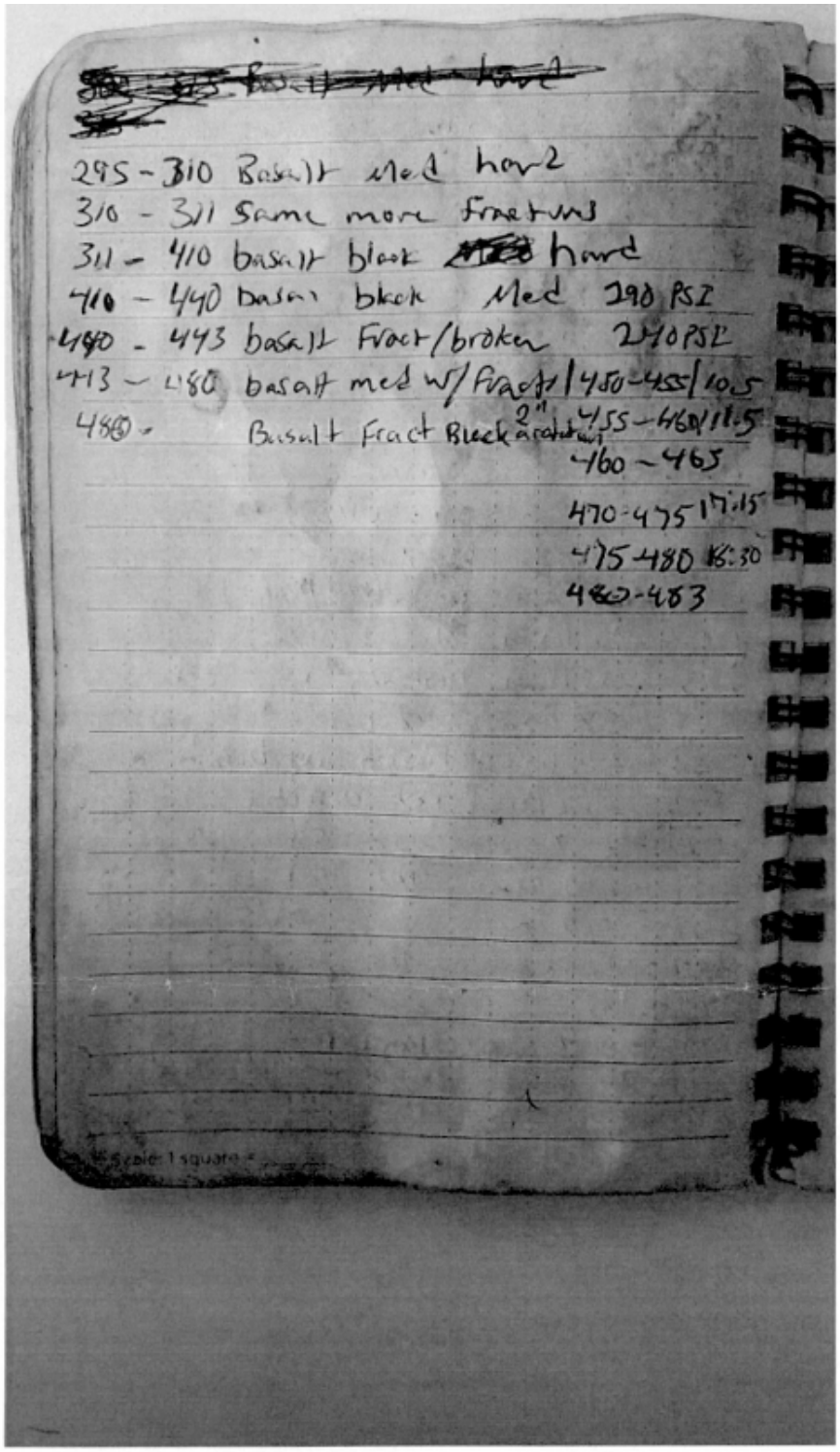
Figure C3-6. McCain Well 3 Water Well Report completed 05/11/2021.



McCain Foods Scratch Lot
0 - 10 Sands & Clay
10 - 15 broken loose rock
15 - 50 Riley to add or sample
50 - 77 Med basalt
77 - 85 broken basalt Soft
85 - 95 Med basalt black Soft Seam
@ 90'
95 - 115.5 Hard basalt black
115.5 - 121 basalt broken w/clay
121 - 128 basalt Med (WB)
128 - 180 basalt hard Black
180 - 192 Basalt Broken (WB 1,000+)
192 - 203 Basalt Med
203 - 205 Basalt broken/Fract
205 - 238 Basalt Med black
238 - 241 Basalt broken Soft brown
241 - 244 Porous Red basalt 243
244 - 249 Basalt brown Soft
249 - 269 Basalt Med Black
269 - 274 Basalt light brown w/Siltstone
274 - 275.5 Basalt Med
275.5 - 280 Same
280 - - 284 Basalt Very broken & Ratty
284 - 292 Basalt black & brown vesicular
292 - 295 same with mor fractures
Scale: 1 square =

The Department of Ecology does NOT warranty the Data and/or information on this well report.

Figure C3-7. McCain Well 3 Formation Field Notes, Page 1 of 2, in Water Well Report completed 05/11/2021.



The Department of Ecology does NOT warranty the Data and/or information on this well report.

Figure C3-8. McCain Well 3 Formation Field Notes, Page 2 of 2, in Water Well Report completed 05/11/2021.

C-4. McCain Well 4: Ecology Well ID Tag



Figure C4-1. McCain Well 4 at McManamon Road, Othello (NE ¼ of NW ¼. Section 33, T16N, R29E). Photos taken during June 9, 2025, project field trip.

Project Name: McCain Foods
City, State: Othello, WA
TRS: NE1/4 NW1/4 Sect. 33 T16N R29EWM
Well No.: 4

Ground Surface Elev.: 940 ft (approximate)
Casing Stickup: 3 ft
Start - Finish Date: 5/30/2014 - 12/11/2014
Driller / Method: Blue Star Enterprises / Air Rotary

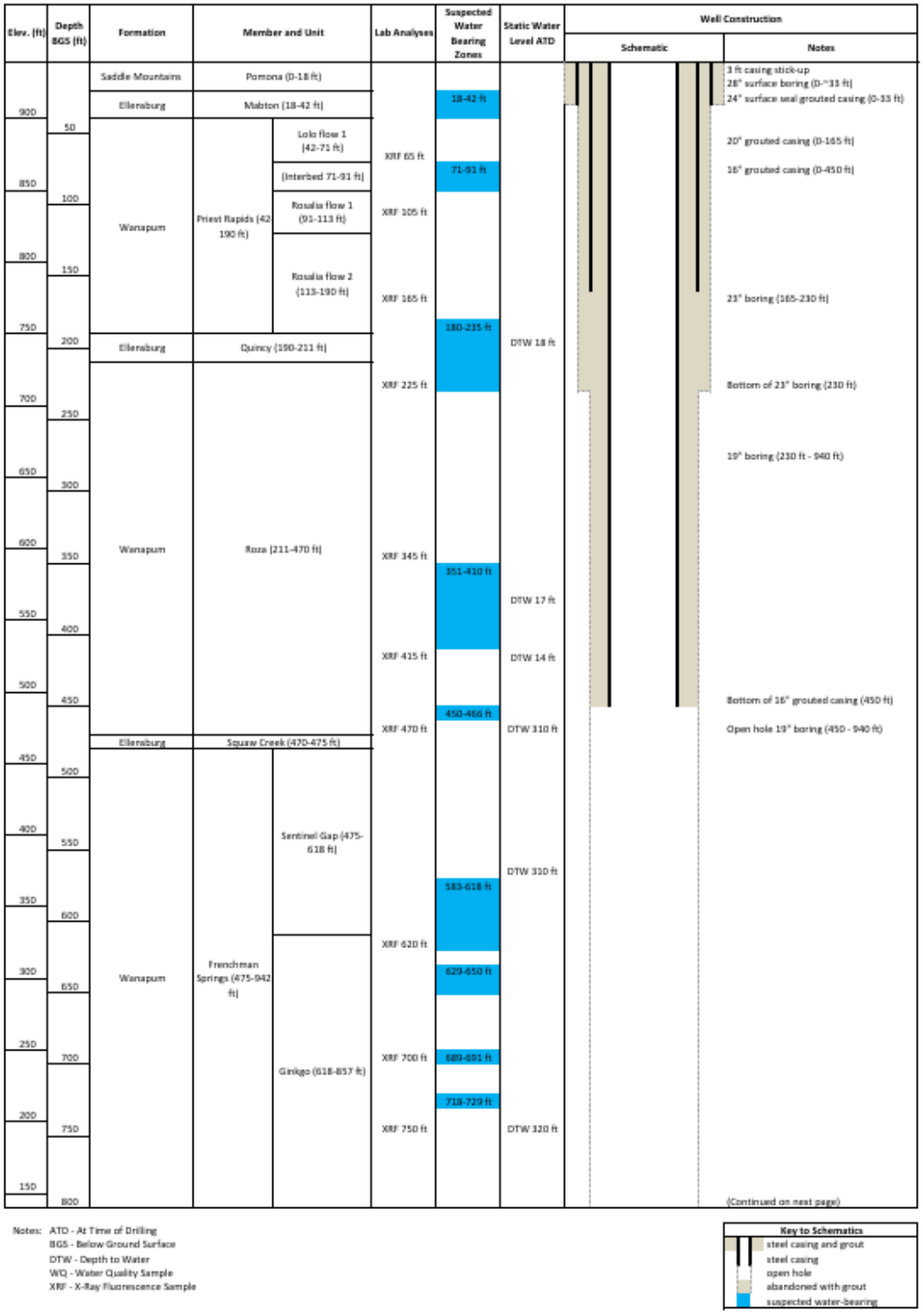
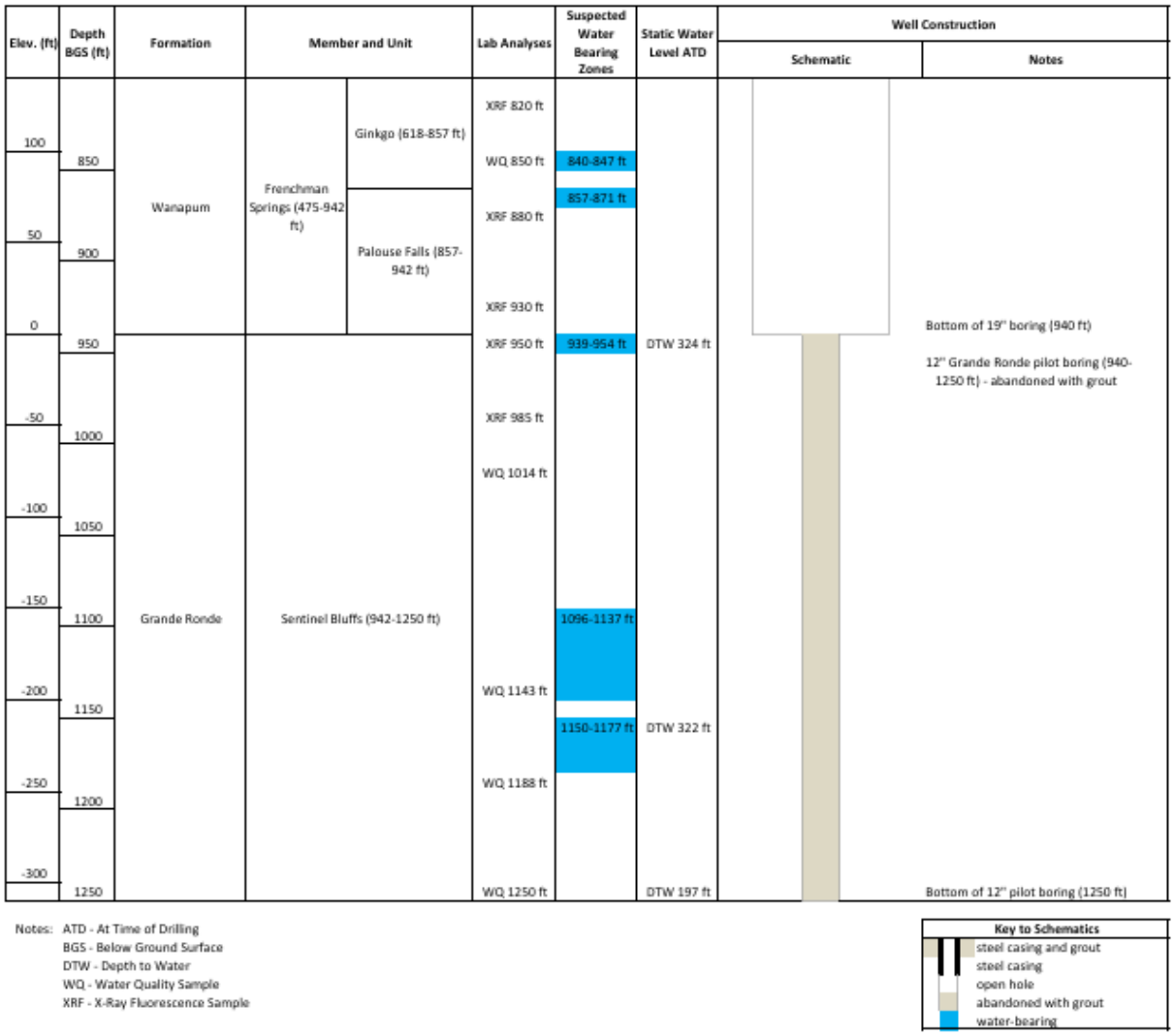


Figure C4-2. McCain Well 4 Construction Log (2014), Page 1 of 2.

Project Name: McCain Foods
City, State: Othello, WA
TRS: NE1/4 NW1/4 Sect. 33 T16N R29EWM
Well No.: 4

Ground Surface Elev.: 940 ft (approximate)
Casing Stickup: 3 ft
Start - Finish Date: 5/30/2014 - 12/11/2014
Driller / Method: Blue Star Enterprises / Air Rotary



Notes: ATD - At Time of Drilling
BGS - Below Ground Surface
DTW - Depth to Water
WQ - Water Quality Sample
XRF - X-Ray Fluorescence Sample

Figure C4-2. McCain Well 4 Construction Log (2014), Page 2 of 2.

C-5. Othello Well 2: Ecology Well ID Tag No. No Data

Well Details	Location Details
Well Owner: **TOWN OF OTHELLO**	Tax Parcel Number:
Well Tag ID:	Well Address: NKA/WELL #2, OTHELLO 99344
Notice of Intent Number:	County: ADAMS
Group Number: Not Applicable	Public Land Survey: NW-NW / S03 / T15N / R29E
Well Report ID: 173634	Well Type: Water / Subtype: Unknown
Well Diameter: 8 in.	Well Completion Date: 04-01-1940
Well Depth: 697 ft.	Well Report Received Date: 04-01-1940

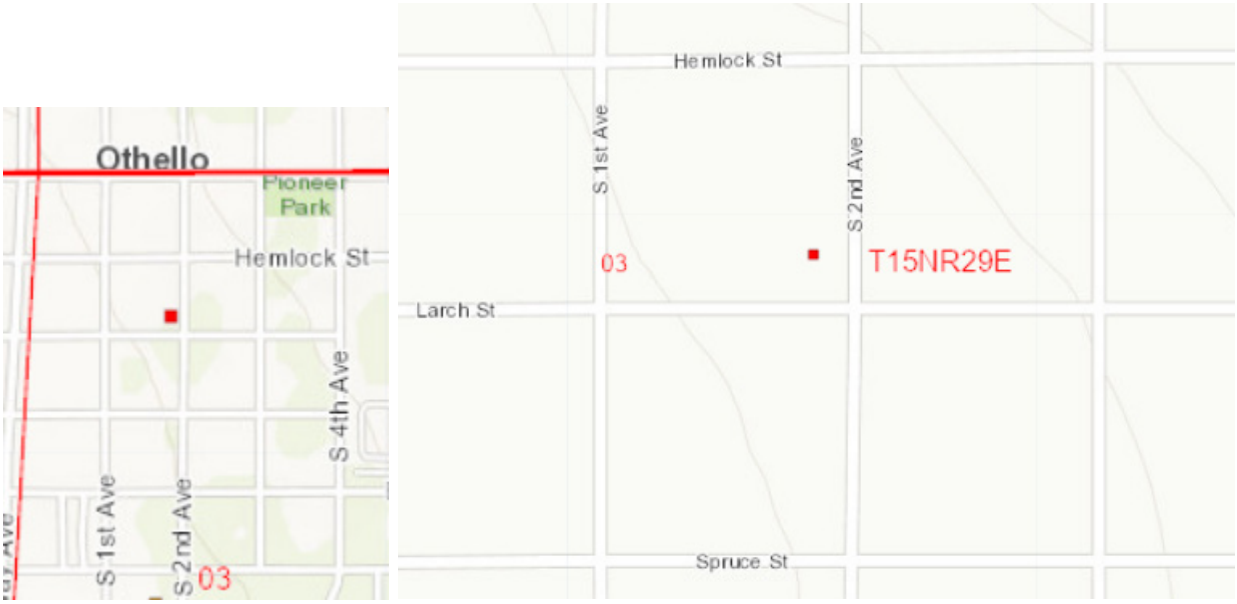
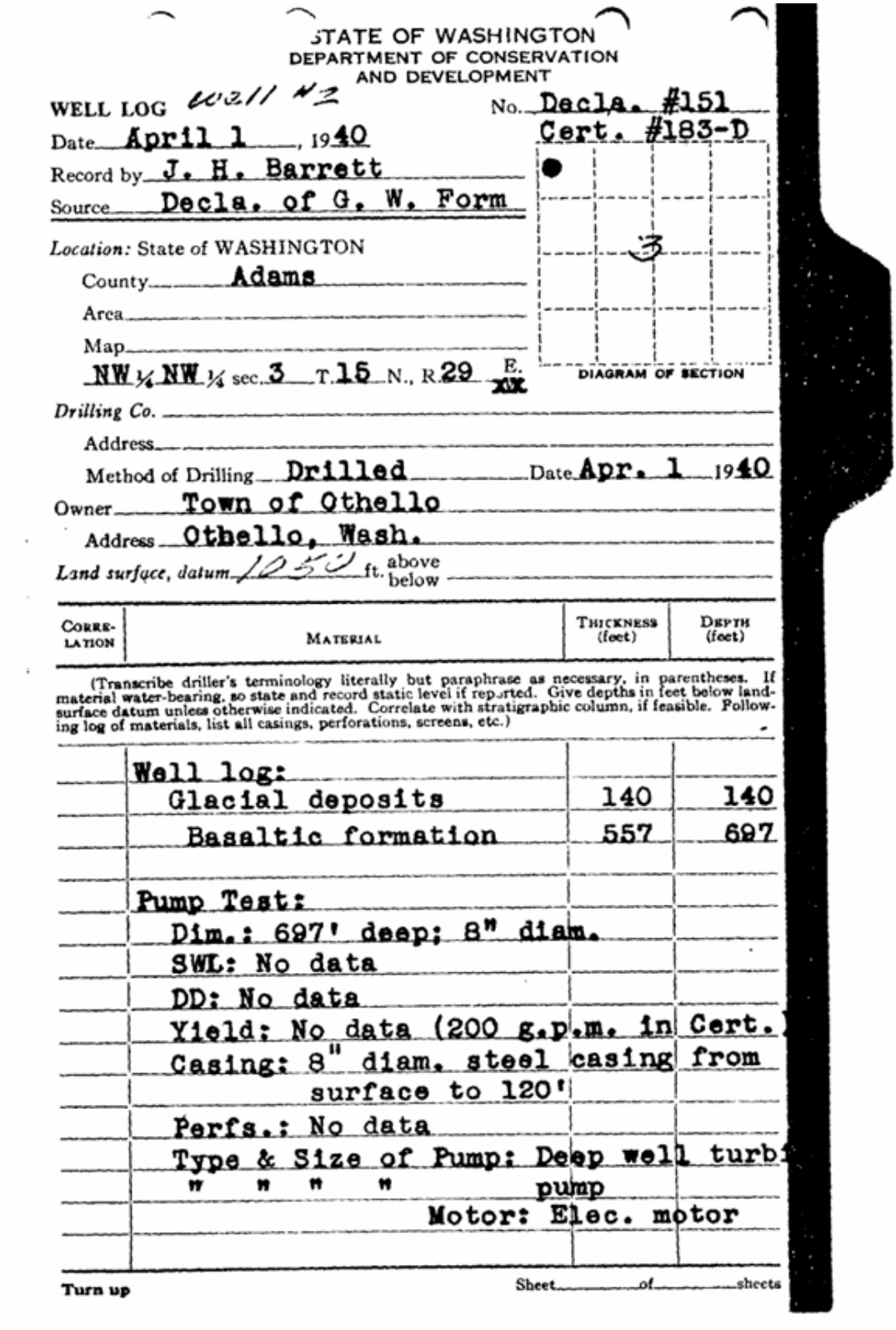


Figure C5-1. Othello Well 2 (1940). Location information from Washington State Well Report Viewer (https://appswr.ecology.wa.gov/WellConstruction/Map/WCLSWebMap)



STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
AND DEVELOPMENT

WELL LOG Well #2 No. Decla. #151
Cert. #183-D

Date April 1, 1940

Record by J. H. Barrett

Source Decla. of G. W. Form

DIAGRAM OF SECTION

Location: State of WASHINGTON

County Adams

Area

Map

NW¼ NW¼ sec. 3 T. 15 N., R. 29 E. XX

Drilling Co.

Address

Method of Drilling Drilled Date Apr. 1 1940

Owner Town of Othello

Address Othello, Wash.

Land surface, datum 1050 ft. above / below

CORRELATION	MATERIAL	THICKNESS (feet)	DEPTH (feet)
	(Transcribe driller's terminology literally but paraphrase as necessary, in parentheses. If material water-bearing, so state and record static level if reported. Give depths in feet below land-surface datum unless otherwise indicated. Correlate with stratigraphic column, if feasible. Following log of materials, list all casings, perforations, screens, etc.)		
	Well log:		
	Glacial deposits	140	140
	Basaltic formation	557	697
	Pump Test:		
	Dim.: 697' deep; 8" diam.		
	SWL: No data		
	DD: No data		
	Yield: No data (200 g.p.m. in Cert.		
	Casing: 8" diam. steel casing from surface to 120'		
	Perfs.: No data		
	Type & Size of Pump: Deep well turbine pump		
	" " " " Motor: Elec. motor		

Turn up

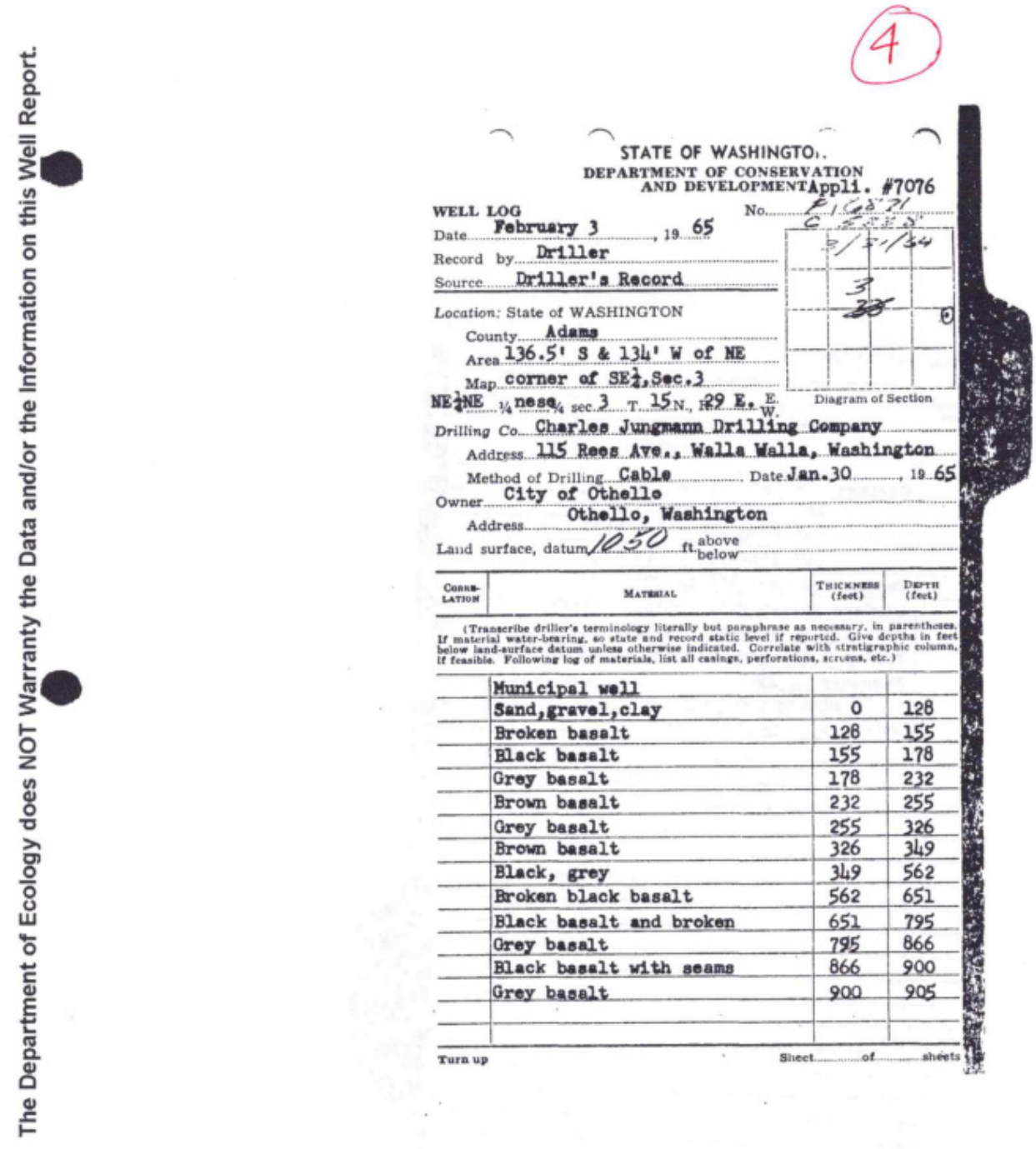
Sheet ____ of ____ sheets

Figure C5-2. Othello Well 2. Well log (1940). Page 1 of 1.

Well #2 - AFL224

Source Status	Active	**Usage**	Emergency	**WRIA**	Esquatzel Coulee
Type	Groundwater Well	**Capacity (gpm)**	260	**Township**	15
Effective Date	10/1/1995	**Treated**	No	**Range**	29E
Inactive Date		**Metered**	Yes	**Section**	3
DOE Well Tag Number	**AFL224**	**Well Depth (ft)**	**588**	**Qtr/Qtr Section**	NWNE

C-6. Othello Well 4: Ecology Well ID Tag No. AEL069



4

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
AND DEVELOPMENT Appl. #7076

WELL LOG No. E 15 21 C E S 3

Date February 3, 19 65

Record by Driller

Source Driller's Record

Location: State of WASHINGTON

County Adams

Area 136.5' S & 134' W of NE

Map corner of SE¼, Sec. 3

NE¼NE ¼ neSE ¼ sec. 3 T. 15 N., R. 29 E. E. W.

Diagram of Section

Drilling Co. Charles Jungmann Drilling Company

Address 115 Rees Ave., Walla Walla, Washington

Method of Drilling Cable Date Jan. 30, 19 65

Owner City of Othello

Address Othello, Washington

Land surface, datum 1050 ft above / below

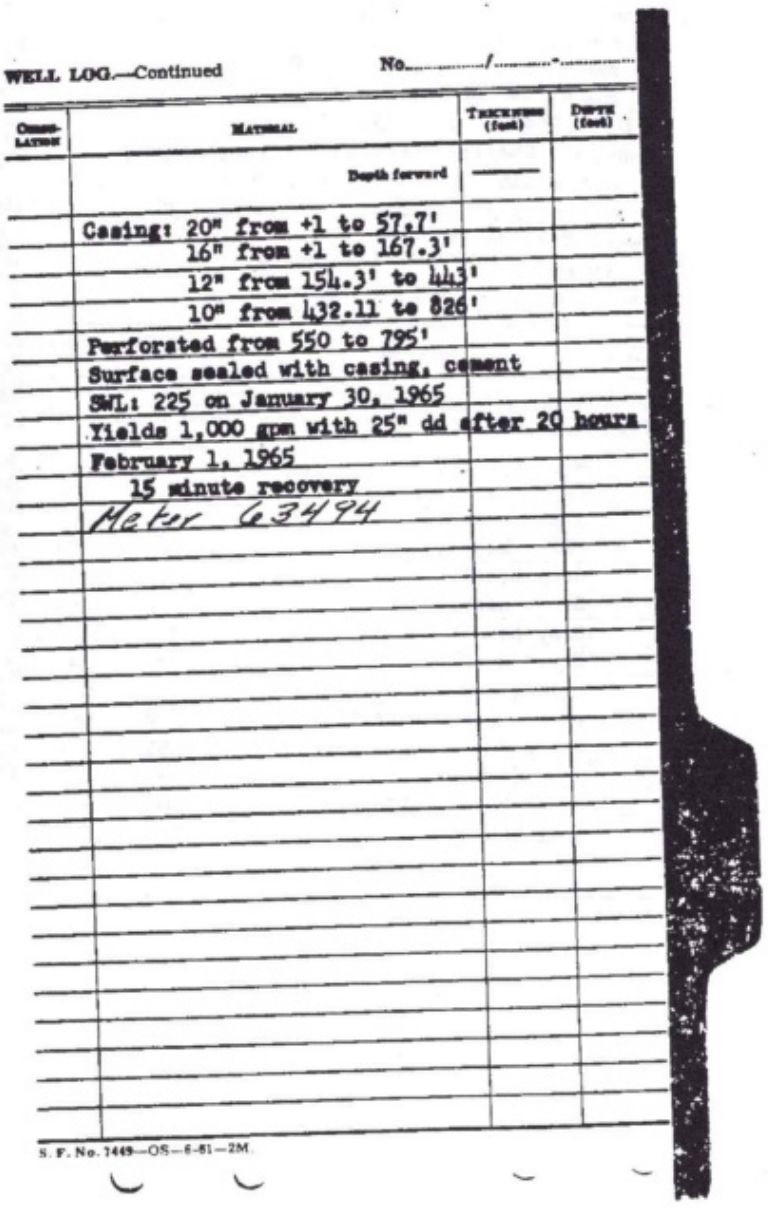
Correlation	Material	Thickness (feet)	Depth (feet)
	(Transcribe driller's terminology literally but paraphrase as necessary, in parentheses. If material water-bearing, so state and record static level if reported. Give depths in feet below land-surface datum unless otherwise indicated. Correlate with stratigraphic column, if feasible. Following log of materials, list all casings, perforations, screens, etc.)		
	Municipal well		
	Sand, gravel, clay	0	128
	Broken basalt	128	155
	Black basalt	155	178
	Grey basalt	178	232
	Brown basalt	232	255
	Grey basalt	255	326
	Brown basalt	326	349
	Black, grey	349	562
	Broken black basalt	562	651
	Black basalt and broken	651	795
	Grey basalt	795	866
	Black basalt with seams	866	900
	Grey basalt	900	905

Turn up Sheet ... of ... sheets

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

Figure C6-1. Othello Well 4. Well log (1965). Page 1 of 2.

The Dep The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

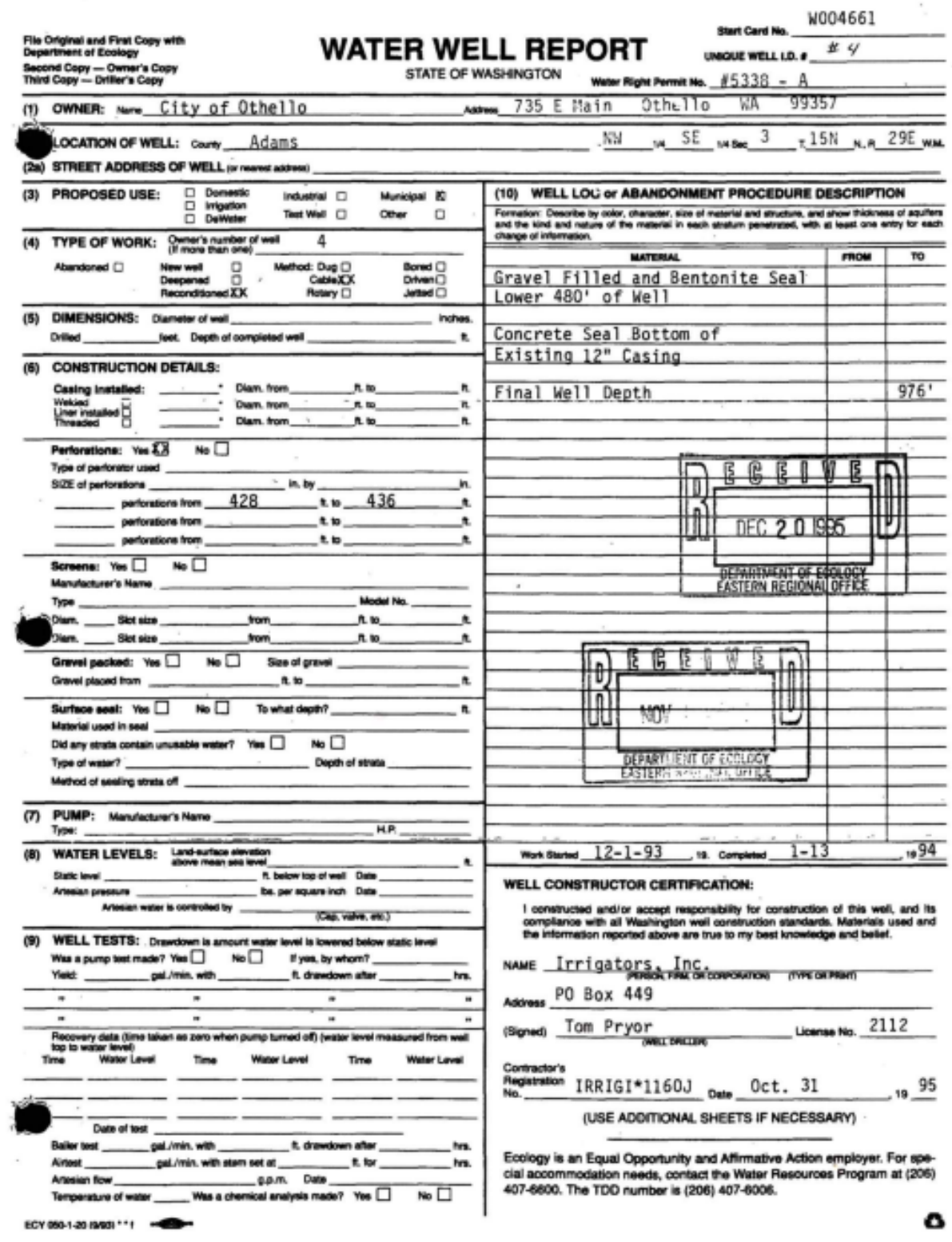


WELL LOG.—Continued No...../.....-.....

CONSOLIDATION	MATERIAL	THICKNESS (feet)	DEPTH (feet)
	Depth forward	———	
	Casing: 20" from +1 to 57.7'		
	16" from +1 to 167.3'		
	12" from 154.3' to 443'		
	10" from 432.11 to 826'		
	Perforated from 550 to 795'		
	Surface sealed with casing, cement		
	SWL: 225 on January 30, 1965		
	Yields 1,000 gpm with 25" dd after 20 hours		
	February 1, 1965		
	15 minute recovery		
	Meter 63494		

S. F. No. 7449—OS—6-81—2M

Figure C6-2. Othello Well 4. Well log (1965). Page 2 of 2.



File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. W004661
UNIQUE WELL I.D. # # 4
Water Right Permit No. #5338 - A

(1) OWNER: Name City of Othello Address 735 E Main Othello WA 99357

LOCATION OF WELL: County Adams NW 1/4 SE 1/4 Sec 3 T 15N N.R. 29E W.M.

(2a) STREET ADDRESS OF WELL (or nearest address)

(3) PROPOSED USE: ☐ Domestic ☐ Industrial ☐ Municipal ☒ ☐ Irrigation ☐ Test Well ☐ Other ☐ ☐ DeWater

(4) TYPE OF WORK: Owner's number of well (if more than one) 4
Abandoned ☐ New well ☐ Method: Dug ☐ Bored ☐ Deepened ☐ Cable ☒ Driven ☐ Reconditioned ☒ Rotary ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well _____ inches. Drilled _____ feet. Depth of completed well _____ ft.

(6) CONSTRUCTION DETAILS:
Casing Installed: _____" Diam. from _____ ft. to _____ ft.
Welded ☐ Threaded ☐ _____" Diam. from _____ ft. to _____ ft.
Liner installed ☐ _____" Diam. from _____ ft. to _____ ft.

Perforations: Yes ☒ No ☐
Type of perforator used _____
SIZE of perforations _____ in. by _____ in.
_____ perforations from 428 ft. to 436 ft.
_____ perforations from _____ ft. to _____ ft.
_____ perforations from _____ ft. to _____ ft.

Screens: Yes ☐ No ☐
Manufacturer's Name _____
Type _____ Model No. _____
Diam. ____ Slot size _____ from _____ ft. to _____ ft.
Diam. ____ Slot size _____ from _____ ft. to _____ ft.

Gravel packed: Yes ☐ No ☐ Size of gravel _____
Gravel placed from _____ ft. to _____ ft.

Surface seal: Yes ☐ No ☐ To what depth? _____ ft.
Material used in seal _____
Did any strata contain unusable water? Yes ☐ No ☐
Type of water? _____ Depth of strata _____
Method of sealing strata off _____

(7) PUMP: Manufacturer's Name _____
Type: _____ H.P. _____

(8) WATER LEVELS: Land-surface elevation above mean sea level _____ ft.
Static level _____ ft. below top of well Date _____
Artesian pressure _____ lbs. per square inch Date _____
Artesian water is controlled by _____ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom? _____
Yield: _____ gal./min. with _____ ft. drawdown after _____ hrs.
" " " "
" " " "
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test _____
Bailer test _____ gal./min. with _____ ft. drawdown after _____ hrs.
Airtest _____ gal./min. with stem set at _____ ft. for _____ hrs.
Artesian flow _____ g.p.m. Date _____
Temperature of water _____ Was a chemical analysis made? Yes ☐ No ☐

ECY 050-1-20 (9/93) * * 1

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION
Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Gravel Filled and Bentonite Seal Lower 480' of Well		
Concrete Seal Bottom of Existing 12" Casing		
Final Well Depth		976'

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DEC 20 1995
DEPARTMENT OF ECOLOGY
EASTERN REGIONAL OFFICE

RECEIVED
NOV
DEPARTMENT OF ECOLOGY
EASTERN REGIONAL OFFICE

Work Started 12-1-93 19 Completed 1-13 19 94

WELL CONSTRUCTOR CERTIFICATION:
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

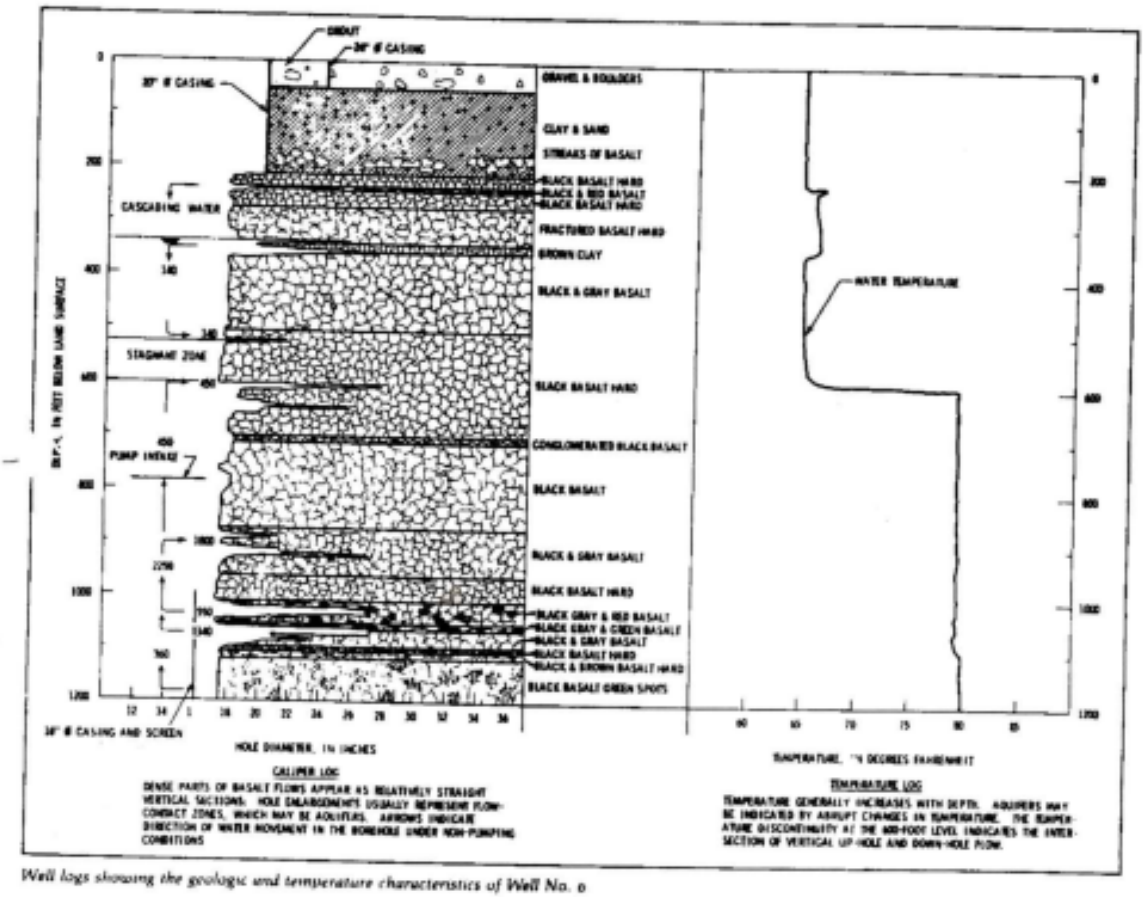
NAME Irrigators, Inc. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address PO Box 449
(Signed) Tom Pryor (WELL DRILLER) License No. 2112
Contractor's Registration No. IRRIGI*1160J Date Oct. 31 19 95

(USE ADDITIONAL SHEETS IF NECESSARY)

Ecology is an Equal Opportunity and Affirmative Action employer. For special accommodation needs, contact the Water Resources Program at (206) 407-6600. The TDD number is (206) 407-6006.

Figure C6-3. Othello Well 4. Well log (1995). Page 1 of 2.

15/29 - 4



Well logs showing the geologic and temperature characteristics of Well No. 6

air or mud rotary drill rig with the following characteristics:

- 100-foot derrick capable of handling a 270,000-pound working load
- 27-½-inch diameter rotary table
- total power requirements, including support equipment, 2,500 horsepower
- 40,000-pound drill collar weight
- 2,400 cubic feet per minute air delivery capability at 800 pounds per square inch
- maximum drilling depth ranges from 1,000 to 5,000 feet for 24-inch and 9-⅞-inch diameter holes respectively.

The well was completed on December 15, 1979.

Borehole Construction

When completed, Well No. 6 extended to a depth of 1,200 feet. The borehole is uncased where it penetrates solid, unfractured rock. The well required casing only in the upper 220 feet and in a lower 205-foot section near the bottom. The 20-inch diameter surface casing was placed in unconsolidated material overlying the consolidated basalt formations. The lower 16-inch diameter casing and screen were installed to prevent caving of a large fracture zone, which is believed to be the most productive aquifer, at the 1,000-foot depth. Total construction cost for the borehole was approximately $206,000.

Figure C6-4. Othello Well 4. Well log (1995). Page 2 of 2.

File Original and First Copy with Department of Ecology
Second Copy—Owner's Copy
Third Copy—Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. [redacted] (4)

Water Right Permit No.

(1) OWNER: Name City of Othello Address 512 E. Main Street Othello, WA 99

(2) LOCATION OF WELL: County Adams Well #4 ¼ ¼ Sec. 3 T. 15 N., R. 29 W.M.

(2a) STREET ADDDRESS OF WELL (or nearest address)

(3) PROPOSED USE: ☐ Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☐ Municipal ☒ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) 4
Abandoned ☐ New well ☐ Deepened ☒ Reconditioned ☐ Method: Dug ☐ Cable ☐ Rotary ☒ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 9 7/8 inches. Drilled 1450 feet. Depth of completed well 1450 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: n/a " Diam. from ft. to ft.
Welded ☐ Liner installed ☐ Threaded ☐ " Diam. from ft. to ft.
" Diam. from ft. to ft.
Perforations: Yes ☐ No ☒
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.
Screens: Yes ☐ No ☒
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.
Gravel packed: Yes ☐ No ☒ Size of gravel
Gravel placed from ft. to ft.
Surface seal: Yes ☒ No ☐ To what depth? ft.
Material used in seal Done Previously
Did any strata contain unusable water? Yes ☐ No ☐
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level ft.
Static level ft. below top of well Date
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test gal./min. with ft. drawdown after hrs.
Airtest gal./min. with stem set at ft. for hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Hard grey basalt 175 PSI	898	930
Medium grey - broken seams	930	935
Broken & pourous 250 PSI	935	945
Medium grey - broken seams	945	970
Hard grey basalt	970	986
Pourous basalt	986	1004
Broken basalt - pourous seams	1004	1023
Medium grey	1023	1047
Hard grey	1047	1067
Black pourous PSI 260	1067	1073
Broken basalt	1073	1080
Medium grey - broken seams	1080	1120
Hard grey basalt	1120	1161
Soft black basalt	1161	1170
Medium black basalt	1170	1242
Red pourous 320 PSI	1242	1246
Soft black basalt	1246	1260
Medium basalt - broken seams	1260	1377
Soft black basalt	1377	1396
Hard grey - broken seams 340 PSI	1396	1450

Drilled 9 7/8" hole

RECEIVED FEB 11 1992 DEPT OF ECOLOGY

Work started 12/16-91 19 Completed 1-5-92 19

WELL CONSTRUCTOR CERTIFICATION:
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME BJ Exploration Co., INC. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address Rt 4 Box 4517 Kennewick, WA 99337
(Signed) [signature] (WELL DRILLER) License No. 0337
Contractor's Registration No. BJEXPC1I320K Date 2/4/92 19

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20 (10/87) -1329-

Figure C6-5. Othello Well 4. Well log (1992). Page 1 of 1.

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

28139

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. W004661 (4)

UNIQUE WELL I.D. #

Water Right Permit No.

(1) OWNER: Name City of Othello Address 512 E Main St. Othello WA 99344

(2) LOCATION OF WELL: County Adams NE 1/4 SE 1/4 Sec 3 T. 15 N, R. 29 W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) Well # 4

(3) PROPOSED USE: ☐ Domestic ☐ Industrial ☐ Municipal ☒
☐ Irrigation ☐ Test Well ☐ Other ☐
☐ DeWater

(4) TYPE OF WORK: Owner's number of well (if more than one) 4
Abandoned ☐ New well ☐ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☒ Rotary ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well ____ inches.
Drilled ____ feet. Depth of completed well 976 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: ____" Diam. from ____ ft. to ____ ft.
Welded ☐ ____" Diam. from ____ ft. to ____ ft.
Liner installed ☐ ____" Diam. from ____ ft. to ____ ft.
Threaded ☐

Perforations: Yes ☒ No ☐
Type of perforator used Mills Knife
SIZE of perforations ____ in. by ____ in.
48 perforations from 428 ft. to 436 ft.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.

Screens: Yes ☐ No ☐
Manufacturer's Name ____
Type ____ Model No. ____
Diam. ____ Slot size ____ from ____ ft. to ____ ft.
Diam. ____ Slot size ____ from ____ ft. to ____ ft.

Gravel packed: Yes ☐ No ☐ Size of gravel ____
Gravel placed from ____ ft. to ____ ft.

Surface seal: Yes ☐ No ☐ To what depth? ____ ft.
Material used in seal ____
Did any strata contain unusable water? Yes ☐ No ☐
Type of water? ____ Depth of strata ____
Method of sealing strata off ____

(7) PUMP: Manufacturer's Name ____
Type: ____ H.P. ____

(8) WATER LEVELS: Land-surface elevation above mean sea level ____ ft.
Static level 396 ft. below top of well Date 1/24/94
Artesian pressure ____ lbs. per square inch Date ____
Artesian water is controlled by ____ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom? ____
Yield: ____ gal./min. with ____ ft. drawdown after ____ hrs.
" " " "
" " " "
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test ____
Bailer test ____ gal./min. with ____ ft. drawdown after ____ hrs.
Airtest ____ gal./min. with stem set at ____ ft. for ____ hrs.
Artesian flow ____ g.p.m. Date ____
Temperature of water ____ Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Existing well drilled 1965; to 905'		
Deepened in 1992 to 1450'		
Irrigators Inc. was retained by City of Othello to eliminate upflow & downflow of water in well		
1) Existing 12" casing perforated	428	436
Set bridge	-	440
Cemented Perforated casing	416.5	440
Drilled out cement plug - down flow from behind bottom of casing eliminated		
2) Backfilled with chlorinated pea- gravel	994	1450
Backfilled with bentonite chips	979	994
Pressure grouted with neat cement	976	979
Upflow from Grande Rhonde Aquifer eliminated		
Well was video logged to verify sealing of Aquifers		

Work Started 12/1/93 19. Completed 1/13 19 94

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME IRRIGATORS, INC. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

Address P O BOX 449 Moses Lk WA 98

(Signed) Delos K Boyer (WELL DRILLER) License No. 1064

Contractor's Registration No. IRRIGI*1160J Date 1/11/97 19 97

(USE ADDITIONAL SHEETS IF NECESSARY)

Ecology is an Equal Opportunity and Affirmative Action employer. For special accommodation needs, contact the Water Resources Program at (206) 407-6600. The TDD number is (206) 407-6006.

ECY 050-1-20 (9/93) * * I

Figure C6-6. Othello Well 4. Well log (1997). Page 1 of 1.

Othello - Well #4 - AEL069

Source Status	Active	**Usage**	Permanent	**WRIA**	Esquatzel Coulee
Type	Groundwater Well	**Capacity (gpm)**	450	**Township**	15
Effective Date	1/1/1970	**Treated**	Yes	**Range**	29E
Inactive Date		**Metered**	Yes	**Section**	3
DOE Well Tag Number	AEL069	**Well Depth (ft)**	904	**Qtr/Qtr Section**	NESE

C-7. Othello Well 5: Ecology Well ID Tag No.

Well Details	Location Details
Well Owner: **CITY OF OTHELLO** Well Tag ID: Notice of Intent Number: Group Number: Not Applicable Well Report ID: 164530 Well Diameter: 20 in. Well Depth: 963 ft.	Tax Parcel Number: Well Address: NKA/WELL #5 RECONDITION, OTHELLO 99344 County: ADAMS Public Land Survey: SE-SW / S03 / T15N / R29E Well Type: Water / Subtype: Unknown Well Completion Date: 04-02-1987 Well Report Received Date: 04-20-1987
Well Owner: **CITY OF OTHELLO** Well Tag ID: Notice of Intent Number: Group Number: Not Applicable Well Report ID: 164531 Well Diameter: 30 in. Well Depth: 1007 ft.	Tax Parcel Number: Well Address: NKA/WELL #5, OTHELLO 99344 County: ADAMS Public Land Survey: SE-SW / S03 / T15N / R29E Well Type: Water / Subtype: Unknown Well Completion Date: 04-09-1974 Well Report Received Date: 04-12-1974

Figure C7-1. Othello Well 5. Location information from Washington State Well Report Viewer (https://appswr.ecology.wa.gov/WellConstruction/Map/WCLSWebMap)

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No. .....
Permit No. .....

(1) **OWNER:** Name City of Othello Address 512 E. Main Street, Othello, WA 99344

(2) **LOCATION OF WELL:** County Adams — SE ¼ SW ¼ Sec. 3 T. 15 N., R. 29E W.M.

Bearing and distance from section or subdivision corner

(3) **PROPOSED USE:** Domestic ☐ Industrial ☐ Municipal ☒
Irrigation ☐ Test Well ☐ Other ☐

(4) **TYPE OF WORK:** Owner's number of well (if more than one) 5
New well ☐ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☒ Driven ☐
Reconditioned ☒ Rotary ☐ Jetted ☐

(5) **DIMENSIONS:** Diameter of well 20/16/12 inches.
Drilled not changed Depth of completed well 963 ft.

(6) **CONSTRUCTION DETAILS:** Not Changed
Casing installed: 20 " Diam. from +1 ft. to > 361 ft.
Threaded ☐ 16 " Diam. from 361 ft. to > 635 ft.
Welded ☒ 12 " Diam. from 635 ft. to > 710 ft.

Perforations: Yes ☒ No ☐
Type of perforator used Mills Knife
SIZE of perforations 3/8 in. by 2.5 in.
~ 650 perforations from 550 ft. to 634 ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes ☐ No ☐ Not Changed
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes ☐ No ☐ Not Changed Size of gravel:
Gravel placed from ft. to ft.

Surface seal: Yes ☐ No ☐ Not Changed To what depth? ft.
Material used in seal
Did any strata contain unusable water? Yes ☐ No ☐
Type of water? Depth of strata
Method of sealing strata off

(7) **PUMP:** Manufacturer's Name Layne & Bowler
Type: Vertical lineshaft turbine HP 350

(8) **WATER LEVELS:** Land-surface elevation above mean sea level 1055 ft.
Static level 277 ft. below top of well Date 3/31/87
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) **WELL TESTS:** Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? SEI
Yield: 1175 gal./min. with 56 ft. drawdown after 4 hrs.
" 1590 " 117 " 8 "
" 1740 " 160 " 16 "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
5	309	60	301	485	290
15	306	125	298	965	288
30	304	185	296	1715	285

Date of test 3/31-4/1/87
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? Yes ☐ No ☒

(10) **WELL LOG:**
Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

MATERIAL	FROM	TO
Existing well was drilled by Charles Jungman and completed 4/9/74 per previous WaterWell Report.		
Work done to well at this time consisted basically of bailing from 952', chemical treatments, mechanical agitation, reperforating, sonar jetting, pump installation and testing.		

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APR 2 0 1987
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SPOKANE REGIONAL OFFICE

Work started 11/11 19 86 Completed 4/2 19 87

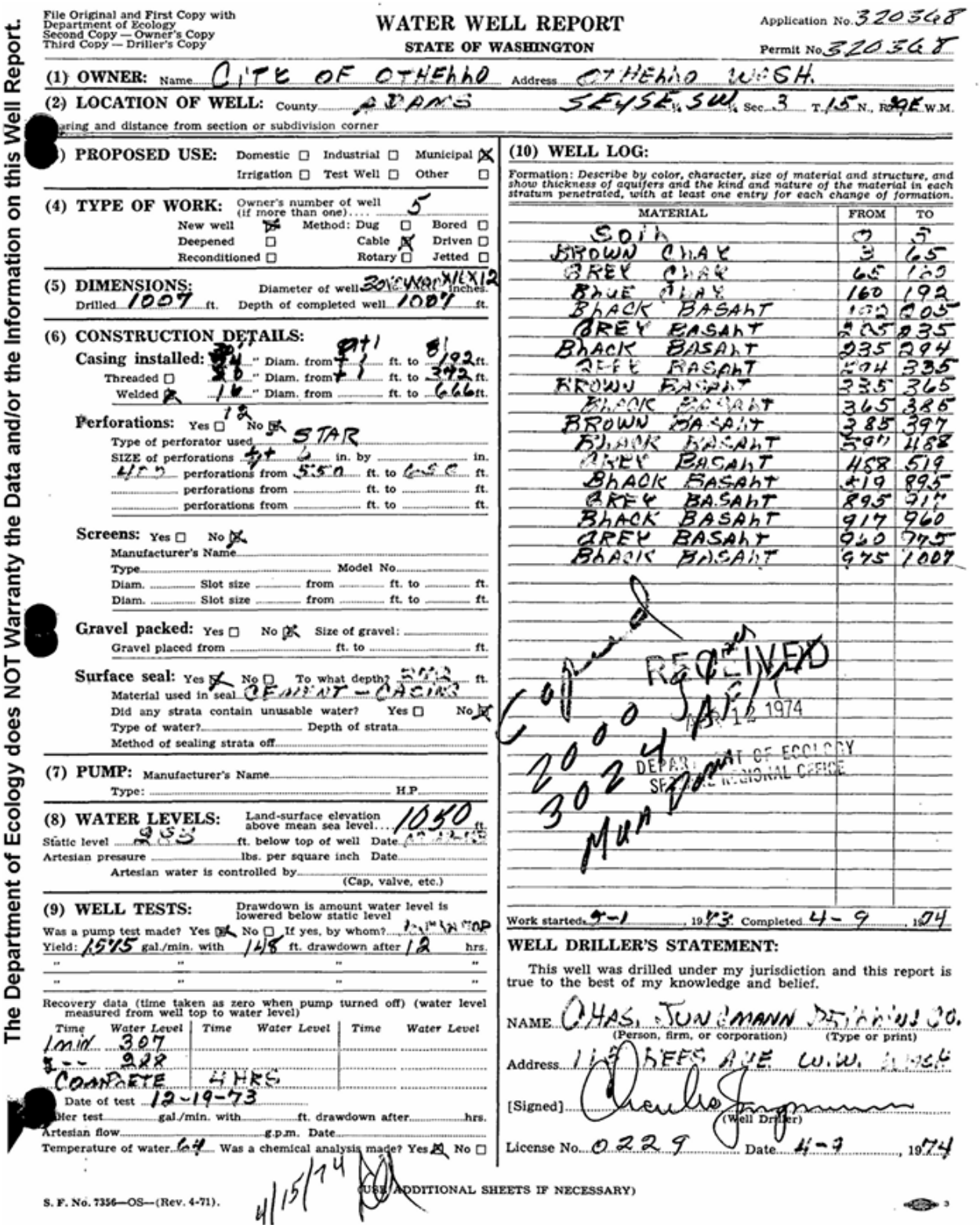
WELL DRILLER'S STATEMENT:
This well was ~~drilled~~ reconditioned under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Schneider Equipment, Inc. (Person, firm, or corporation) (Type or print)
Address 21881 River Road NE, St. Paul, OR 97137
[Signed] Stephen J. Schneider (Well Driller)
License No. 643 Date 4/6 19 87

SEI #8706

ECY 050-1-20 4/20/87 (USE ADDITIONAL SHEETS IF NECESSARY)

C7-2. Othello Well 5. Well log (1987).



File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No. 320348
Permit No. 320348

(1) OWNER: Name CITY OF OTHELLO Address OTHELLO WASH.

(2) LOCATION OF WELL: County ADAMS SE¼SE¼SW¼ Sec. 3 T. 15 N., R. 29E W.M.
Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☒
Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) 5
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☒ Driven ☐
Reconditioned ☐ Rotary ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 20" over 16" inches.
Drilled 1007 ft. Depth of completed well 1007 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 24" Diam. from +1 ft. to 81/92 ft.
Threaded ☐ 20" Diam. from +1 ft. to 342 ft.
Welded ☒ 16" Diam. from ft. to 666 ft.

Perforations: Yes ☐ No ☒ 12
Type of perforator used STAR
SIZE of perforations 4+ 2 in. by in.
407 perforations from 550 ft. to 666 ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes ☐ No ☒
Manufacturer's Name
Type Model No.
Diam. Slot size from ft. to ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes ☐ No ☒ Size of gravel:
Gravel placed from ft. to ft.

Surface seal: Yes ☒ No ☐ To what depth? 342 ft.
Material used in seal CEMENT - CASING
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level 1050 ft.
Static level 955 ft. below top of well Date 12-19-73
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? [illegible]
Yield: 1545 gal./min. with 148 ft. drawdown after 12 hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
1 min	307				
5 "	928				
COMPLETE	4 HRS.				

Date of test 12-19-73
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water 64 Was a chemical analysis made? Yes ☒ No ☐

(10) WELL LOG:
Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
SOIL	0	3
BROWN CLAY	3	65
GREY CLAY	65	160
BLUE CLAY	160	192
BLACK BASALT	192	205
GREY BASALT	205	235
BLACK BASALT	235	294
RED BASALT	294	335
BROWN BASALT	335	365
BLACK BASALT	365	385
BROWN BASALT	385	397
BLACK BASALT	397	458
GREY BASALT	458	519
BLACK BASALT	519	895
GREY BASALT	895	917
BLACK BASALT	917	960
GREY BASALT	960	975
BLACK BASALT	975	1007

RECEIVED
APR 12 1974
DEPARTMENT OF ECOLOGY
SPOKANE REGIONAL OFFICE

Work started 9-1 19 73 Completed 4-9 19 74

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME CHAS. JUNGMANN DRILLING CO.
(Person, firm, or corporation) (Type or print)
Address 1[illegible] BEES AVE W.W. [illegible]
[Signed] (Well Driller)
License No. 0229 Date 4-9 19 74

S. F. No. 7356—OS—(Rev. 4-71). USE ADDITIONAL SHEETS IF NECESSARY)

4/15/74

The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

C7-3. Othello Well 5. Well log (1974).

Well #5 - AFL223

Source Status	Active	**Usage**	Permanent	**WRIA**	Esquatzel Coulee
Type	Groundwater Well	**Capacity (gpm)**	1,200	**Township**	5
Effective Date	1/1/1970	**Treated**	Yes	**Range**	29E
Inactive Date		**Metered**	Yes	**Section**	3
DOE Well Tag Number	AFL223	**Well Depth (ft)**	1007	**Qtr/Qtr Section**	SESW

Figure C7-4. Othello Well 5. Location information from Washington State Well Report Viewer (https://appswr.ecology.wa.gov/WellConstruction/Map/WCLSWebMap)

C-8. Othello Well 6: Ecology ID N/A; Water Right Permit G3-25032

Well Owner: **CITY OF OTHELLO**
Well Tag ID: ABR235
Notice of Intent Number:
Group Number: Not Applicable
Well Report ID: 164532
Well Diameter: 20 in.
Well Depth: 1210 ft.

Tax Parcel Number:
Well Address:
County: ADAMS
Public Land Survey: NE-NE / S04 / T15N / R29E
Well Type: Water / Subtype: Unknown
Well Completion Date: 02-10-1978
Well Report Received Date: 02-14-1978

Well Owner: **CITY OF OTHELLO**
Well Tag ID:
Notice of Intent Number: W253012
Group Number: Not Applicable
Well Report ID: 762052
Well Diameter: 6 in.
Well Depth: 1002 ft.

Tax Parcel Number:
Well Address:
County: ADAMS
Public Land Survey: NE-NE / S04 / T15N / R29E
Well Type: Water / Subtype: Unknown
Well Completion Date: 06-30-2011
Well Report Received Date: 07-25-2011

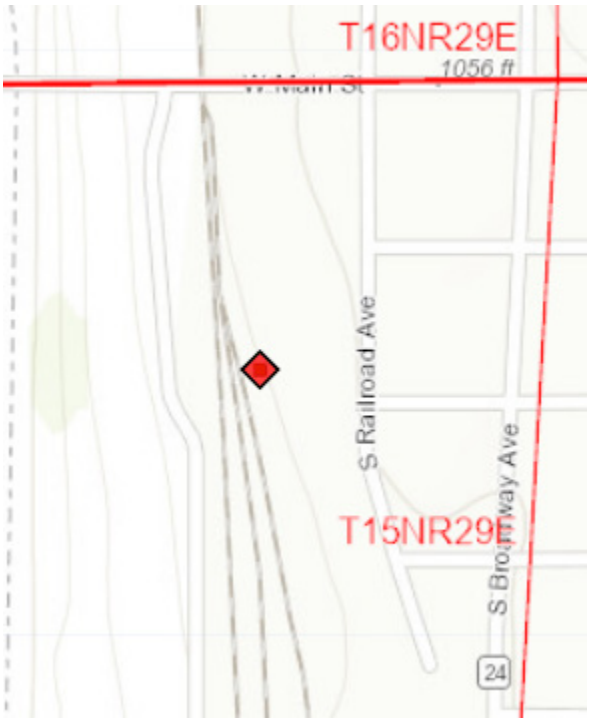


Figure C8-1. Othello Well 6. Location information from Washington State Well Report Viewer (https://appswr.ecology.wa.gov/WellConstruction/Map/WCLSWebMap)

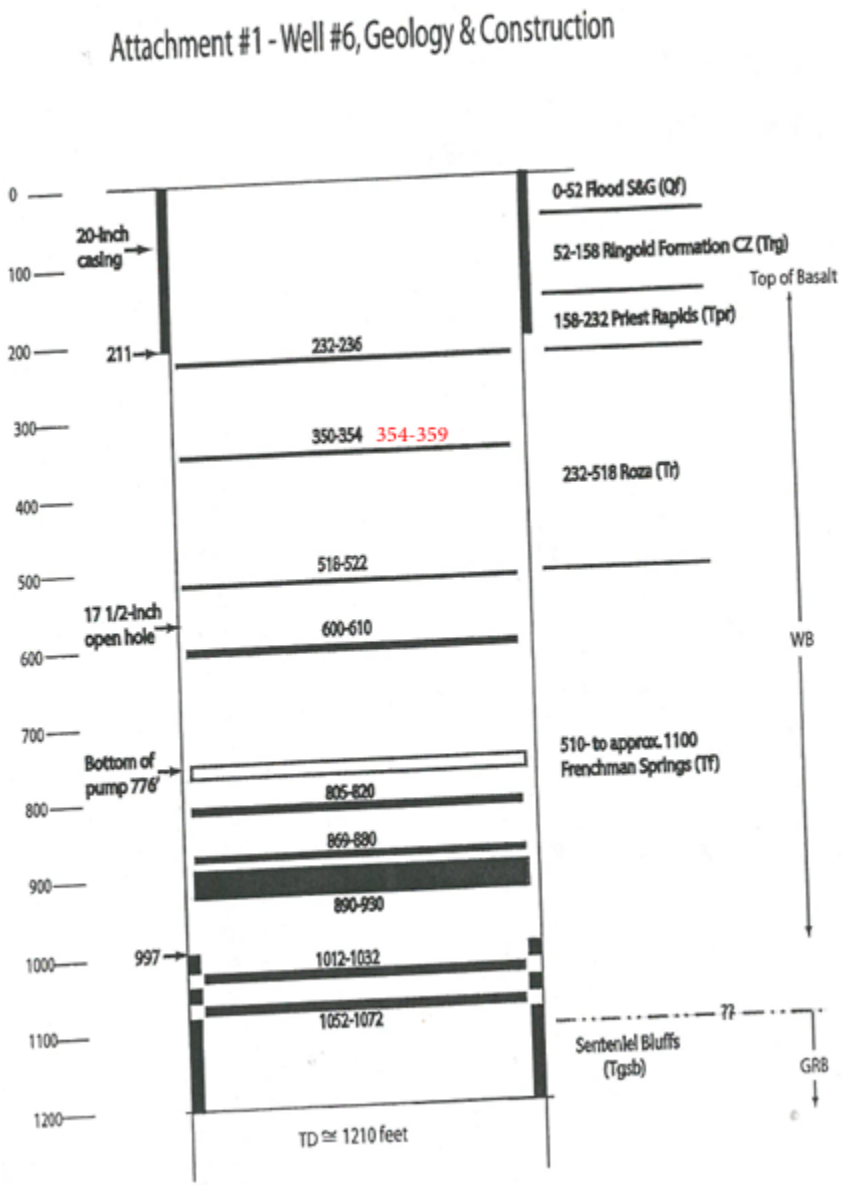
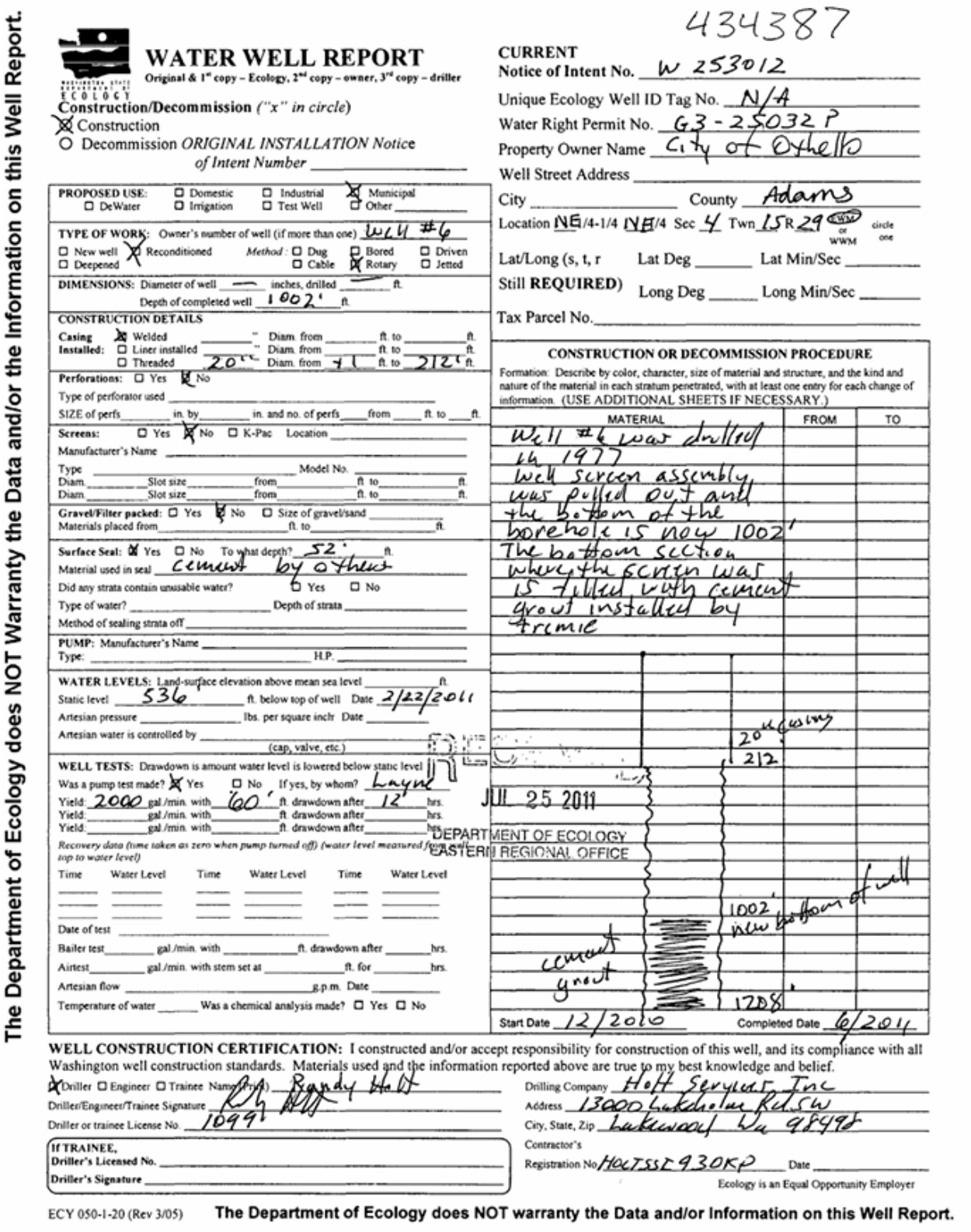


Figure C8-2. Othello Well 6. Well log.



The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

434387

WATER WELL REPORT

Original & 1st copy – Ecology, 2nd copy – owner, 3rd copy – driller

Construction/Decommission *("x" in circle)*

(X) Construction

( ) Decommission *ORIGINAL INSTALLATION Notice of Intent Number* _____

CURRENT
Notice of Intent No. W 253012
Unique Ecology Well ID Tag No. N/A
Water Right Permit No. G3-25032P
Property Owner Name City of Othello
Well Street Address _____
City _____ County Adams
Location NE/4-1/4 NE/4 Sec 4 Twn 15 R 29 (EWM or WWM) circle one
Lat/Long (s, t, r Still **REQUIRED**) Lat Deg _____ Lat Min/Sec _____ Long Deg _____ Long Min/Sec _____
Tax Parcel No. _____

PROPOSED USE: ☐ Domestic ☐ Industrial (X) Municipal ☐ DeWater ☐ Irrigation ☐ Test Well ☐ Other _____

TYPE OF WORK: Owner's number of well (if more than one) Well #6
☐ New well (X) Reconditioned ☐ Deepened
Method: ☐ Dug ☐ Bored ☐ Driven ☐ Cable (X) Rotary ☐ Jetted

DIMENSIONS: Diameter of well — inches, drilled — ft.
Depth of completed well 1002' ft.

CONSTRUCTION DETAILS
Casing Installed: (X) Welded ☐ Liner installed ☐ Threaded 20" Diam. from 71 ft. to 212' ft.
Perforations: ☐ Yes (X) No
Type of perforator used _____
SIZE of perfs _____ in. by _____ in. and no. of perfs ____ from ____ ft. to ____ ft.
Screens: ☐ Yes (X) No ☐ K-Pac Location _____
Manufacturer's Name _____
Type _____ Model No. _____
Diam. _____ Slot size _____ from _____ ft. to _____ ft.
Diam. _____ Slot size _____ from _____ ft. to _____ ft.
Gravel/Filter packed: ☐ Yes (X) No ☐ Size of gravel/sand _____
Materials placed from _____ ft. to _____ ft.
Surface Seal: (X) Yes ☐ No To what depth? 52' ft.
Material used in seal cement by others
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? _____ Depth of strata _____
Method of sealing strata off _____
PUMP: Manufacturer's Name _____
Type: _____ H.P. _____
WATER LEVELS: Land-surface elevation above mean sea level _____ ft.
Static level 536 ft. below top of well Date 2/22/2011
Artesian pressure _____ lbs. per square inch Date _____
Artesian water is controlled by _____ (cap, valve, etc.)
WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? (X) Yes ☐ No If yes, by whom? Layne
Yield: 2000 gal./min. with 60' ft. drawdown after 12' hrs.
Yield: _____ gal./min. with _____ ft. drawdown after _____ hrs.
Yield: _____ gal./min. with _____ ft. drawdown after _____ hrs.
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test _____
Bailer test _____ gal./min. with _____ ft. drawdown after _____ hrs.
Airtest _____ gal./min. with stem set at _____ ft. for _____ hrs.
Artesian flow _____ g.p.m. Date _____
Temperature of water _____ Was a chemical analysis made? ☐ Yes ☐ No

CONSTRUCTION OR DECOMMISSION PROCEDURE
Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. (USE ADDITIONAL SHEETS IF NECESSARY.)

MATERIAL	FROM	TO
Well #6 was drilled in 1977 well screen assembly was pulled out until the bottom of the borehole is now 1002' The bottom section where the screen was is filled with cement grout installed by tremie		
	20' casing	
	212	
	1002' new bottom of well	
cement grout		
	1208'	

JUL 25 2011
DEPARTMENT OF ECOLOGY
EASTERN REGIONAL OFFICE

Start Date 12/2010 Completed Date 6/2011

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

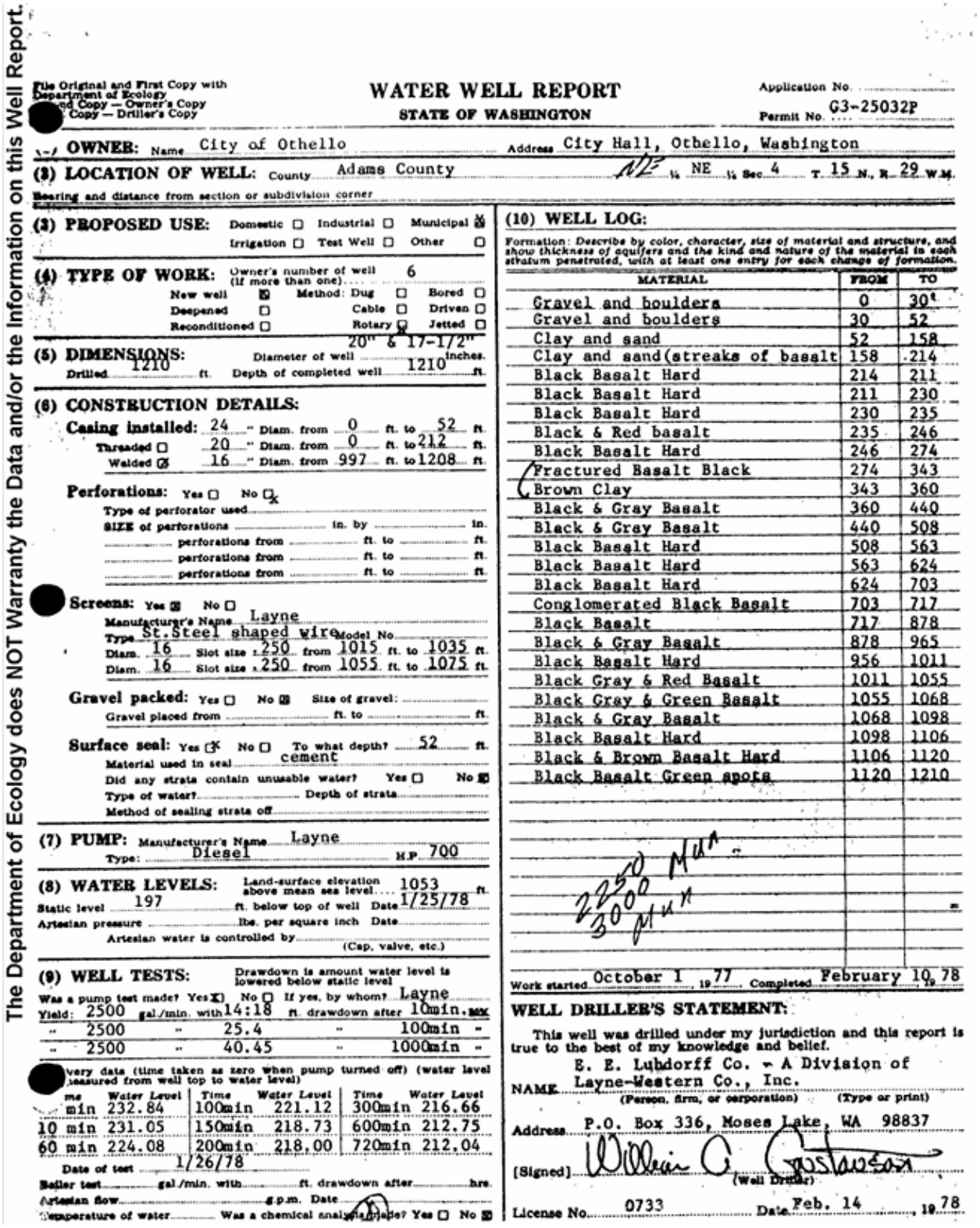
(X) Driller ☐ Engineer ☐ Trainee Name (print) Randy Holt
Driller/Engineer/Trainee Signature _____
Driller or trainee License No. 1049
Drilling Company Holt Services, Inc
Address 13000 Lakeholm Rd SW
City, State, Zip Lakewood Wa 98498
Contractor's Registration No HOLTSSI930KP Date _____

If TRAINEE,
Driller's Licensed No. _____
Driller's Signature _____

Ecology is an Equal Opportunity Employer

ECY 050-1-20 (Rev 3/05) **The Department of Ecology does NOT warranty the Data and/or Information on this Well Report.**

Figure C8-3. Othello Well 6. Well log (2011).



The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

File Original and First Copy with Department of Ecology
nd Copy — Owner's Copy
Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Application No.
Permit No. G3-25032P

(1) OWNER: Name City of Othello Address City Hall, Othello, Washington

(2) LOCATION OF WELL: County Adams County NE ¼ NE ¼ Sec. 4 T. 15 N., R. 29 W.M.

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☐ Industrial ☐ Municipal ☒
Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) 6
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☒ Jetted ☐

(5) DIMENSIONS: Diameter of well 20" & 17-1/2" inches.
Drilled 1210 ft. Depth of completed well 1210 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 24 " Diam. from 0 ft. to 52 ft.
Threaded ☐ 20 " Diam. from 0 ft. to 212 ft.
Welded ☒ 16 " Diam. from 997 ft. to 1208 ft.

Perforations: Yes ☐ No ☒
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes ☒ No ☐
Manufacturer's Name Layne
Type St.Steel shaped wire Model No.
Diam. 16 Slot size .250 from 1015 ft. to 1035 ft.
Diam. 16 Slot size .250 from 1055 ft. to 1075 ft.

Gravel packed: Yes ☐ No ☒ Size of gravel:
Gravel placed from ft. to ft.

Surface seal: Yes ☒ No ☐ To what depth? 52 ft.
Material used in seal cement
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name Layne
Type: Diesel H.P. 700

(8) WATER LEVELS: Land-surface elevation above mean sea level 1053 ft.
Static level 197 ft. below top of well Date 1/25/78
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? Layne
Yield: 2500 gal./min. with 14:18 ft. drawdown after 10min.
" 2500 " 25.4 " 100min
" 2500 " 40.45 " 1000min

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
min	232.84	100min	221.12	300min	216.66
10 min	231.05	150min	218.73	600min	212.75
60 min	224.08	200min	218.00	720min	212.04

Date of test 1/26/78
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? Yes ☐ No ☒

(10) WELL LOG:
Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

MATERIAL	FROM	TO
Gravel and boulders	0	30
Gravel and boulders	30	52
Clay and sand	52	158
Clay and sand(streaks of basalt	158	214
Black Basalt Hard	214	211
Black Basalt Hard	211	230
Black Basalt Hard	230	235
Black & Red basalt	235	246
Black Basalt Hard	246	274
Fractured Basalt Black	274	343
Brown Clay	343	360
Black & Gray Basalt	360	440
Black & Gray Basalt	440	508
Black Basalt Hard	508	563
Black Basalt Hard	563	624
Black Basalt Hard	624	703
Conglomerated Black Basalt	703	717
Black Basalt	717	878
Black & Gray Basalt	878	965
Black Basalt Hard	956	1011
Black Gray & Red Basalt	1011	1055
Black Gray & Green Basalt	1055	1068
Black & Gray Basalt	1068	1098
Black Basalt Hard	1098	1106
Black & Brown Basalt Hard	1106	1120
Black Basalt Green spots	1120	1210

2250 Min
2300 Min

Work started October 1 19 77 Completed February 10 19 78

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

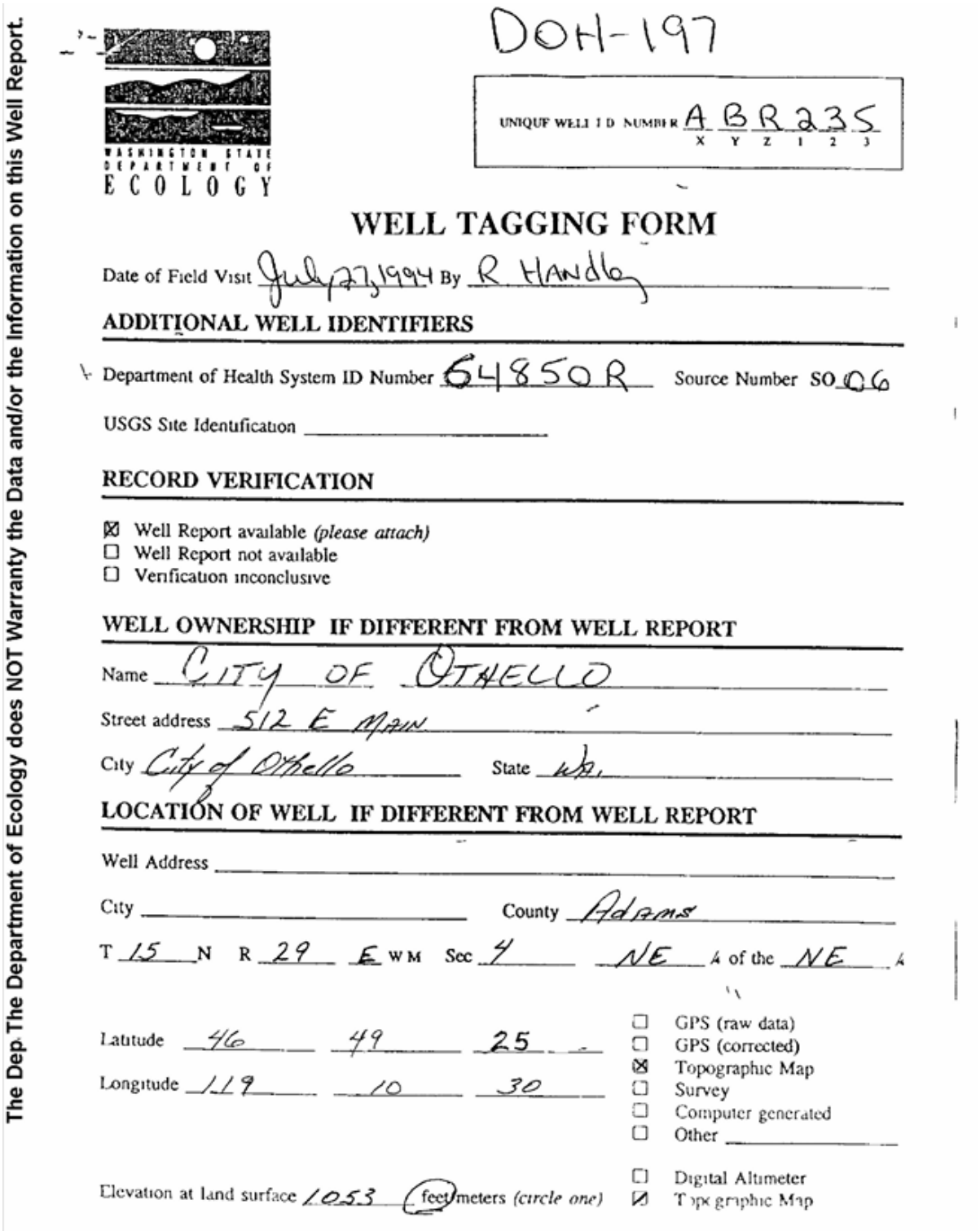
NAME E. E. Luhdorff Co. - A Division of Layne-Western Co., Inc.
(Person, firm, or corporation) (Type or print)

Address P.O. Box 336, Moses Lake, WA 98837

[Signed] William C. Gustafson
(Well Driller)

License No. 0733 Date Feb. 14 19 78

Figure C8-3. Othello Well 6. Well log (1978).



The Dep The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

WASHINGTON STATE DEPARTMENT OF ECOLOGY

DOH-197

UNIQUE WELL I D NUMBER ABR235
X Y Z 1 2 3

WELL TAGGING FORM

Date of Field Visit July 27, 1994 By R Handley

ADDITIONAL WELL IDENTIFIERS

Department of Health System ID Number 64850R Source Number SO 06

USGS Site Identification _____

RECORD VERIFICATION

☒ Well Report available *(please attach)*
☐ Well Report not available
☐ Verification inconclusive

WELL OWNERSHIP IF DIFFERENT FROM WELL REPORT

Name CITY OF OTHELLO

Street address 512 E Main

City City of Othello State Wa.

LOCATION OF WELL IF DIFFERENT FROM WELL REPORT

Well Address _____

City _____ County Adams

T 15 N R 29 E WM Sec 4 NE ¼ of the NE ¼

Latitude 46 49 25
Longitude 119 10 30

☐ GPS (raw data)
☐ GPS (corrected)
☒ Topographic Map
☐ Survey
☐ Computer generated
☐ Other _____

Elevation at land surface 1053 (feet) meters *(circle one)*

☐ Digital Altimeter
☒ Topographic Map

Figure C8-4. Othello Well 6. Well Tag Page 1 of 2.

The Dep The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

Additional information if available

☐ Location marked on topographic map *(please attach)*

☐ Location marked on air photo *(please attach)*

Water Right # G3 25032P Priority Date _____

Circle one Application (Permit) Certificate Claim Exempt

WELL CHARACTERISTICS

Physical Description of Well (size of casing type of well housing etc) 24 Casing 0 52 (Surface Seal)
20 Casing 0 212 16 casing 997 to 1208 Block Bld 900 HP Motor

Location of Well Identification Tag Pump Base Plate S. W Corner.

Was Supplemental Tag needed for ease of identifying well?
☑ NO ☐ YES

If yes where was tag placed? _____

Scale 1 24 000 (1 =2 000)

N

D C B A
E F G H
M L K J
N P Q R

Indicate the location of the well within the Section by drawing a dot at that point

SECTION 4

COMMENTS _____

Please attach this form to the Well Report and submit it to the Department of Ecology. Water Right Permit Application Forms and Well Report Forms are available from the Department of Ecology Publication

Figure C8-5. Othello Well 6. Well Tag Page 2 of 2.

Well #6 - ABR235

Source Status	Active	**Usage**	Seasonal	**WRIA**	Esquatzel Coulee
Type	Groundwater Well	**Capacity (gpm)**	2,000	**Township**	15
Effective Date	1/1/1970	**Treated**	Yes	**Range**	29E
Inactive Date		**Metered**	Yes	**Section**	4
DOE Well Tag Number	ABR235	**Well Depth (ft)**	1200	**Qtr/Qtr Section**	NENE

Figure C8-6. Othello Well 6. Location information from Washington State Well Report Viewer (https://appswr.ecology.wa.gov/WellConstruction/Map/WCLSWebMap)

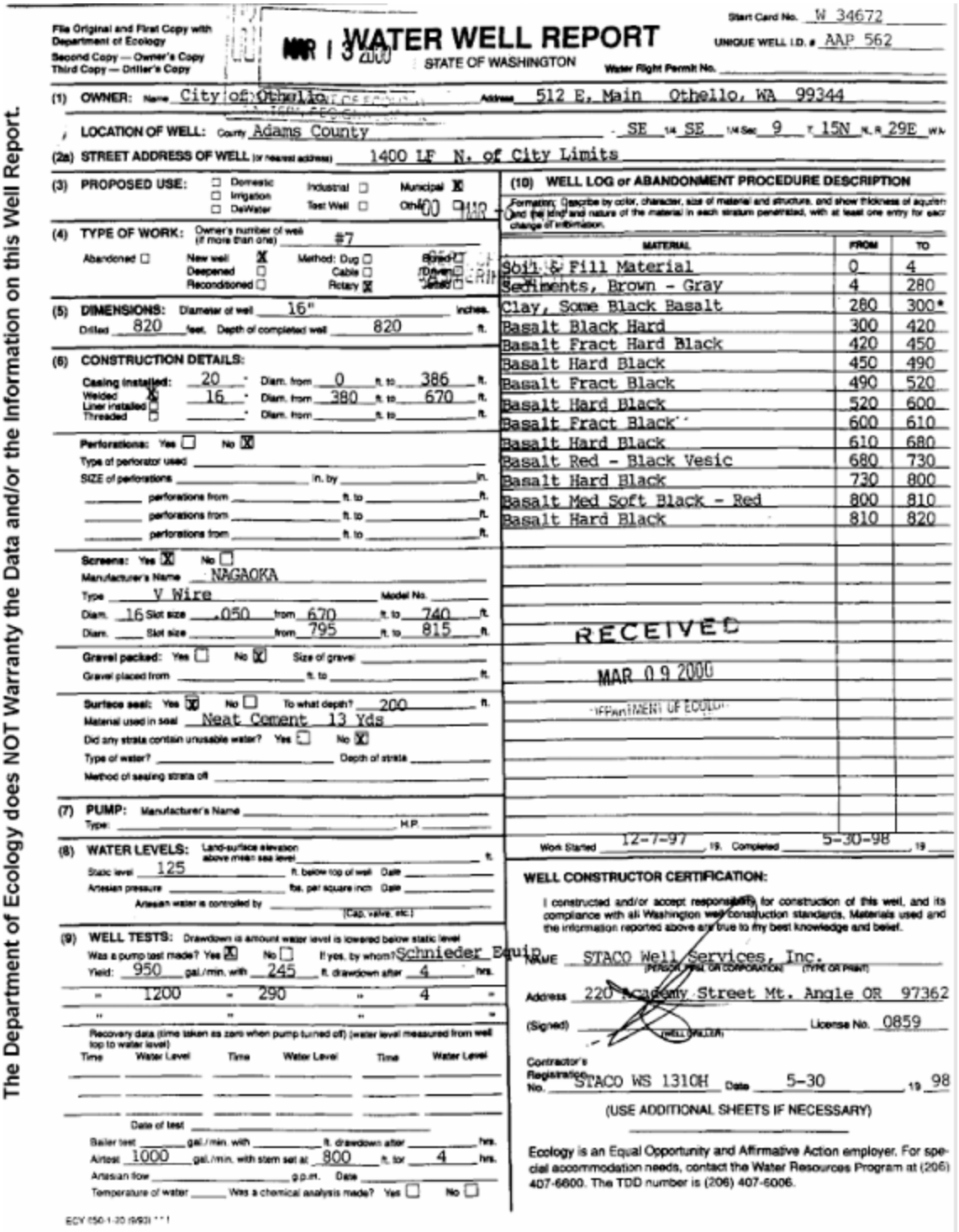
C-9. Othello Well 7: Ecology Well ID Tag: AAP562

Well Owner: **CITY OF OTHELLO**

Well Tag ID: AAP562
Notice of Intent Number: W034672
Group Number: Not Applicable
Well Report ID: 253118
Well Diameter: 16 in.
Well Depth: 820 ft.

Tax Parcel Number:
Well Address: 1400 LF N O CITY LIMITS
County: ADAMS
Public Land Survey: SE-SE / S09 / T15N / R29E
Well Type: Water / Subtype: Unknown
Well Completion Date: 05-30-1998
Well Report Received Date: 05-09-2000

Figure C9-1. Othello Well 7. Location information from Washington State Well Report Viewer (https://appswr.ecology.wa.gov/WellConstruction/Map/WCLSWebMap)



The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT
STATE OF WASHINGTON

Start Card No. W 34672
UNIQUE WELL I.D. # AAP 562
Water Right Permit No.

(1) OWNER: Name City of Othello Address 512 E. Main Othello, WA 99344

LOCATION OF WELL: County Adams County SE 1/4 SE 1/4 Sec 9 T. 15N N. R. 29E W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) 1400 LF N. of City Limits

(3) PROPOSED USE: ☐ Domestic ☐ Industrial ☐ Municipal ☒ ☐ Irrigation ☐ Test Well ☐ Other ☐ ☐ DeWater

(4) TYPE OF WORK: Owner's number of well (if more than one) #7
Abandoned ☐ New well ☒ Method: Dug ☐ Bored ☐ Deepened ☐ Cable ☐ Driven ☐ Reconditioned ☐ Rotary ☒ Jetted ☐

(5) DIMENSIONS: Diameter of well 16" inches. Drilled 820 feet. Depth of completed well 820 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 20" Diam. from 0 ft. to 386 ft.
Welded ☒ 16" Diam. from 380 ft. to 670 ft.
Liner installed ☐ " Diam. from ft. to ft.
Threaded ☐

Perforations: Yes ☐ No ☒
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes ☒ No ☐
Manufacturer's Name NAGAOKA
Type V Wire Model No.
Diam. 16 Slot size .050 from 670 ft. to 740 ft.
Diam. Slot size from 795 ft. to 815 ft.

Gravel packed: Yes ☐ No ☒ Size of gravel
Gravel placed from ft. to ft.

Surface seal: Yes ☒ No ☐ To what depth? 200 ft.
Material used in seal Neat Cement 13 Yds
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level ft.
Static level 125 ft. below top of well Date
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? Schnieder Equip.
Yield: 950 gal./min. with 245 ft. drawdown after 4 hrs.
" 1200 " 290 " 4 "
" " " " "
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test gal./min. with ft. drawdown after hrs.
Airtest 1000 gal./min. with stem set at 800 ft. for 4 hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? Yes ☐ No ☐

ECY 050-1-20 (6/93)

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION
Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Soil & Fill Material	0	4
Sediments, Brown - Gray	4	280
Clay, Some Black Basalt	280	300*
Basalt Black Hard	300	420
Basalt Fract Hard Black	420	450
Basalt Hard Black	450	490
Basalt Fract Black	490	520
Basalt Hard Black	520	600
Basalt Fract Black	600	610
Basalt Hard Black	610	680
Basalt Red - Black Vesic	680	730
Basalt Hard Black	730	800
Basalt Med Soft Black - Red	800	810
Basalt Hard Black	810	820

RECEIVED
MAR 09 2000
DEPARTMENT OF ECOLOGY

Work Started 12-7-97 19 Completed 5-30-98 19

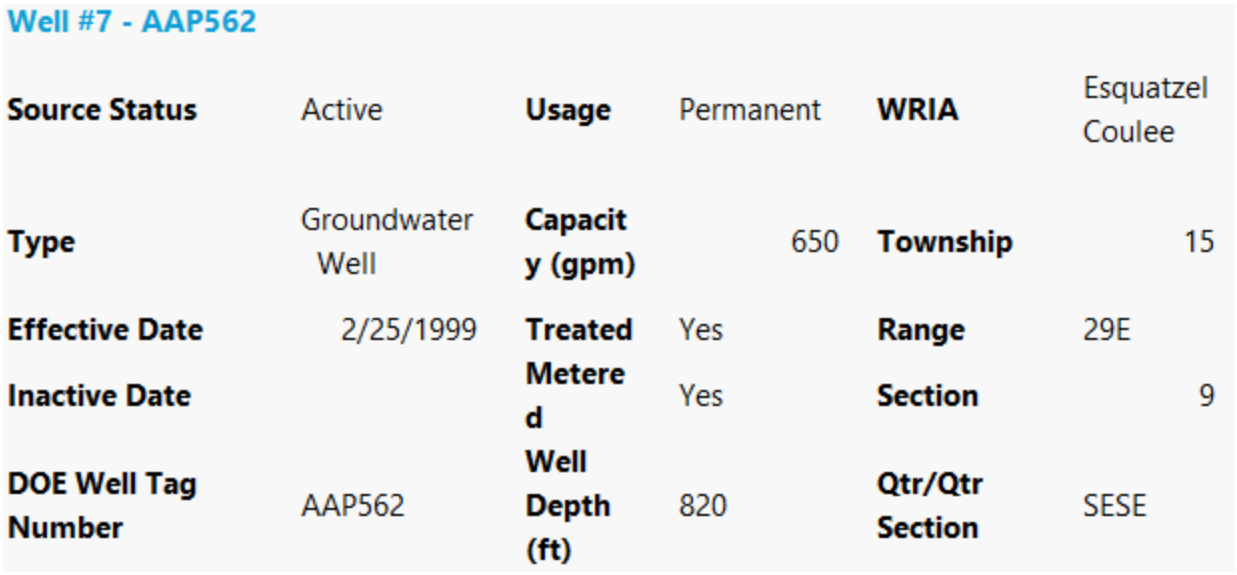
WELL CONSTRUCTOR CERTIFICATION:
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME STACO Well Services, Inc. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 220 Academy Street Mt. Angle OR 97362
(Signed) (WELL DRILLER) License No. 0859
Contractor's Registration No. STACO WS 131OH Date 5-30 19 98

(USE ADDITIONAL SHEETS IF NECESSARY)

Ecology is an Equal Opportunity and Affirmative Action employer. For special accommodation needs, contact the Water Resources Program at (206) 407-6600. The TDD number is (206) 407-6006.

Figure C9-2. Othello Well 7. Well ID: AAP 562. Well log (1998).



Well #7 - AAP562

Source Status	Active	**Usage**	Permanent	**WRIA**	Esquatzel Coulee
Type	Groundwater Well	**Capacity (gpm)**	650	**Township**	15
Effective Date	2/25/1999	**Treated**	Yes	**Range**	29E
Inactive Date		**Metered**	Yes	**Section**	9
DOE Well Tag Number	AAP562	**Well Depth (ft)**	820	**Qtr/Qtr Section**	SESE

Figure C9-3. Othello Well 7. Well ID: AAP 562. Viewer (https://appswr.ecology.wa.gov/WellConstruction/Map/WCLSWebMap)

C-10. Othello Well 8: Ecology Well ID AAS228



Figure C10-1. Othello Well #8. Photos taken during June 9, 2025, project field trip.

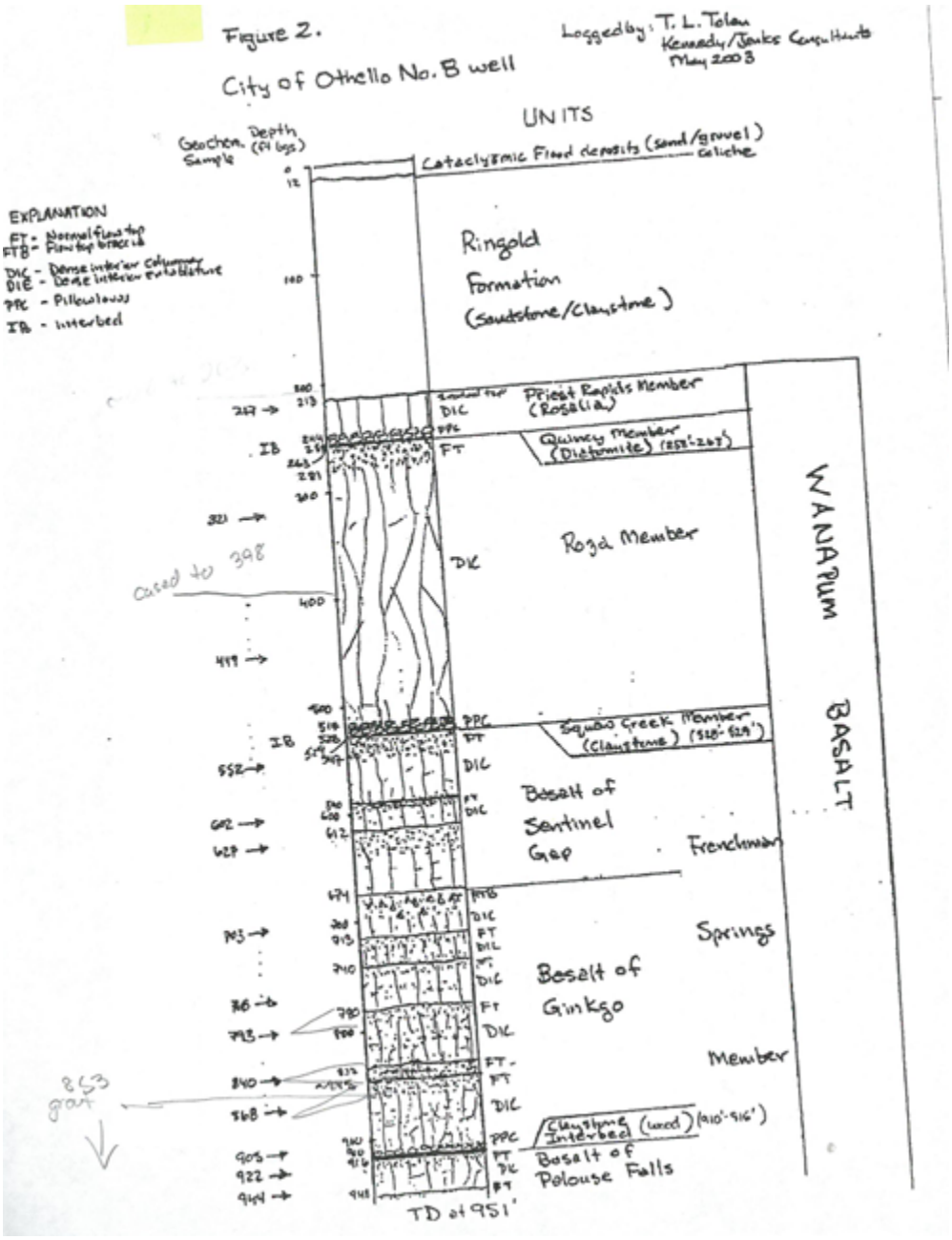
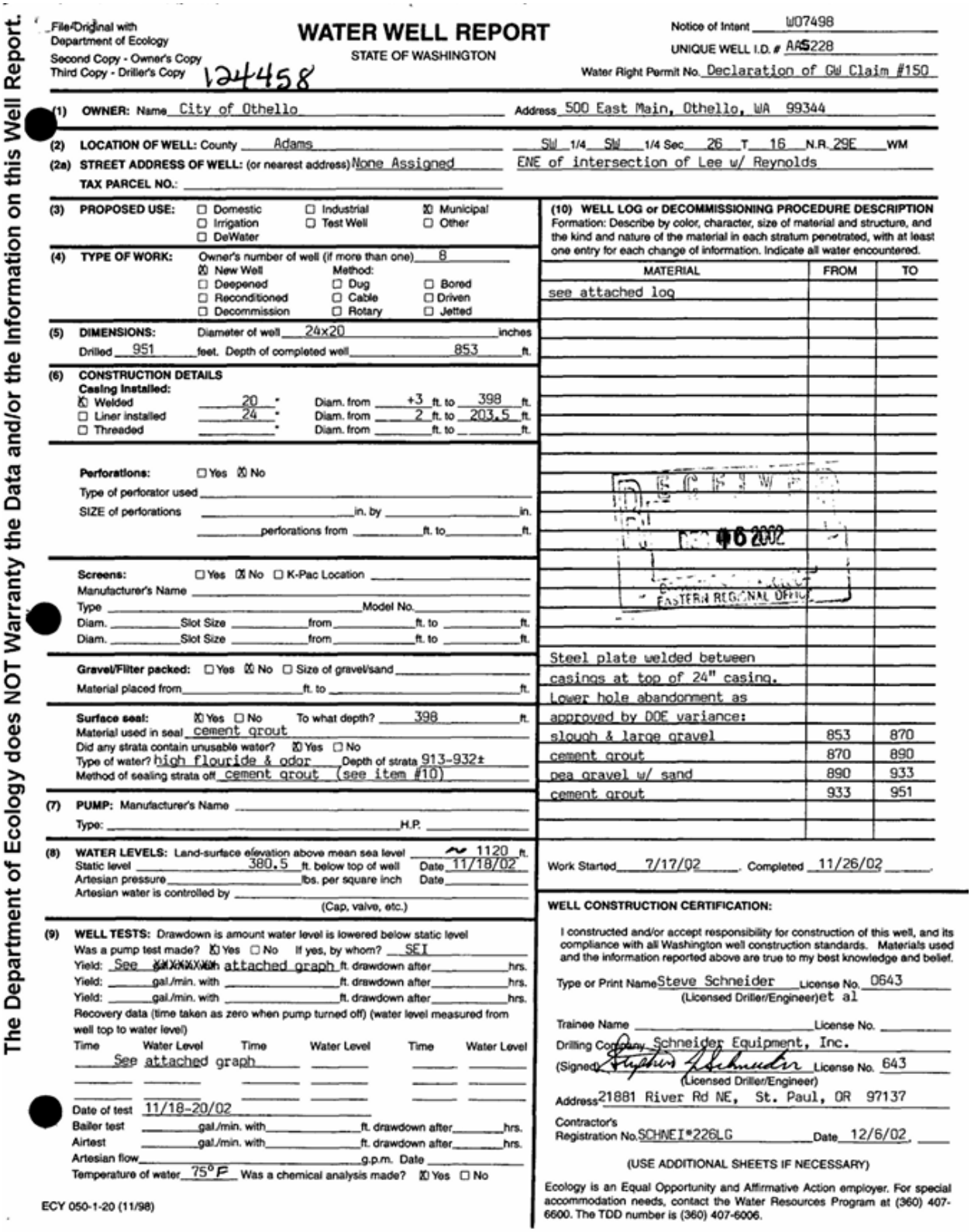


Figure C10-2. Othello Well #8. Well ID: AAS228. Well log (2003).



The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

File Original with Department of Ecology
Second Copy - Owner's Copy
Third Copy - Driller's Copy 124458

WATER WELL REPORT
STATE OF WASHINGTON

Notice of Intent W07498
UNIQUE WELL I.D. # AAS228
Water Right Permit No. Declaration of GW Claim #150

(1) OWNER: Name City of Othello Address 500 East Main, Othello, WA 99344

(2) LOCATION OF WELL: County Adams SW 1/4 SW 1/4 Sec 26 T 16 N.R. 29E WM
(2a) STREET ADDRESS OF WELL: (or nearest address) None Assigned ENE of intersection of Lee w/ Reynolds
TAX PARCEL NO.:

(3) PROPOSED USE: ☐ Domestic ☐ Industrial ☒ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐ DeWater

(4) TYPE OF WORK: Owner's number of well (if more than one) 8
☒ New Well Method: ☐ Dug ☐ Bored ☐ Deepened ☐ Cable ☐ Driven ☐ Reconditioned ☐ Rotary ☐ Jetted ☐ Decommission

(5) DIMENSIONS: Diameter of well 24x20 inches
Drilled 951 feet. Depth of completed well 853 ft.

(6) CONSTRUCTION DETAILS
Casing Installed:
☒ Welded 20 " Diam. from +3 ft. to 398 ft.
☐ Liner installed 24 " Diam. from 2 ft. to 203.5 ft.
☐ Threaded " Diam. from ft. to ft.

Perforations: ☐ Yes ☒ No
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.

Screens: ☐ Yes ☒ No ☐ K-Pac Location
Manufacturer's Name
Type Model No.
Diam. Slot Size from ft. to ft.
Diam. Slot Size from ft. to ft.

Gravel/Filter packed: ☐ Yes ☒ No ☐ Size of gravel/sand
Material placed from ft. to ft.

Surface seal: ☒ Yes ☐ No To what depth? 398 ft.
Material used in seal cement grout
Did any strata contain unusable water? ☒ Yes ☐ No
Type of water? high flouride & odor Depth of strata 913-932±
Method of sealing strata off cement grout (see item #10)

(7) PUMP: Manufacturer's Name
Type: H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level ~1120 ft.
Static level 380.5 ft. below top of well Date 11/18/02
Artesian pressure lbs. per square inch Date
Artesian water is controlled by (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☒ Yes ☐ No If yes, by whom? SEI
Yield: See attached graph gal./min. with ft. drawdown after hrs.
Yield: gal./min. with ft. drawdown after hrs.
Yield: gal./min. with ft. drawdown after hrs.
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
See attached graph					

Date of test 11/18-20/02
Bailer test gal./min. with ft. drawdown after hrs.
Airtest gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m. Date
Temperature of water 75° F Was a chemical analysis made? ☒ Yes ☐ No

ECY 050-1-20 (11/98)

(10) WELL LOG or DECOMMISSIONING PROCEDURE DESCRIPTION
Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. Indicate all water encountered.

MATERIAL	FROM	TO
see attached log		
Steel plate welded between casings at top of 24" casing. Lower hole abandonment as approved by DOE variance:		
slough & large gravel	853	870
cement grout	870	890
pea gravel w/ sand	890	933
cement grout	933	951

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Work Started 7/17/02 Completed 11/26/02

WELL CONSTRUCTION CERTIFICATION:
I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

Type or Print Name Steve Schneider License No. 0643
(Licensed Driller/Engineer) et al
Trainee Name License No.
Drilling Company Schneider Equipment, Inc.
(Signed) Stephen Schneider License No. 643
(Licensed Driller/Engineer)
Address 21881 River Rd NE, St. Paul, OR 97137
Contractor's Registration No. SCHNEI*226LG Date 12/6/02

(USE ADDITIONAL SHEETS IF NECESSARY)

Ecology is an Equal Opportunity and Affirmative Action employer. For special accommodation needs, contact the Water Resources Program at (360) 407-6600. The TDD number is (360) 407-6006.

Figure C10-3. Othello Well #8. Well ID: AAS228. Well log (2002).

The Dep The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

124458

City of Othello Well No 8

by Schneider Drilling Co

Start Card #W07498 Label #AAS228

FM	TO	DESCRIPTION
0	4	Sandy loam
4	7	Sandy loam & gravel w/ cobbles
7	12	Cobbles, gravel, & claystone, pink (caliche)
12	28	Claystone, pink, soft & gravel, brown w/ cobbles
28	68	Claystone, pink & gravel, cobbles & occasional boulder
68	108	Claystone, grey & pink, soft
108	120	Clay, tan - brown, sticky, medium
120	140	Sandstone, brown, medium, weathered & clay, tan
140	160	Sandstone, brown, medium, weathered
160	165	Sandstone, brown & clay, grey, sticky
165	200	Clay, grey, soft-medium
200	213	Clay, tan - grey, stcky, medium
213	216	Basalt, black, medium, fractured
216	243	Basalt, grey, hard, fractured
243	244	Basalt, brown, medium, fractured
244	248	Basalt, brown, medium, broken
248	252	Basalt, brown, soft, vesicular, broken w/ claystone, yellow
252	258	Basalt, brown & grey, medium, well fractured
258	281	Basalt, brown, soft, vesicular, broken w/ claystone, yellow
281	437	Basalt, grey, hard, some fractures
437	444	Basalt, black, hard, fractured, w/ trace of clay, green
444	517	Basalt, black turning to grey w/ depth, very hard, fractured
517	528	Basalt, black, hard, fractured
528	529	Clay & sandstone, brown & tan & basalt, black, medium-soft
529	569	Basalt, black, soft, broken, vesicular (blue-green in vesicles)
569	592	Basalt, black, hard, some fractures
592	593	Basalt, black, soft, fractured
593	602	Basalt, black, soft, broken, fractured, vesicular
602	612	Basalt, dark grey, medium, fractured

Figure C10-4. Othello Well #8. Well ID: AAS228. Well report (2002). Page 1 of 2.

The Dep The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report.

612	619	Basalt, black, medium-soft, fractured, vesicular w/ some claystone, green
619	640	Basalt, grey, medium-hard, fractured
640	670	Basalt, black, medium-soft, broken w/ some claystone, green
670	674	Basalt, dark grey, hard fractured
674	683	Basalt, black w/some brown, medium, fractured, vesicular w/some claystone, green
683	687	Basalt, dark grey w/pink & green tints, soft, cindery, vesicular
687	695	Basalt, dark grey, medium, some fractures
695	697	Basalt, dark grey, medium, fractured
697	700	Basalt, dark grey, medium, fractured, w/ claystone, green
700	708	Basalt, dark grey, medium, fractured, w/ claystone, blue-green
708	723	Basalt, dark grey, medium-hard, fractured
723	739	Basalt, dark grey, medium, fractured w/vesicles
739	743	Basalt, dark grey, hard-medium, fractured
743	761	Basalt, dark grey, medium, fractured, w/ vesicles
761	763	Basalt, dark grey, medium-hard, fractured
763	780	Basalt, dark grey, hard, some fractures
780	798	Basalt, black, medium, fractured, vesicular
798	833	Basalt, dark grey, hard, some fractures
833	838	Basalt, dark grey, medium, some fractures w/occasional vesicles
838	839	Basalt, dark grey, hard, fractured w/occasional vesicles
839	840	Basalt, dark grey, medium, some fractures w/occasional vesicles & claystone, green
840	844	Basalt, dark grey, medium, some fractures w/occasional vesicles
844	858	Basalt, dark grey, medium, some fractures
858	905	Basalt, dark grey, hard, very few fractures
905	910	Basalt, black, medium, fractured
910	914	Basalt, black, soft, fractured, vesicular w/claystone, green & grey
914	915	Clay, green w/some basalt, dark grey
915	932	Basalt, dark grey, soft, fractured w/claystone, green
932	937	Basalt, grey, medium, fractured w/claystone, green
937	948	Basalt, dark grey, medium, fractured w/claystone, green
948	951	Basalt, grey, hard, some fractures

Figure C10-5. Othello Well #8. Well ID: AAS228. Well report (2002). Page 2 of 2.

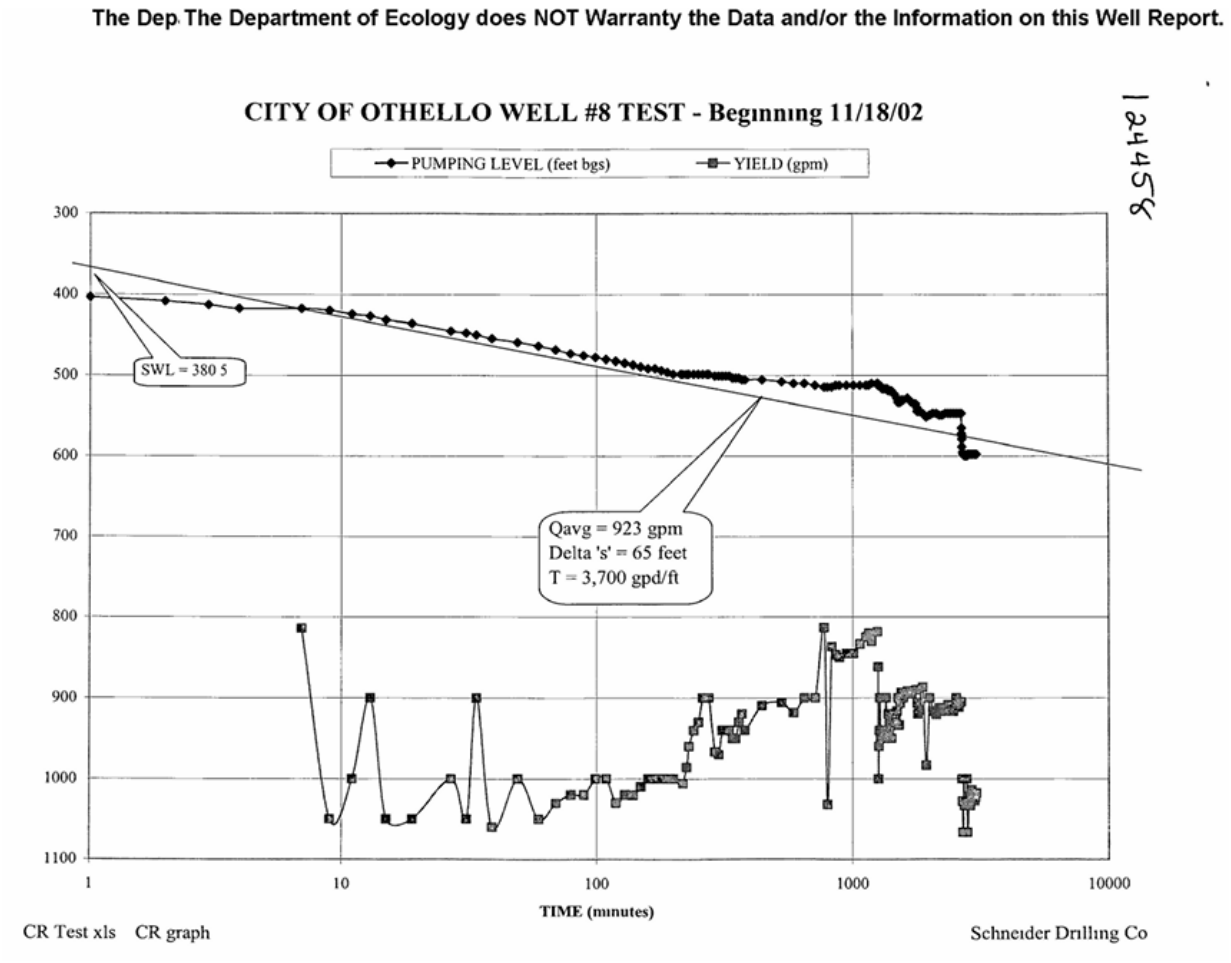


Figure C10-6. Othello Well #8. Well ID: AAS228. Well test (2002).

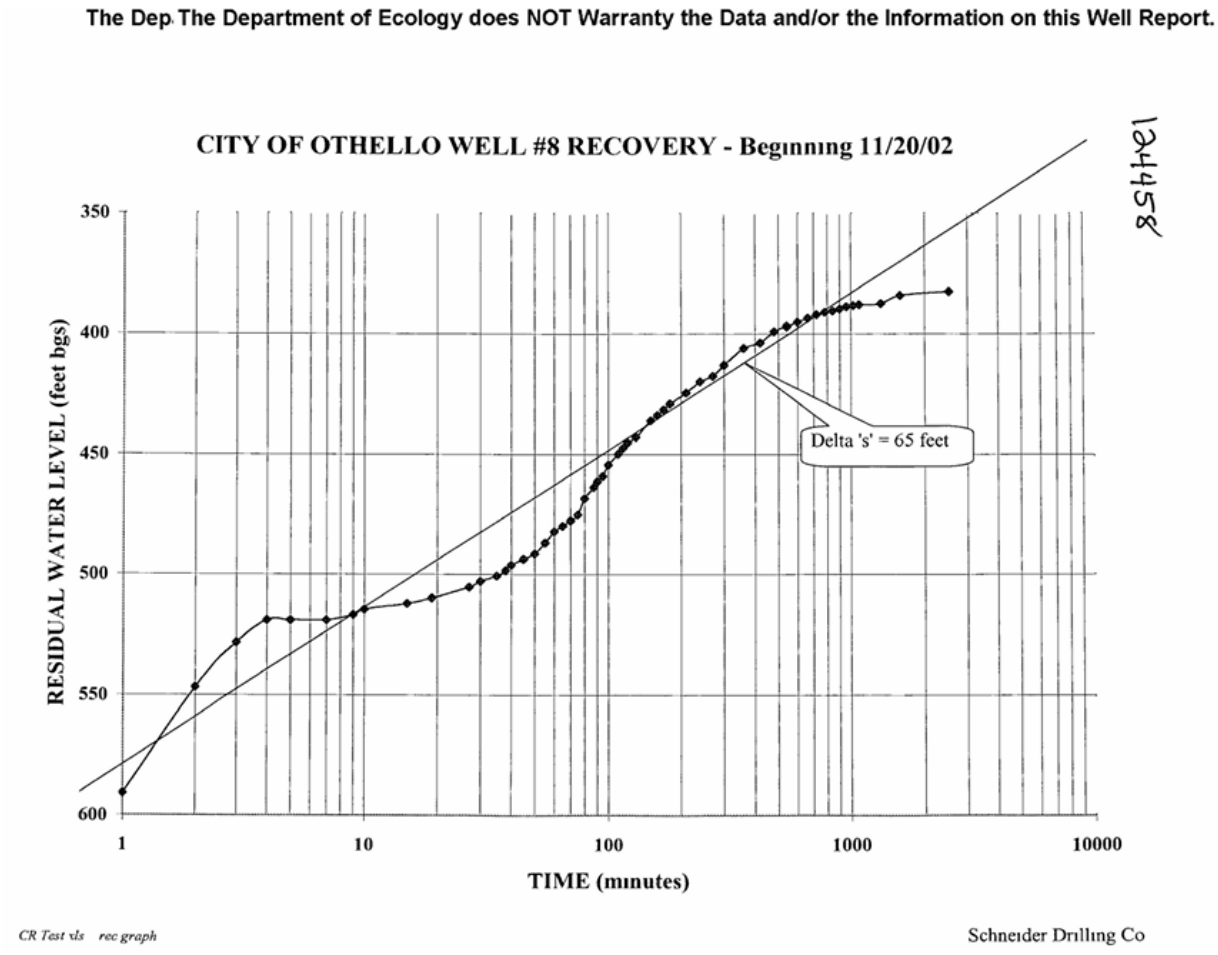


Figure C10-6. Othello Well #8. Well ID: AAS228. Well recovery report (2002).

Well #8 - AAS228

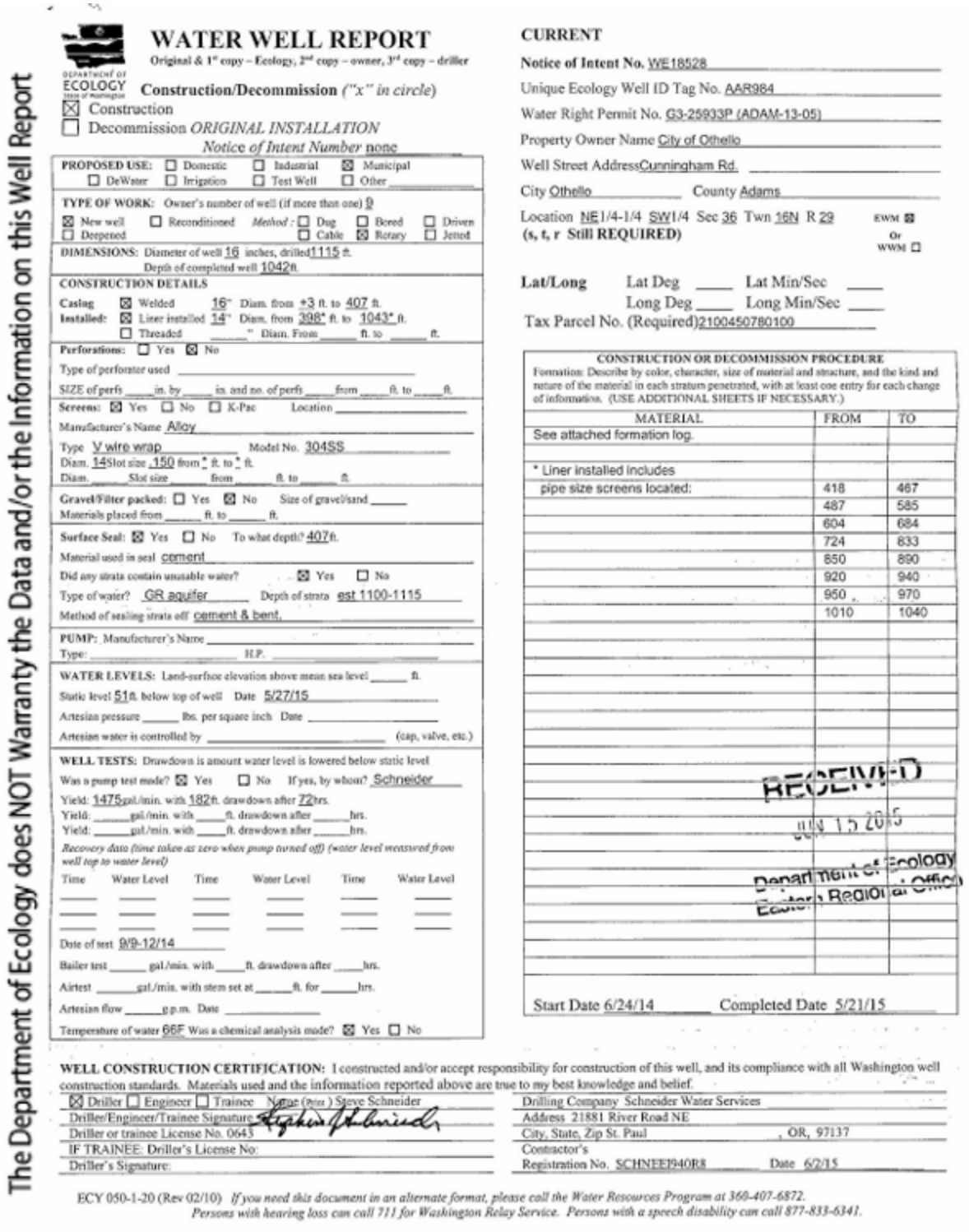
Source Status	Active	**Usage**	Permanent	**WRIA**	Lower Crab
Type	Groundwater Well	**Capacity (gpm)**	500	**Township**	18
Effective Date	8/26/2003	**Treated**	Yes	**Range**	29E
Inactive Date		**Metered**	Yes	**Section**	26
DOE Well Tag Number	AAS228	**Well Depth (ft)**	853	**Qtr/Qtr Section**	SWSW

Figure C10-7. Othello Well #8. Location information from Washington State Well Report viewer (https://appswr.ecology.wa.gov/WellConstruction/Map/WCLSWebMap)

C-11. Othello Well 9: Ecology Well ID AAR984



Figure C11-1. Othello Well #9. Photos taken during June 9, 2025, project field trip.



The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report

WATER WELL REPORT

Original & 1st copy – Ecology, 2nd copy – owner, 3rd copy – driller

DEPARTMENT OF ECOLOGY State of Washington

Construction/Decommission *("x" in circle)*

☒ Construction

☐ Decommission *ORIGINAL INSTALLATION*

Notice of Intent Number none

PROPOSED USE: ☐ Domestic ☐ Industrial ☒ Municipal ☐ DeWater ☐ Irrigation ☐ Test Well ☐ Other

TYPE OF WORK: Owner's number of well (if more than one) 9

☒ New well ☐ Reconditioned *Method:* ☐ Dug ☐ Bored ☐ Driven ☐ Deepened ☐ Cable ☒ Rotary ☐ Jetted

DIMENSIONS: Diameter of well 16 inches, drilled 1115 ft. Depth of completed well 1042 ft.

CONSTRUCTION DETAILS

Casing Installed: ☒ Welded 16" Diam. from +3 ft. to 407 ft. ☒ Liner installed 14" Diam. from 398* ft. to 1043* ft. ☐ Threaded ____" Diam. From ____ ft. to ____ ft.

Perforations: ☐ Yes ☒ No

Type of perforator used ____

SIZE of perfs ____ in. by ____ in. and no. of perfs ____ from ____ ft. to ____ ft.

Screens: ☒ Yes ☐ No ☐ K-Pac Location ____

Manufacturer's Name Alloy

Type V wire wrap Model No. 304SS

Diam. 14 Slot size .150 from * ft. to * ft.

Diam. ____ Slot size ____ from ____ ft. to ____ ft.

Gravel/Filter packed: ☐ Yes ☒ No Size of gravel/sand ____

Materials placed from ____ ft. to ____ ft.

Surface Seal: ☒ Yes ☐ No To what depth? 407 ft.

Material used in seal cement

Did any strata contain unstable water? ☒ Yes ☐ No

Type of water? GR aquifer Depth of strata est 1100-1115

Method of sealing strata off cement & bent.

PUMP: Manufacturer's Name ____

Type: ____ H.P. ____

WATER LEVELS: Land-surface elevation above mean sea level ____ ft.

Static level 51 ft. below top of well Date 5/27/15

Artesian pressure ____ lbs. per square inch Date ____

Artesian water is controlled by ____ (cap, valve, etc.)

WELL TESTS: Drawdown is amount water level is lowered below static level

Was a pump test made? ☒ Yes ☐ No If yes, by whom? Schneider

Yield: 1475 gal./min. with 182 ft. drawdown after 72 hrs.

Yield: ____ gal./min. with ____ ft. drawdown after ____ hrs.

Yield: ____ gal./min. with ____ ft. drawdown after ____ hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test 9/9-12/14

Bailer test ____ gal./min. with ____ ft. drawdown after ____ hrs.

Airtest ____ gal./min. with stem set at ____ ft. for ____ hrs.

Artesian flow ____ g.p.m. Date ____

Temperature of water 66F Was a chemical analysis made? ☒ Yes ☐ No

CURRENT

Notice of Intent No. WE18528

Unique Ecology Well ID Tag No. AAR984

Water Right Permit No. G3-25933P (ADAM-13-05)

Property Owner Name City of Othello

Well Street Address Cunningham Rd.

City Othello County Adams

Location NE 1/4-1/4 SW 1/4 Sec 36 Twn 16N R 29 EWM ☒ Or WWM ☐

(s, t, r Still REQUIRED)

Lat/Long Lat Deg ____ Lat Min/Sec ____ Long Deg ____ Long Min/Sec ____

Tax Parcel No. (Required) 2100450780100

CONSTRUCTION OR DECOMMISSION PROCEDURE

Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information. (USE ADDITIONAL SHEETS IF NECESSARY.)

MATERIAL	FROM	TO
See attached formation log.		
* Liner installed includes		
pipe size screens located:	418	467
	487	585
	604	684
	724	833
	850	890
	920	940
	950	970
	1010	1040

RECEIVED JUN 15 2015 Department of Ecology Eastern Regional Office

Start Date 6/24/14 Completed Date 5/21/15

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

☒ Driller ☐ Engineer ☐ Trainee Name (type) Steve Schneider

Driller/Engineer/Trainee Signature Stephen Schneider

Driller or trainee License No. 0643

IF TRAINEE: Driller's License No:

Driller's Signature:

Drilling Company Schneider Water Services

Address 21881 River Road NE

City, State, Zip St. Paul , OR, 97137

Contractor's Registration No. SCHNEEI940R8 Date 6/2/15

ECY 050-1-20 (Rev 02/10) *If you need this document in an alternate format, please call the Water Resources Program at 360-407-6872. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call 877-833-6341.*

Figure C11-2. Othello Well #9. Well log (2015).



The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report

CITY OF OTHELLO
Well No. 9 - Tag AAR984
Formation Log
by Schneider Water Services

FM	TO	DESCRIPTION
0	3	Top soil, brown
3	8	Sand, silty with some caliche
8	13	Caliche, tan, silty, soft-hard
13	21	Caliche, pink & tan, hard
21	33	Sand, brown, medium, cemented
33	35	Siltstone, tan, medium-hard
35	39	Siltstone, tan & yellow, medium-soft
39	52	Siltstone, tan & yellow, soft & some clay
52	72	Clay, tan, medium-soft & some soft siltstone lenses
72	85	Clay, tan, soft with some siltstone, grey, soft
85	91	Clay, grey, medium-soft
91	98	Clay, tan, soft
98	107	Siltstone, brown, medium-soft
107	117	Clay, tan, medium-soft
117	137	Siltstone, brown, medium-soft
137	146	Clay, tan, soft
146	166	Siltstone, brown & tan, medium-hard
166	174	Basalt, brown, weathered, medium-soft
174	178	Siltstone, dark brown, weathered, medium-hard
178	188	Basalt, brown & grey, medium, fractured
188	208	Basalt, grey with brown, hard-medium, fractured
208	213	Basalt, brown with black, soft-medium, fractured, vesicular & claystone, brown, soft-medium
213	220	Basalt, black, soft, very fractured, vesicular with claystone, brown
220	224	Claystone, tan, medium
224	234	Basalt, brown, soft-medium, fractured
234	244	Basalt, black & brown, very fractured, vesicular, soft & claystone, tan, soft
244	249	Basalt, black & grey, hard, some fractures
249	250	Claystone, tan & yellow, soft
250	268	Basalt, black & grey, hard, some fractures
268	271	Basalt, black & grey, hard, some fractures & claystone
271	415	Basalt, black & grey, hard, some fractures
415	422	Claystone, dark brown, hard
422	425	Basalt, grey, medium, broken, vesicular & some claystone, dark brown, hard
425	434	Basalt, grey, medium, broken, vesicular & some claystone, tan, hard
434	437	Basalt, grey, hard
437	440	Basalt, grey, hard, fractured & some quartz, brown & claystone, tan, hard
440	471	Basalt, black & grey with occasional brown, hard, some fractures
471	487	Basalt, grey, hard
487	490	Basalt, grey & brown, hard, fractured
490	493	Basalt, brown & black, medium, fractured, some vesicles & some claystone, green, medium
493	499	Basalt, dark grey, medium-hard, some fractures
499	502	Basalt, black, soft, vesicular
502	510	Basalt, dark grey, medium-hard, some fractures
510	518	Basalt, black, soft, vesicular w/claystone, black, medium
518	536	Basalt, dark grey, medium, fractured, some vesicles & some claystone, black, medium
536	542	Basalt, grey, hard, some fractures & some claystone, green, medium

Page 1 of 2

Figure C11-2. Othello Well #9. Well formation log (2015). Page 1 of 2.



The Department of Ecology does NOT Warranty the Data and/or the Information on this Well Report

CITY OF OTHELLO
Well No. 9 - Tag AAR984
Formation Log
by Schneider Water Services

FM	TO	DESCRIPTION
542	544	Basalt, black, medium, fractured, vesicular
544	550	Basalt, grey, medium-hard, vesicular, some fractures
550	555	Basalt, grey, medium, fractured & claystone, blue & brown, medium
555	565	Basalt, black & some grey, medium, fractured, vesicular
565	575	Basalt, dark grey, medium, some fractures
575	587	Basalt, black, medium, fractured, some vesicules
587	599	Basalt, grey, medium-hard
599	656	Basalt, dark grey, soft-medium, fractured, vesicular
656	660	Basalt, dark grey, medium-hard, fractured
660	668	Basalt, dark grey & black, medium, fractured, vesicular
668	688	Basalt, dark grey, medium-hard, some fractures & vesicles
688	696	Basalt, dark grey, hard, some fractures
696	713	Basalt, dark grey, medium-hard, fracutred w/some blue mineral
713	716	Basalt, brownish grey, medium, fractured w/claystone, grey, hard
716	732	Basalt, dark grey, hard, fractured
732	739	Basalt, dark grey & black, medium-hard, fractured, vesicular
739	741	Basalt, grey, hard, fractured, some vesicles
741	746	Basalt, grey, hard, some fractures & vesicles
746	749	Basalt, grey & brown, medium, vesicular, fractured & some claystone
749	772	Basalt, dark grey, medium-hard, fractured, vesicular & some claystone
772	793	Basalt, grey, very hard, some fractures
793	802	Basalt, dark grey, hard, fractured, vesicular, some claystone, blue
802	827	Basalt, grey, hard, fractured, vesicular
827	859	Basalt, grey, hard, some fractures
859	887	Basalt, black, soft, fractured, vesicular w/some claystone & clay, black
887	895	Basalt, grey, hard, some fractures
895	907	Basalt, grey, hard, some fractures & some clay, green, firm
907	920	Basalt, grey, hard, some fractures
920	940	Basalt, black, soft, fractured, vesicular w/claystone, black & blue, medium
940	951	Basalt, black, medium, fractured, some small vesicules
951	966	Basalt, grey, medium, fractured, vesicular
966	990	Basalt, grey, hard, some fractures
990	998	Basalt, dark grey, medium-hard, fractured
998	1013	Basalt, grey, hard, some fractures
1013	1019	Basalt, dark grey, medium, fractured, vesicular
1019	1037	Basalt, dark grey, medium-hard, fractured, vesicular
1037	1070	Basalt, grey, hard, some fractures
1070	1071	Basalt, grey, medium-hard, fractured w/some clear & blue mineral
1071	1074	Claystone, redish brown, medium, fractured, vesicular w/some clear & blue mineral
1074	1080	Basalt, brown, medium, fractured, veiscular w/some clear & blue mineral
1080	1083	Basalt, grey, medium-hard, fractured, vesicular w/blue mineral
1083	1089	Basalt, grey, medium-hard, fractured
1089	1092	Basalt, grey, hard, some fractures
1092	1094	Basalt, dark grey, medium-hard, fracutred
1094	1098	Basalt, grey, hard, some fractures
1098	1107	Basalt, dark grey, hard, fractured, vesicular
1107	1113	Basalt, dark grey, hard, some fractures
1113	1115	Basalt, dark grey, medium-hard, fractured, vesicular

Page 2 of 2

Figure C11-2. Othello Well #9. Well formation log (2015). Page 2 of 2.

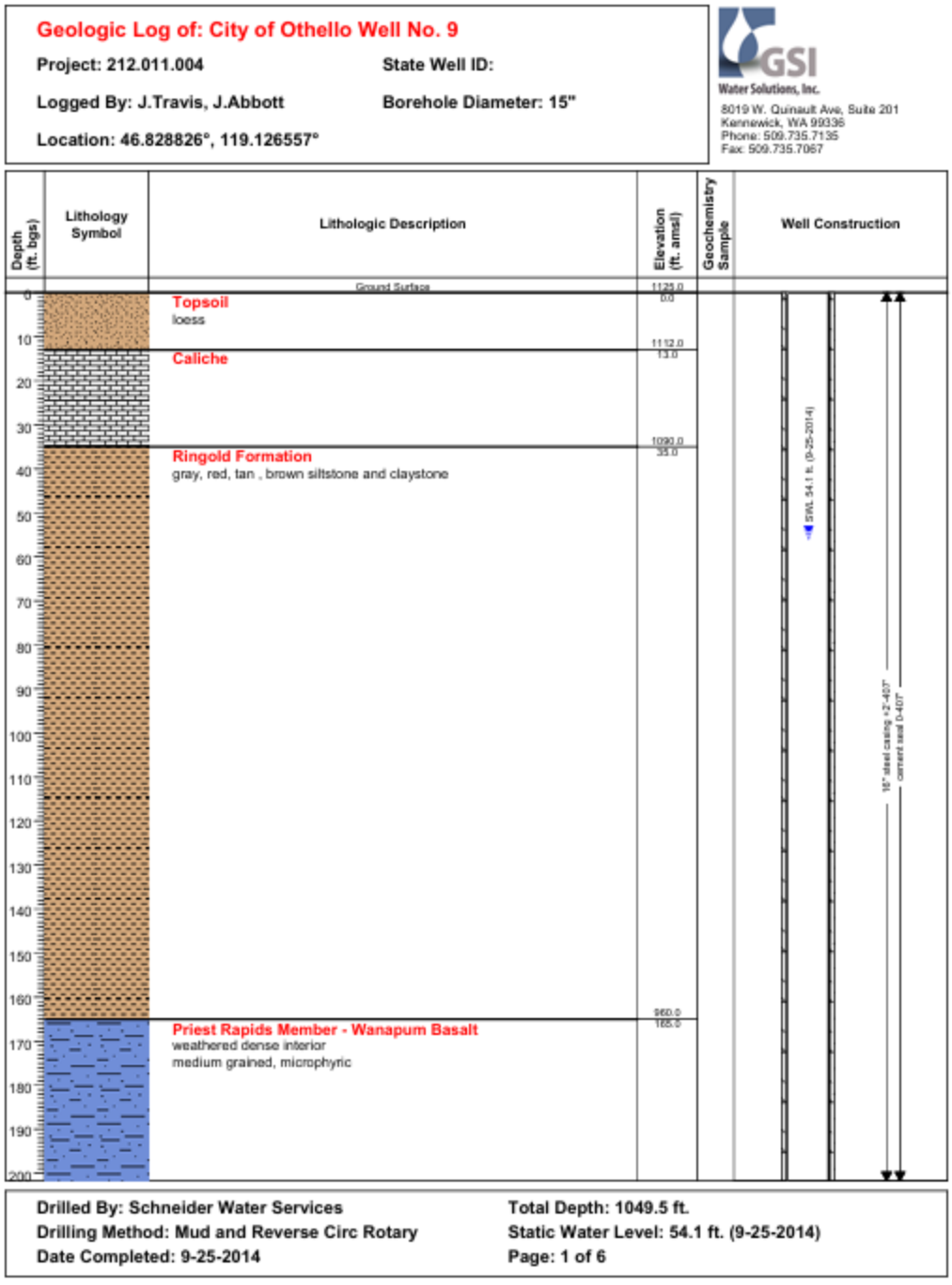


Figure C11-3. Othello Well #9. Geologic log (2014). Page 1 of 6.

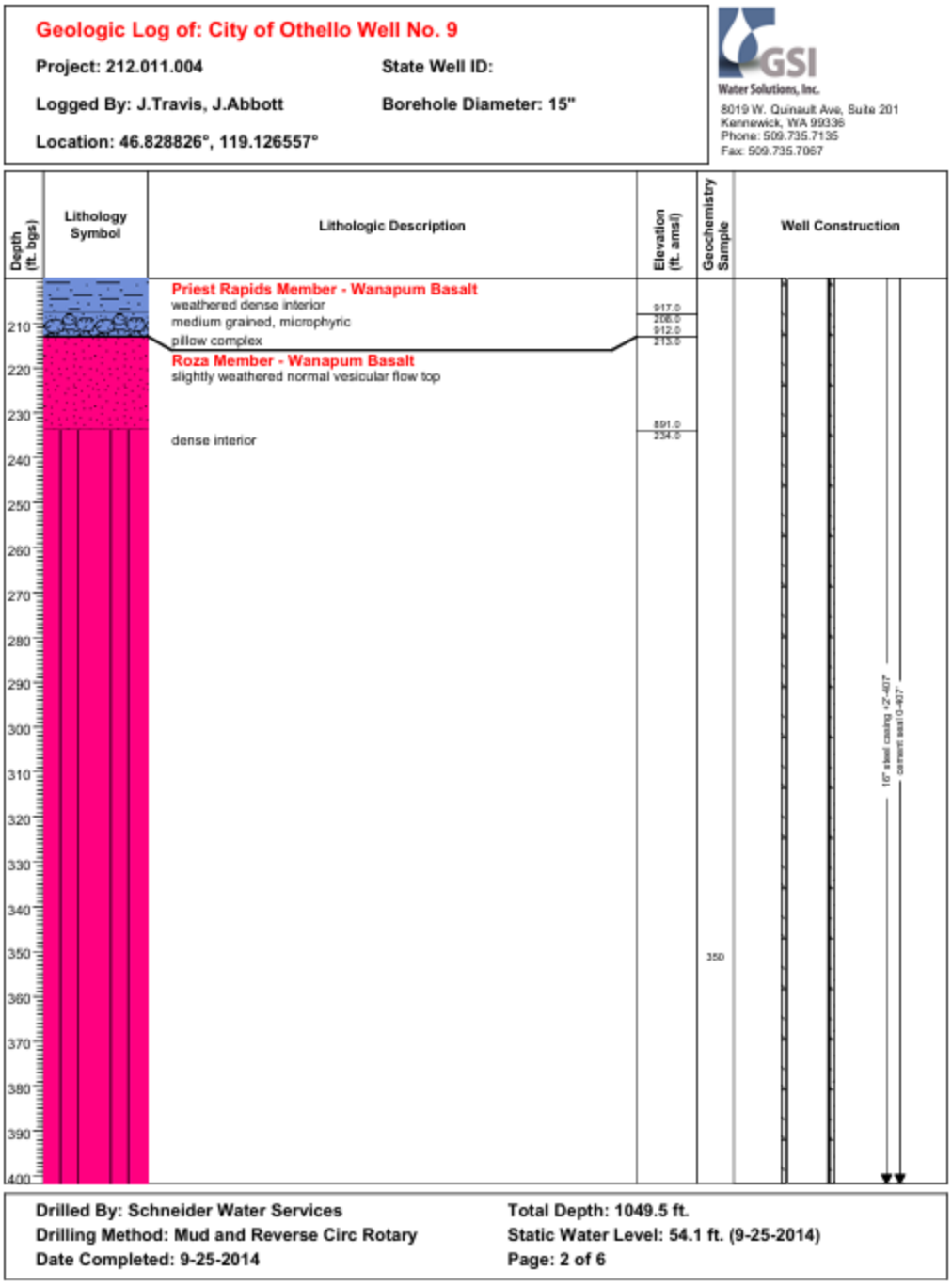


Figure C11-4. Othello Well #9. Geologic log (2014). Page 2 of 6.

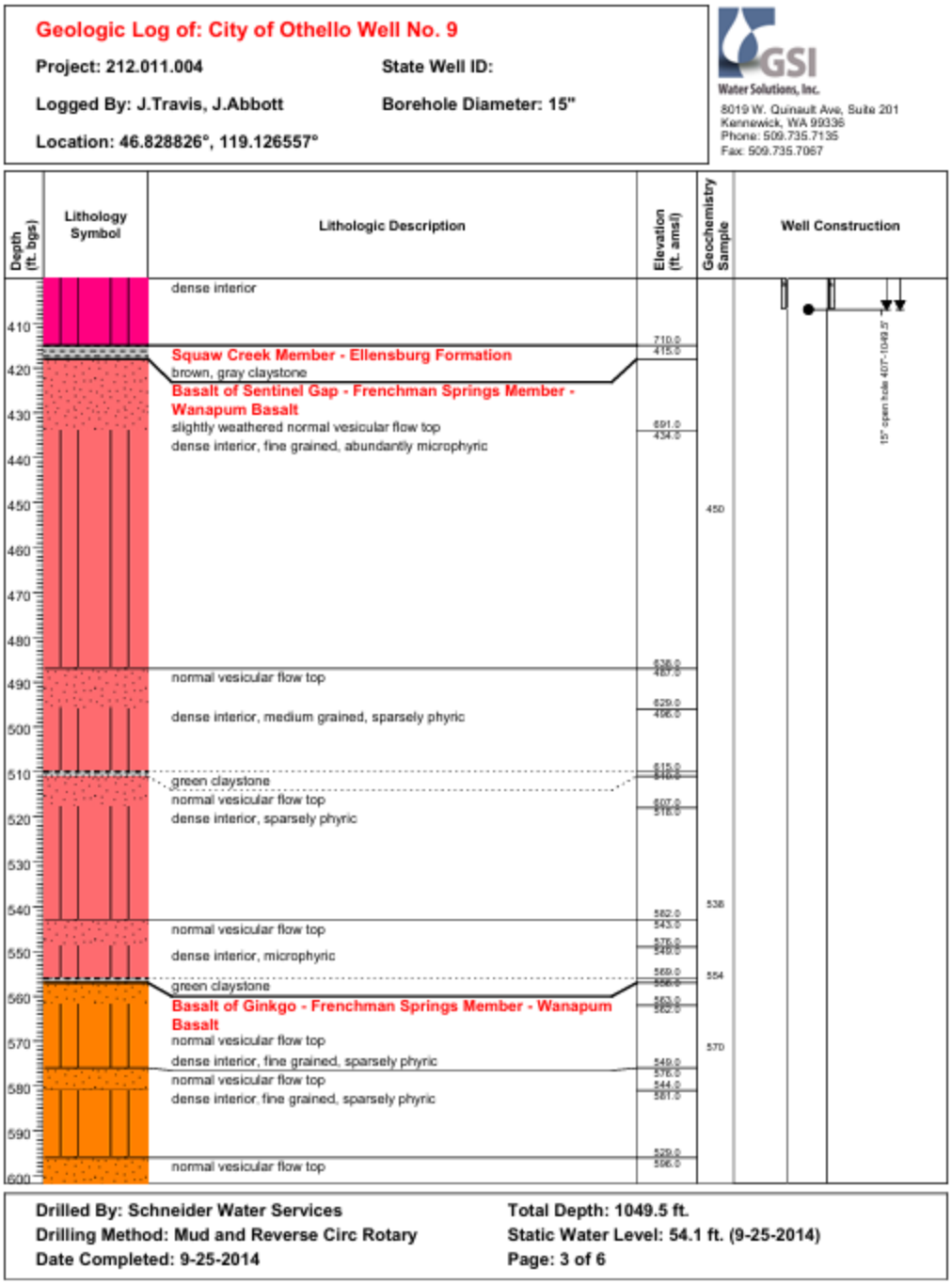


Figure C11-5. Othello Well #9. Geologic log (2014). Page 3 of 6.

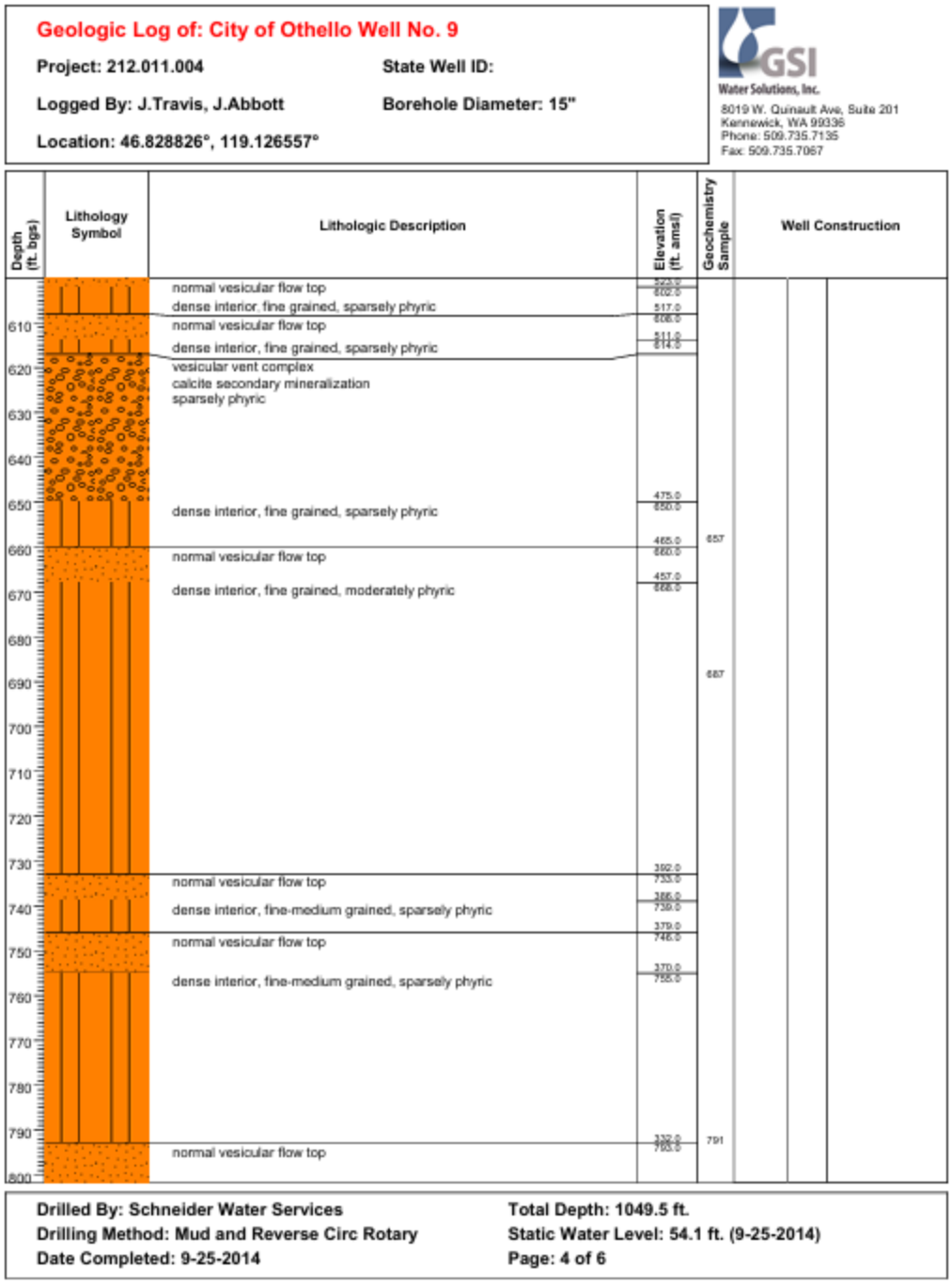


Figure C11-6. Othello Well #9. Geologic log (2014). Page 4 of 6.

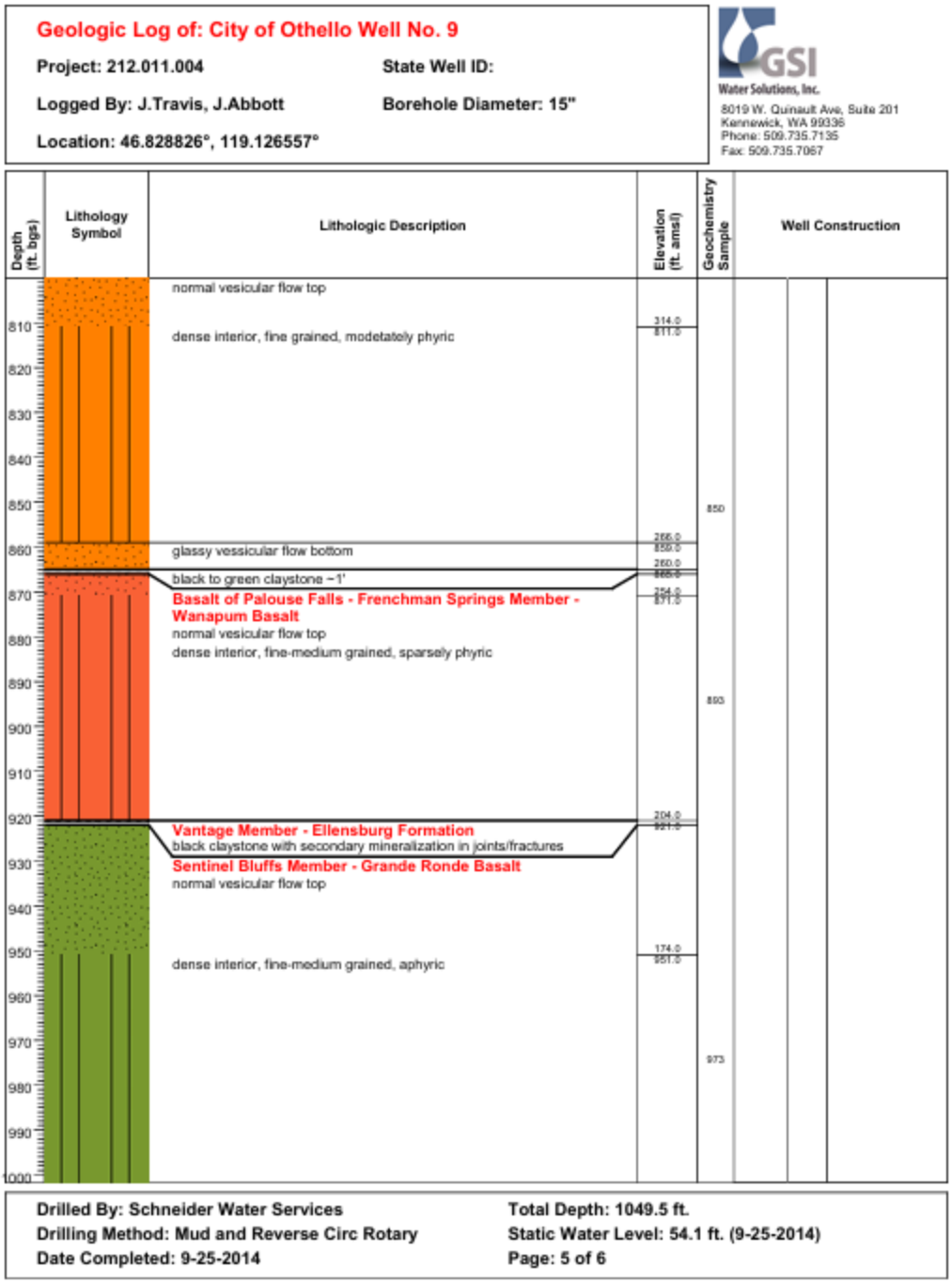


Figure C11-7. Othello Well #9. Geologic log (2014). Page 5 of 6.

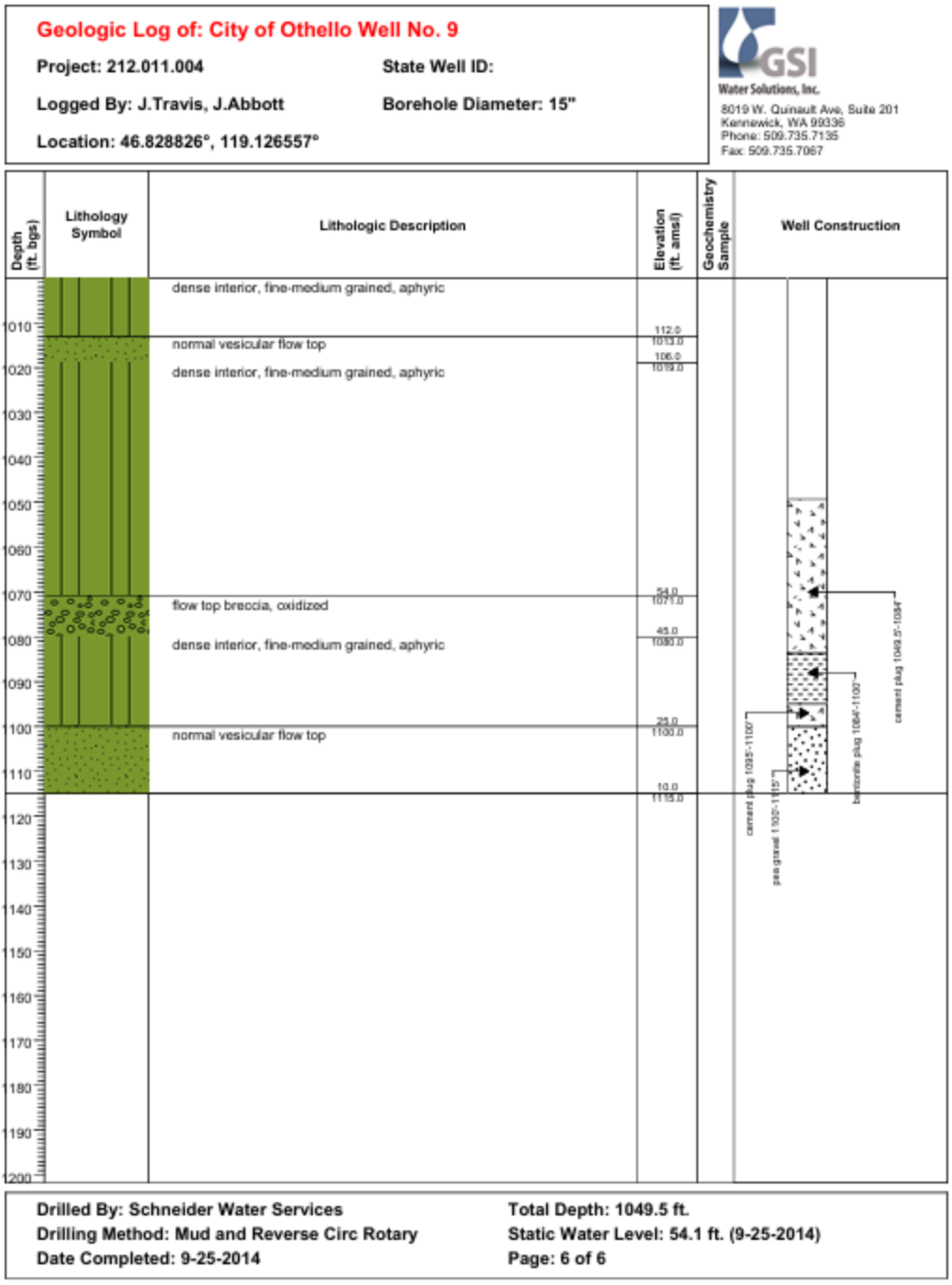
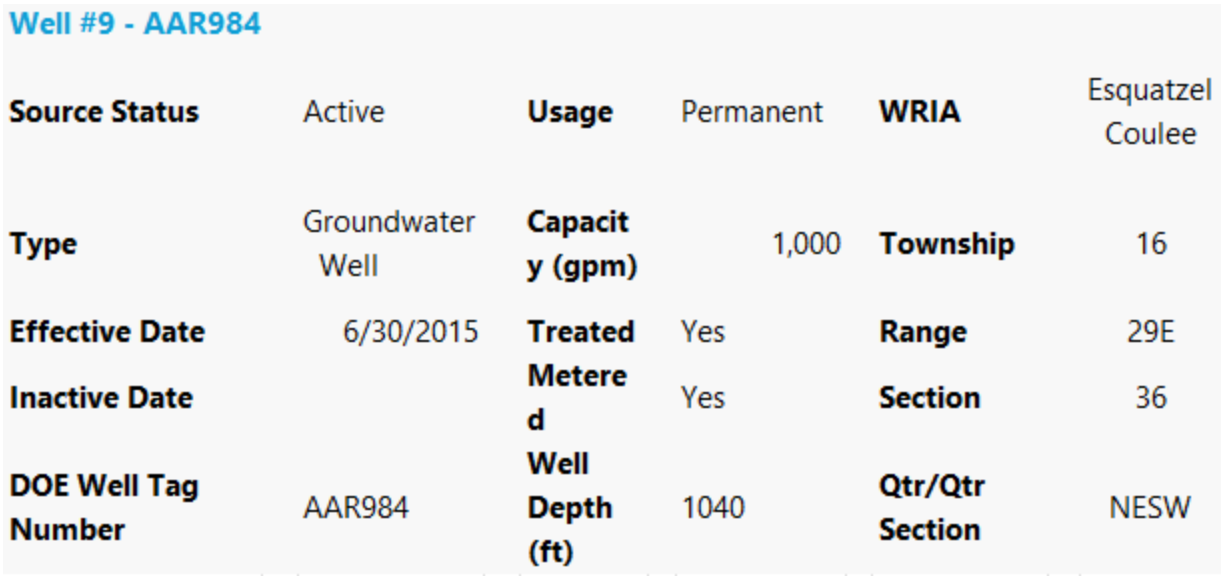


Figure C11-8. Othello Well #9. Geologic log (2014). Page 6 of 6.



Well #9 - AAR984

Source Status	Active	**Usage**	Permanent	**WRIA**	Esquatzel Coulee
Type	Groundwater Well	**Capacity (gpm)**	1,000	**Township**	16
Effective Date	6/30/2015	**Treated**	Yes	**Range**	29E
Inactive Date		**Metered**	Yes	**Section**	36
DOE Well Tag Number	AAR984	**Well Depth (ft)**	1040	**Qtr/Qtr Section**	NESW

Figure C11-9. Othello Well 7. Well ID: AAR 984. Viewer (https://appswr.ecology.wa.gov/WellConstruction/Map/WCLSWebMap)

C-12. Port of Othello Well 3: ALF727

Well Details	Location Details
Well Owner: **PORT OF OTHELLO**	Tax Parcel Number: 2630330120001
Well Tag ID: ALF727	Well Address: BRUCE RD
Notice of Intent Number: W210598	County: ADAMS
Group Number: Not Applicable	Public Land Survey: NE-NE / S33 / T16N / R30E
Well Report ID: 543533	Well Type: Water / Subtype: Unknown
Well Diameter: 16 in.	Well Completion Date: 01-03-2008
Well Depth: 960 ft.	Well Report Received Date: 05-12-2008

This is the most eastern well in cross section A-A' in the ASR Feasibility Study (Aspect, 2017; Figure C-1b).

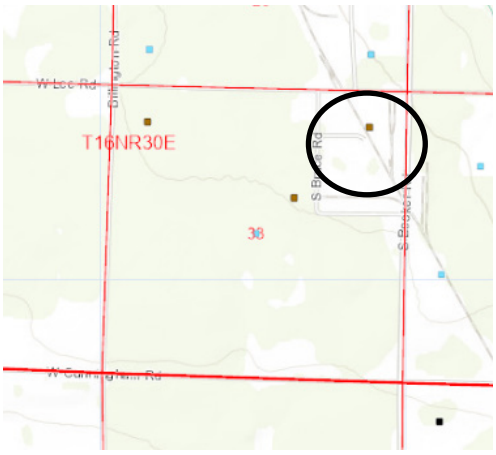
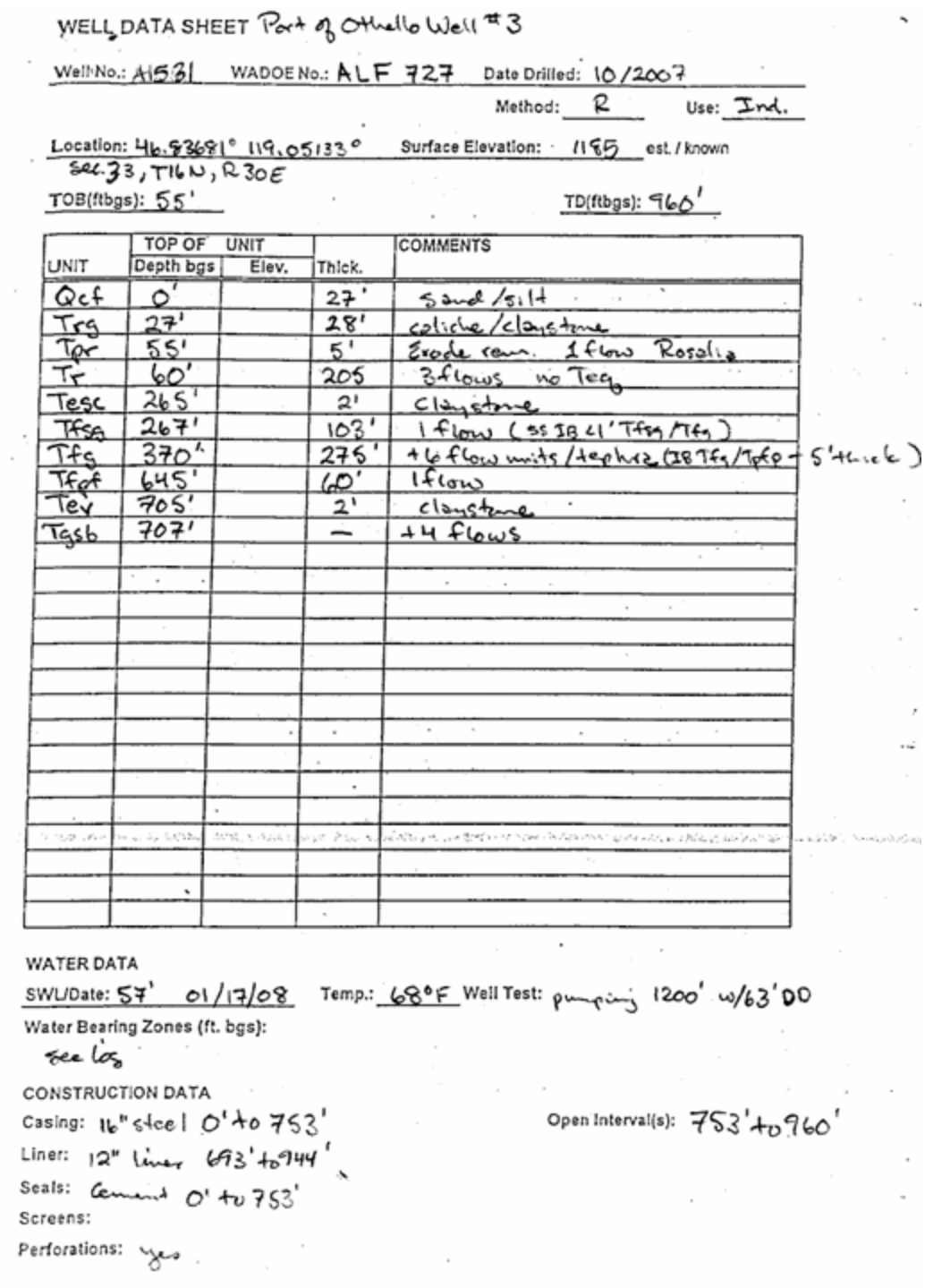


Figure C12-1. Port of Othello Well 3. Well ID: ALF 727. Viewer (https://appswr.ecology.wa.gov/WellConstruction/Map/WCLSWebMap)



WELL DATA SHEET Port of Othello Well #3

Well No.: A1531 WADOE No.: ALF 727 Date Drilled: 10/2007

Method: R Use: Ind.

Location: 46.83681° 119.05133° Surface Elevation: 1185 est. / known

Sec. 33, T16N, R30E

TOB(ftbgs): 55' TD(ftbgs): 960'

UNIT	TOP OF UNIT Depth bgs	Elev.	Thick.	COMMENTS
Qcf	0'		27'	sand/silt
Trg	27'		28'	caliche/claystone
Tpr	55'		5'	Frodo ranch. 1 flow Rosalia
Tr	60'		205	3 flows no Teq
Tesc	265'		2'	claystone
Tfsg	267'		103'	1 flow (35 IB 41' Tfsg/Tfg)
Tfg	370'		275'	+6 flow units/tephra (18 Tfg/Tfg + 5' thick)
Tfgf	645'		60'	1 flow
Tev	705'		2'	claystone
Tgsb	707'		—	+4 flows

WATER DATA

SWL/Date: 57' 01/17/08 Temp.: 68°F Well Test: pumping 1200' w/63'DD

Water Bearing Zones (ft. bgs):

see log

CONSTRUCTION DATA

Casing: 16" steel 0' to 753' Open Interval(s): 753' to 960'

Liner: 12" liner 693' to 944'

Seals: Cement 0' to 753'

Screens:

Perforations: yes

Figure C12-2. Port of Othello Well 3. Well ID: ALF 727. Well data sheet (2008).

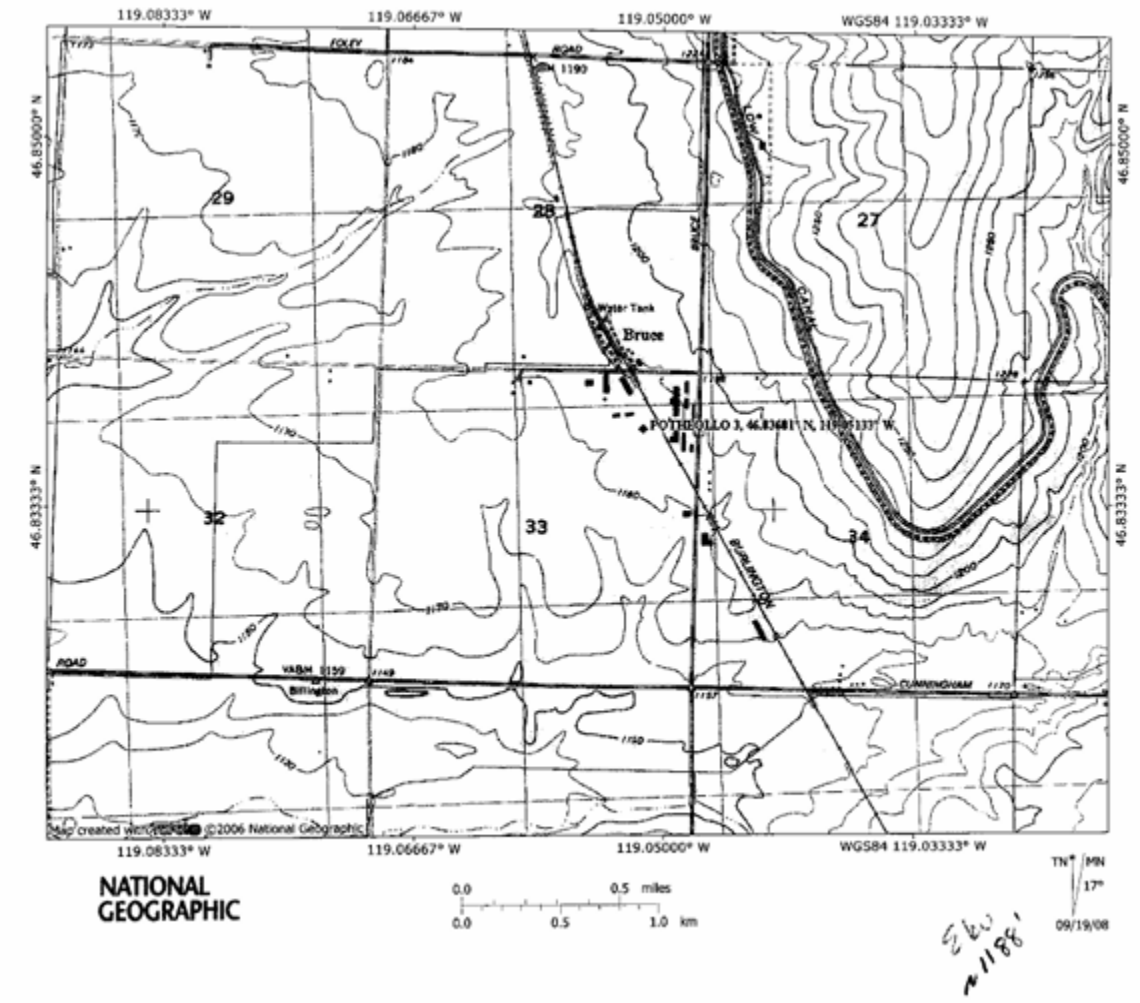
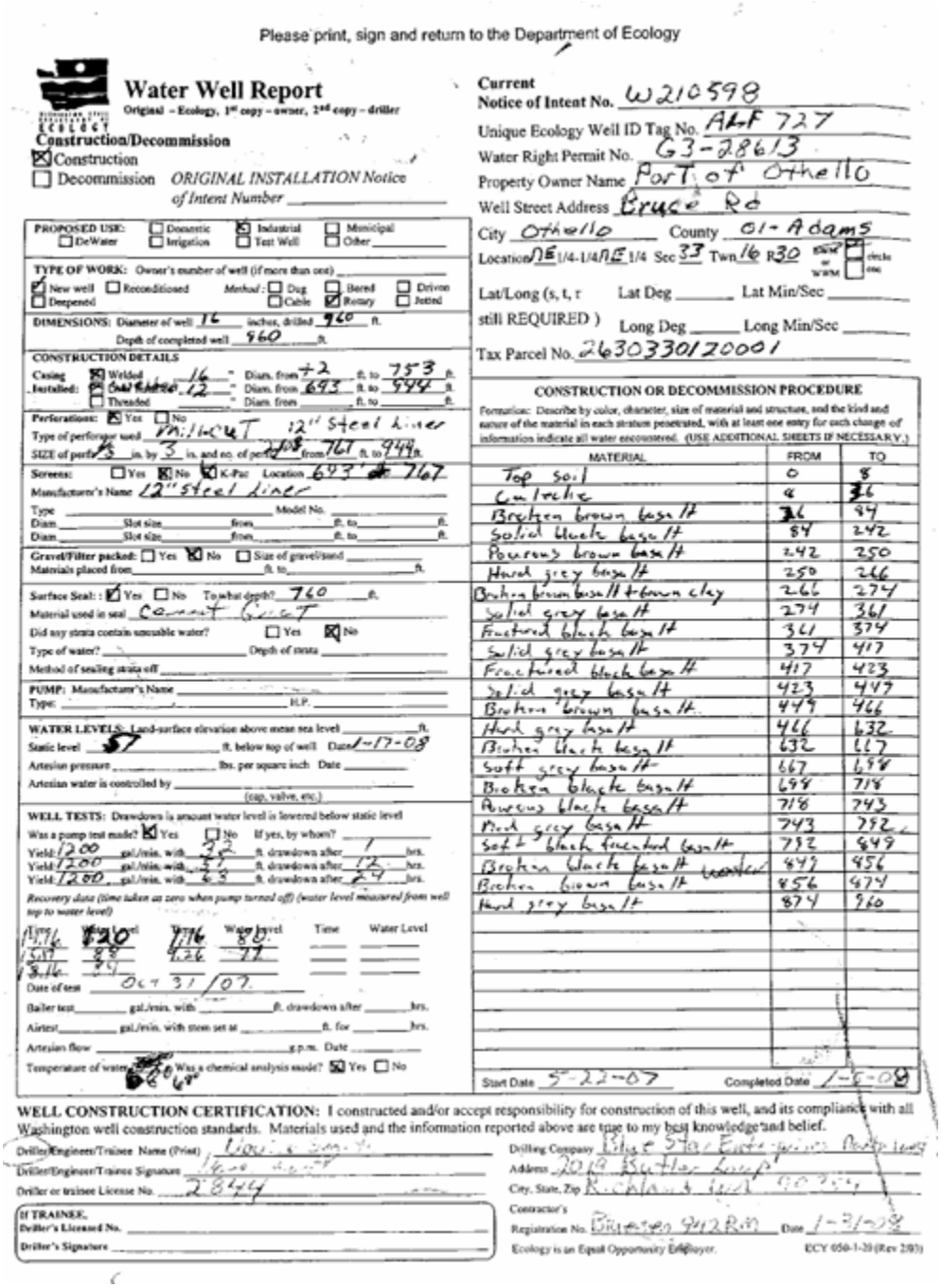


Figure C12-3. Port of Othello Well 3. Well ID: ALF 727. Well location (2008).



Please print, sign and return to the Department of Ecology

Water Well Report
Original – Ecology, 1st copy – owner, 2nd copy – driller

Construction/Decommission
☒ Construction
☐ Decommission ORIGINAL INSTALLATION Notice of Intent Number _____

Current Notice of Intent No. W210598
Unique Ecology Well ID Tag No. ALF 727
Water Right Permit No. G3-28613
Property Owner Name Port of Othello
Well Street Address Bruce Rd
City Othello County 01-Adams
Location NE 1/4-1/4 NE 1/4 Sec 33 Twn 16 R 30 E/W WM
Lat/Long (s, t, r still REQUIRED) Lat Deg _____ Lat Min/Sec _____ Long Deg _____ Long Min/Sec _____
Tax Parcel No. 263033012000 1

PROPOSED USE: ☐ Domestic ☒ Industrial ☐ Municipal ☐ DeWater ☐ Irrigation ☐ Test Well ☐ Other
TYPE OF WORK: Owner's number of well (if more than one) _____
☑ New well ☐ Reconditioned Method: ☐ Dug ☐ Bored ☐ Driven ☐ Deepened ☐ Cable ☑ Rotary ☐ Jetted
DIMENSIONS: Diameter of well 16 inches, drilled 960 ft. Depth of completed well 960 ft.
CONSTRUCTION DETAILS
Casing Installed: ☒ Welded 16" Diam. from +2 ft. to 753 ft. ☐ Threaded 12" Diam. from 693 ft. to 944 ft.
Perforations: ☒ Yes ☐ No Type of perforator used Mill cut 12" steel liner
SIZE of perf 3/8 in. by 3 in. and no. of perf 208 from 761 ft. to 944 ft.
Screens: ☐ Yes ☒ No ☒ K-Pac Location 693 to 767
Manufacturer's Name 12" steel liner
Type _____ Model No. _____
Diam. _____ Slot size _____ from _____ ft. to _____ ft.
Diam. _____ Slot size _____ from _____ ft. to _____ ft.
Gravel/Filter packed: ☐ Yes ☒ No ☐ Size of gravel/sand _____
Materials placed from _____ ft. to _____ ft.
Surface Seal: ☑ Yes ☐ No To what depth? 760 ft.
Material used in seal Cement Grout
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? _____ Depth of strata _____
Method of sealing strata off _____
PUMP: Manufacturer's Name _____ Type: _____ H.P. _____
WATER LEVELS: Land-surface elevation above mean sea level _____ ft.
Static level 57 ft. below top of well Date 1-17-08
Artesian pressure _____ lbs. per square inch Date _____
Artesian water is controlled by _____ (cap, valve, etc.)
WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☒ Yes ☐ No If yes, by whom? _____
Yield: 1200 gal./min. with 35 ft. drawdown after 1 hrs.
Yield: 1200 gal./min. with 43 ft. drawdown after 12 hrs.
Yield: 1200 gal./min. with 45 ft. drawdown after 24 hrs.
Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level
5:16	820	7:16	80		
5:17	89	4:26	77		
8:16	59				

Date of test Oct 31/07
Bailer test _____ gal./min. with _____ ft. drawdown after _____ hrs.
Airtest _____ gal./min. with stem set at _____ ft. for _____ hrs.
Artesian flow _____ g.p.m. Date _____
Temperature of water 68° Was a chemical analysis made? ☒ Yes ☐ No

CONSTRUCTION OR DECOMMISSION PROCEDURE
Formation: Describe by color, character, size of material and structure, and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information indicate all water encountered. (USE ADDITIONAL SHEETS IF NECESSARY.)

MATERIAL	FROM	TO
Top soil	0	8
Cobbles	8	36
Broken brown basalt	36	84
Solid black basalt	84	242
Porous brown basalt	242	250
Hard grey basalt	250	266
Broken brown basalt + brown clay	266	274
Solid grey basalt	274	361
Fractured black basalt	361	374
Solid grey basalt	374	417
Fractured black basalt	417	423
Solid grey basalt	423	449
Broken brown basalt	449	466
Hard grey basalt	466	632
Broken black basalt	632	667
Soft grey basalt	667	698
Broken black basalt	698	718
Porous black basalt	718	743
Med grey basalt	743	792
Soft black fractured basalt	792	849
Broken black basalt water	849	856
Broken brown basalt	856	874
Hard grey basalt	874	960

Start Date 5-22-07 Completed Date 1-5-08

WELL CONSTRUCTION CERTIFICATION: I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.
Driller/Engineer/Trainee Name (Print) _____
Driller/Engineer/Trainee Signature _____
Driller or trainee License No. 2844
Drilling Company Blue Star Enterprises, Northwest
Address 2019 Butler Loop
City, State, Zip Richland, WA 99352
Contractor's Registration No. BLUESE 942RM Date 1-7-08
IF TRAINEE, Driller's Licensed No. _____ Driller's Signature _____
Ecology is an Equal Opportunity Employer. ECY 050-1-20 (Rev 2/93)

Figure C12-4. Port of Othello Well 3. Well ID: ALF 727. Well log (2008).

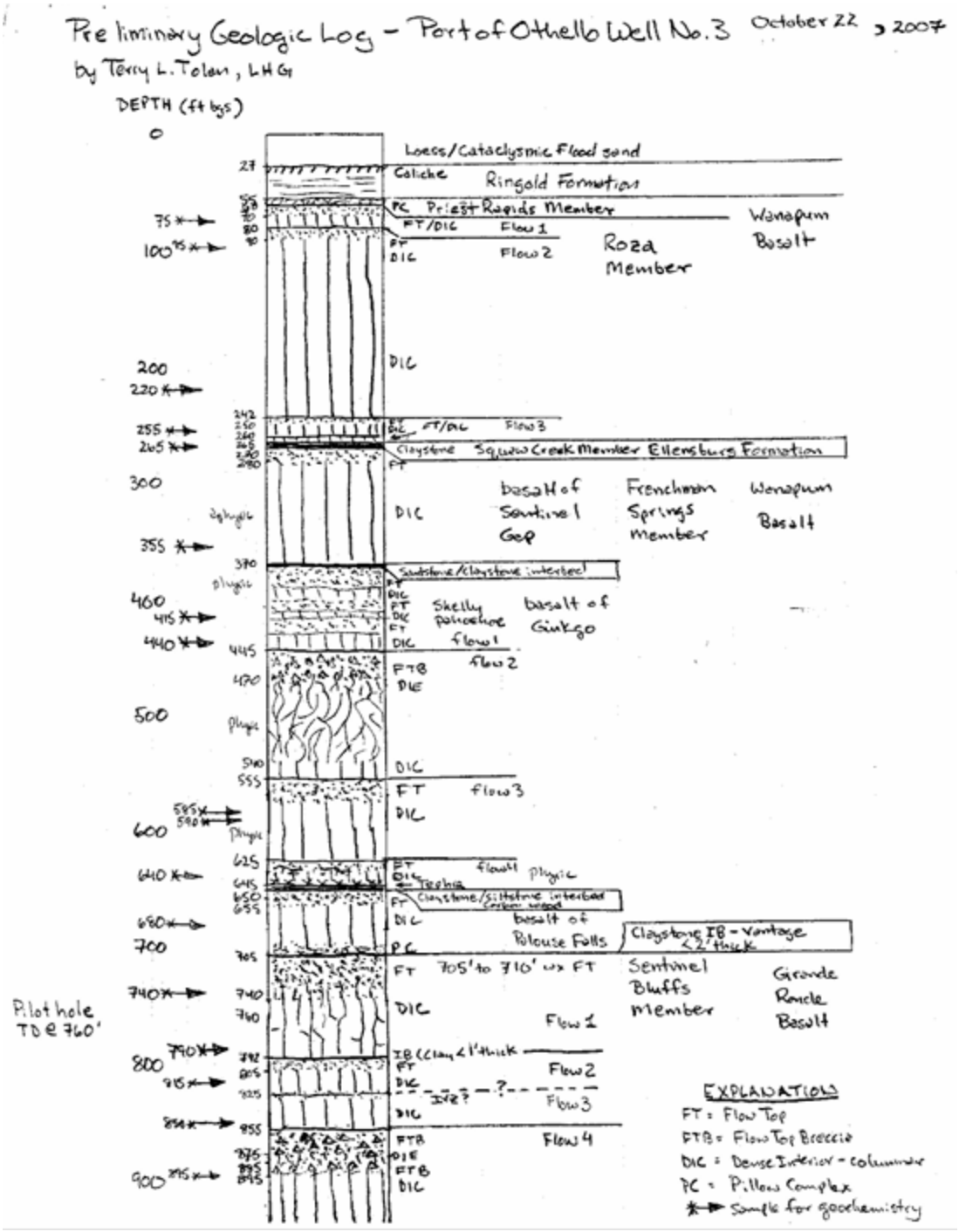


Figure C12-5. Port of Othello Well 3. Well ID: ALF 727. Geologic log (2007).

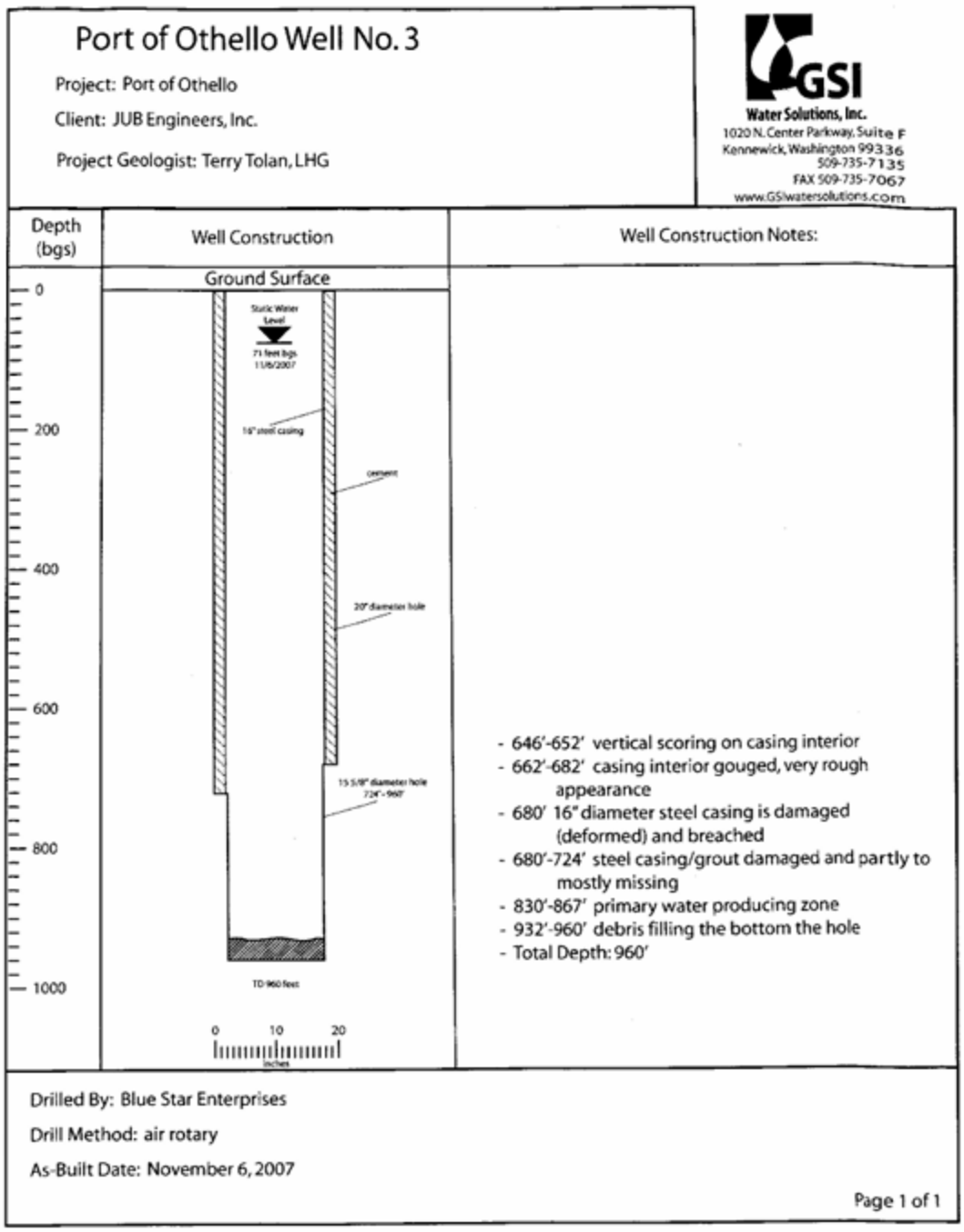


Figure C12-6. Port of Othello Well 3. Well ID: ALF 727. Well construction (2007).

16.4 Appendix D: Surface Water Sampling Locations



Figure D-1. a) Bridge near Well 8 crossing EL-68 facing north. Sampling will use a hose and a pump from the bridge into the canal. B) EL-68 facing south.

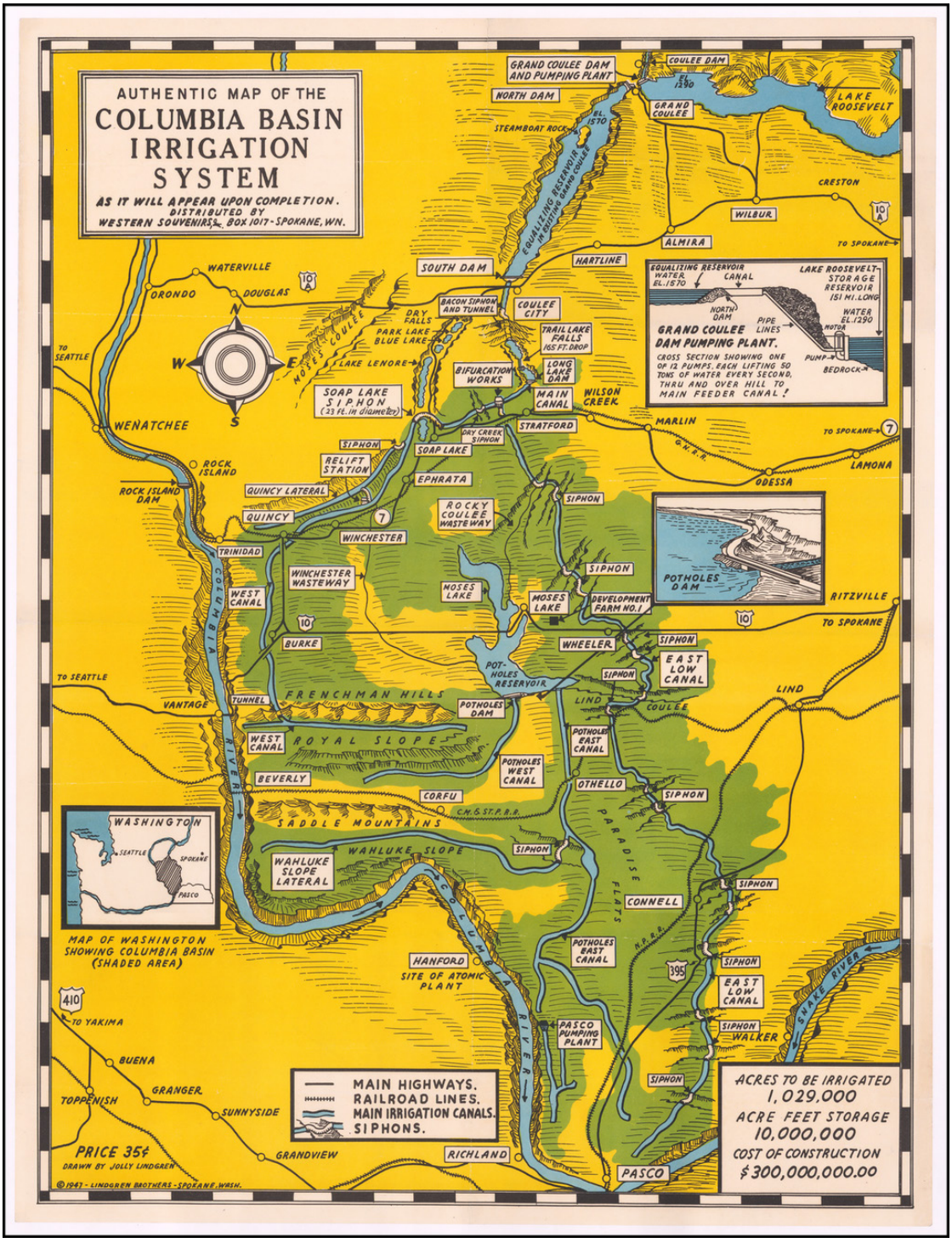


Figure D-2. Map of Columbia Basin Irrigation System (1947) highlighting bifurcation works, East Low Canal, and Othello.

16.5 Appendix E: Standard Operating Procedures (SOP)

Table E-1. SOPs

Section	Sample	SOP	Filename	Method Description
E-1 pg. 2-6	Cryptosporidium & Giardia	USEPA Method 1623 and 1623.1	110_EPA_Method_1623_and_1623_ASI.pdf	UW Field & Analytical Services, Inc. (ASI) Laboratory
E-2 pg. 7-8	Cryptosporidium & Giardia	Chain of Custody	Analytical Services Inc_Chain_of_Custody_2025.pdf	UW Field & Analytical Services, Inc. (ASI) Laboratory
E-3 pg. 9-17	Bacteria: *E. coli,* Enterococci, Coliphage	Analytical Methods Approved for Compliance Monitoring under the Ground Water Rule 40 CFR 141.402(c)(2)	EPA_gwr_approved_methods.pdf	EPA methods at UW EOMHL
E-4 pg. 18-20	Bacteria: Enterococci	Enterolert®	Enterolert_IDEXX_DS_EN.pdf	IDEXX methods at UW EOMHL
E-5 pg. 21-23	Bacteria: Enterococci	Enterolert®	IDEXX_Enterolert_Procedure Insert.pdf	IDEXX methods at UW EOMHL
E-6 pg. 24-31	Bacteria: Total coliforms, E.coli	Colilert®	IDEXX_Colilert_ Procedure.pdf	IDEXX methods at UW EOMHL
E-7 pg. 32-60	Virus: DNA	DNeasy® Power Water Kit	HB-2267-003_HB_DNY_PowerWater_0722_WW.pdf	Qiagen methods at UW EOMHL
E-8 pg. 60-89	Virus: RNA	RNeasy® Power Water Kit	HB-2268-004_HB_RNY_PowerWater_1023__WW.pdf	Qiagen methods at UW EOMHL
E-9 pg. 90-100	Virus: DNA	Qubit®dsDNA HS Assay Kit	User Guide_ Qubit dsDNA HS Assay Kits.pdf	Life Technologies methods at UW EOMHL
E-10 pg. 101-111	Virus: RNA	Qubit®dsRNA HS Assay Kit	User Guide_ Qubit RNA HS Assay Kits.pdf	Life Technologies methods at UW EOMHL
E-11 pg. 112-148	Virus: DNA	Nextera® DNA Library Preparation Kit	Nextera DNA Library Prep Reference Guide (15027987).pdf	Illumina methods at methods at UW EOMHL
E-12 pg. 149-180	Sample Collection	EPA SESDPROC-301-R3 Groundwater Sampling	Groundwater-Sampling.pdf	UW Field with EPA SESD methods
E-13 pg. 181-236	Water Quality Sensor	Aqua TROLL 400 Instrument Manual	Aqua_TROLL_400_Manual.pdf	UW Field with In-Situ methods following EPA SOPs
E-14 pg. 237-241	SOP	Preparation of Project Specific Standard Operating Procedures	EOMHL-SOPpreparation.pdf	UW Environmental Health Microbiology Lab (EOMHL)
E-15 Pg 242-248	Lab Accreditations	Crypto; Waiver	260203R AnalyticalServices - EXP 2027-0217.pdf; AccreditationWaiver_UW.pdf	ASI EOMHL

SOPs provided as supplementary file (QAPP-GWVirus-Sampling-AppendixE-SOP-pp241.pdf).

16.6 Appendix F. Glossaries, Acronyms, and Abbreviations

16.6.1 Glossary of General Terms

Ambient: Background or away from point sources of contamination. Surrounding environmental condition.

Analytical Groundwater Model: Analytical groundwater models are mathematical representations used to simplify and analyze groundwater flow and contaminant transport in aquifers. These models rely on analytical solutions to the governing equations of groundwater flow, which are typically based on simplifying assumptions about the aquifer's properties and the flow conditions. Analytical models often assume uniform aquifer properties, such as constant hydraulic conductivity and uniform thickness, and may assume a flat-water table or fully penetrating streams.

Aquifer Storage & Recovery (ASR): the storage of water in a suitable aquifer through a well during times when water is available, and recovery of the water from the same well during times when it is needed (Pyne, 2005). The primary goal is to store excess water during wet season and use it during dry season with water treated to meet groundwater standards.

Assay: to quantitatively compare an unknown sample to established standards. The definition emphasizes accuracy and reproducibility, distinguishing assays from screens, which prioritize scalability over precision.

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of whether the uses are currently attained.

Diel: Of, or pertaining to, a 24-hour period.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Effluent: An outflowing of water from a natural body of water or from a human-made structure. For example, the treated outflow from a wastewater treatment plant.

Enterococci: A subgroup of the fecal streptococci that includes *S. faecalis*, *S. faecium*, *S. gallinarum,* and *S. avium*. The enterococci are differentiated from other streptococci by their ability to grow in 6.5% sodium chloride, at pH 9.6, and at 10 degrees C and 45 degrees C.

Fecal coliform (FC): That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius.

Fecal coliform bacteria are “indicator” organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000-fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

Isoelectric point (IEP): the pH at which a particle (here, a virus) has no net electrical charge at its surface. At pH values below the IEP, the viral surface is net positively charged; above the IEP, it is net negatively charged.

Log_{10} (4) or 4-log Removal in water quality refers to a 99.99% reduction of a specific contaminant or microorganism in water treatment processes. This level of reduction is crucial for ensuring water safety and protecting public health. Log removal is a logarithmic expression of contaminant reduction. Each "log" represents a tenfold decrease in the concentration of the contaminant. Log4 removal specifically means a 10,000-fold reduction in the target constituent. The Ground Water Rule (GWR) introduced by the EPA provides a clear definition and context for 4-log removal of viruses (USEPA, 2006).

Managed Aquifer Recharge (MAR): the purposeful recharge of water to aquifers for subsequent recovery or for environmental benefit (Dillon et al., 2009). MAR is a water resources management tool that encompasses a wide variety of water sources, recharge methods, and storage management practices. MAR can be implemented through various methods, including streambed channel modifications, bank filtration, water spreading, recharge wells, small-scale recharge (e.g., rainwater harvesting), and aquifer storage and recovery (ASR).

Marker: The concept of genetic markers is defined as "a gene or DNA sequence with a known location on a chromosome that can be used to identify individuals or species”. Genetic mapping involves utilizing recombination and traceable genetic markers to identify regions in the genome that contain genetic elements of interest (Ferris & Heise, 2014).

Metagenomic Analysis: methods to study genetic material from entire microbial communities without the need for culturing individual species. For example, analyzing genetic material directly from environmental samples by isolating and cloning bulk DNA from an environmental sample (Schmidt et al., 1991). The term gained widespread use as the field of metagenomics matured in the early 2000s.

ORP: Oxidation Reduction Potential (or redox potential), which is a measurement in millivolts (mV) that indicates a water-based solution's ability to either oxidize or reduce (gain or lose electrons). ORP determines the health of water where positive readings indicate aerobic conditions and negative readings indicate anaerobic conditions. High ORP indicates that oxygen and other oxidants are actively breaking down contaminants, whereas low ORP (negative values) indicates a "reducing" environment with poor water quality and potential contamination.

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Risk Assessment (RA): A framework for a systematic approach to identify, analyze and incorporate knowledge about multiple aspects of risk. Helps quantify and rank identified risks based on likelihood, confidence and consequences. In this study, RA includes model sensitivity analysis, statistical analysis evaluating the validity of the sampling approach, sensitivity of the experimental design, biological and methodological variance, accuracy of laboratory analytical results, accounting for measurement errors and lab result variability. A risk prediction accuracy assessment could determine with 95% confidence the likelihood of a 99.99% reduction in virus presence under a specific ASR plan.

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

Sequencing: The process of determining exact order of the four nucleotide bases—adenine (A), thymine (T), cytosine (C), and guanine (G)—in a DNA molecule, or the four bases in RNA molecules (A, C, G, uracil (U)). Viruses can have either RNA or DNA as their genetic material. This sequence encodes the genetic information that cells use to develop and operate, including instructions for making proteins and regulating gene expression.

Streamflow: Discharge of water in a surface stream (river or creek).

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Synoptic survey: Data collected simultaneously or over a short period of time.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

7-DADMax or 7-day average of the daily maximum temperatures: The arithmetic average of seven consecutive measures of daily maximum temperatures. The 7-DADMax for any individual day is calculated by averaging that day's daily maximum temperature with the daily maximum temperatures of the three days before and the three days after that date.

7Q2 flow: A typical low-flow condition. 7Q2 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every other year on average. The 7Q2 flow is commonly used to represent the average low-flow condition in a water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q2 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

7Q10 flow: A critical low-flow condition. The 7Q10 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every ten years on average. The 7Q10 flow is commonly used to represent the critical flow condition in a water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q10 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

90th percentile: An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90th percentile value is a statistically derived estimate of the division between 90% of samples, which should be less than the value, and 10% of samples, which are expected to exceed the value.

16.6.2 Acronyms and Abbreviations

ASR Aquifer Storage and Recovery

ATCC American Type Culture Collection

BMP Best management practice

CAS Chemical Abstracts Service

CV Coefficient of Variation

DEOHS Department of Environmental and Occupational Health Sciences

DO Dissolved oxygen

DOC Dissolved organic carbon

e.g. For example

Ecology Washington State Department of Ecology

EIM Environmental Information Management database

EOHML Environmental and Occupational Health Microbiology Lab

EPA U.S. Environmental Protection Agency

et al. And others

FC Fecal coliform

GIS Geographic Information System software

GLP Good Laboratory Practice

GPS Global Positioning System

GWR Ground Water Rule

i.e. In other words

IEP Isoelectric Point

IUPAC International Union of Pure and Applied Chemistry

MAR Managed Aquifer Recharge

MEL Manchester Environmental Laboratory

MQO Measurement quality objective

NPDES National Pollutant Discharge Elimination System

ORP Oxidation-Reduction Potential

PCB Polychlorinated biphenyls

QA Quality assurance

QAPO Quality assurance project officer

QAPP Quality assurance project plan

QC Quality control

RPD Relative percent difference

RSD Relative standard deviation

SOP Standard operating procedures

SRM Standard reference materials

TIR Thermal infrared radiation

TMDL Total Maximum Daily Load

TOC Total organic carbon

USGS United States Geological Survey

WAC Washington Administrative Code

WRIA Water Resource Inventory Area

16.6.3 Units of Measurement

°C degrees centigrade

cfs cubic feet per second

cfu colony forming units

cms cubic meters per second, a unit of flow

dw dry weight

ft feet

g	gram, a unit of mass
kcfs	1000 cubic feet per second
kg	kilograms, a unit of mass equal to 1,000 grams
kg/d	kilograms per day
km	kilometer, a unit of length equal to 1,000 meters
L/s	liters per second (0.03531 cubic foot per second)
m	meter
mm	millimeter
mg	milligram
mgd	million gallons per day
mg/d	milligrams per day
mg/kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mg/L/hr	milligrams per liter per hour
mL	milliliter
mmol	millimole or one-thousandth of a mole
mole	an International System of Units (IS) unit of matter
ng/g	nanograms per gram (parts per billion)
ng/kg	nanograms per kilogram (parts per trillion)
ng/L	nanograms per liter (parts per trillion)
NTU	nephelometric turbidity units
pg/g	picograms per gram (parts per trillion)
pg/L	picograms per liter (parts per quadrillion)
psu	practical salinity units

s.u. standard units

µg/g micrograms per gram (parts per million)

µg/kg micrograms per kilogram (parts per billion)

µg/L micrograms per liter (parts per billion)

µm micrometer

µM micromolar (a chemistry unit)

µmhos/cm micromhos per centimeter

µS/cm microsiemens per centimeter, a unit of conductivity

ww wet weight

16.6.4 Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data (Kammin, 2010). For Ecology, it is defined according to WAC 173-50-040: "Formal recognition by [Ecology] that an environmental laboratory is capable of producing accurate and defensible analytical data."

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms *precision* and *bias* be used to convey the information associated with the term *accuracy* (USEPA, 2014).

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella (Kammin, 2010).

Bias: Discrepancy between the expected value of an estimator and the population parameter being estimated (Gilbert, 1987; USEPA, 2014).

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process (USGS, 1998).

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured (Ecology, 2004).

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards but should be referred to by their actual designator, e.g., CRM, LCS (Kammin, 2010; Ecology, 2004).

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator (USEPA, 2014; USEPA, 2020).

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator (USEPA, 2014; USEPA 2020).

Continuing Calibration Verification Standard (CCV): A quality control (QC) sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during an analytical run (Kammin, 2010).

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system (Kammin, 2010; Ecology 2004).

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean (Kammin, 2010).

Data integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading (Kammin, 2010).

Data quality indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity (USEPA, 2006).

Data quality objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA, 2006).

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010).

Data validation: The process of determining that the data satisfy the requirements as defined by the data user (USEPA, 2020). There are various levels of data validation (USEPA, 2009).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology, 2004).

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero (Ecology, 2004).

Duplicate samples: Two samples taken from and representative of the same population and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis (USEPA, 2014).

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport (Ecology, 2004).

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples (Kammin, 2010).

Laboratory Control Sample (LCS)/LCS duplicate: A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. Monitors a lab's performance for bias and precision (USEPA, 2014).

Matrix spike/Matrix spike duplicate: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias and precision errors due to interference or matrix effects (Ecology, 2004).

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness (USEPA, 2006).

Measurement result: A value obtained by performing the procedure described in a method (Ecology, 2004).

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed (USEPA, 2001).

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples (Ecology, 2004; Kammin, 2010).

Method Detection Limit (MDL): The minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results (USEPA, 2016). MDL is a measure of the capability of an analytical method of distinguishing samples that do not contain a specific analyte from a sample that contains a low concentration of the analyte (USEPA, 2020).

Minimum level: Either the sample concentration equivalent to the lowest calibration point in a method or a multiple of the method detection limit (MDL), whichever is higher. For the purposes of NPDES compliance monitoring, EPA considers the following terms to be synonymous: “quantitation limit,” “reporting limit,” and “minimum level” (40 CFR 136).

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all parameters (Kammin, 2010; Ecology, 2004).

Population: The hypothetical set of all possible observations of the type being investigated (Ecology, 2004).

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator (USGS, 1998).

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data (Kammin, 2010).

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives (Kammin, 2010; Ecology, 2004).

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data (Ecology, 2004).

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

RPD = [Abs(*a*-*b*)/((*a* + *b*)/2)] * 100%

where "Abs()" is absolute value and *a* and *b* are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Relative Standard Deviation (RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

RSD = (100% * s)/x

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled (USGS, 1998).

Reporting level: Unless specified otherwise by a regulatory authority or in a discharge permit, results for analytes that meet the identification criteria (i.e., rules for determining qualitative presence/absence of an analyte) are reported down to the concentration of the minimum level established by the laboratory through calibration of the instrument. EPA considers the terms "reporting limit," "quantitation limit," and "minimum level" to be synonymous (40 CFR 136).

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator (USGS, 1998).

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population (USGS, 1998).

Sample (statistical): A finite part or subset of a statistical population (USEPA, 1992).

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit (Ecology, 2004).

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method (USEPA, 2014).

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency (USEPA, 2014).

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010).

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity (Kammin, 2010).

Surrogate: For environmental chemistry, a surrogate is a substance with properties like those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin, 2010).

Systematic planning: A stepwise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning (USEPA, 2006).

16.6.5 References for QA Glossary

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