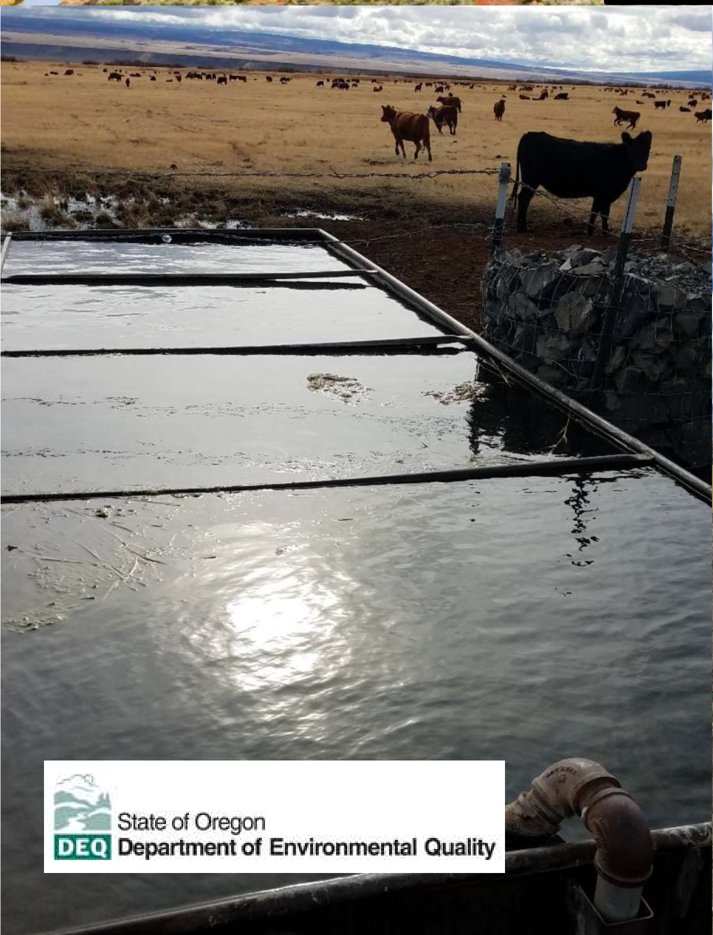
Statewide Groundwater Quality Monitoring Program:

Harney County

DEQ21-LAB-0021-TR (Rev. 1.1)

May 2021



State of Oregon
DEQ Department of Environmental Quality

This report prepared by:

Oregon Department of Environmental Quality
Laboratory and Environmental Assessment Division
7202 NE Evergreen Parkway
Hillsboro, OR 97124

www.oregon.gov/DEQ

Authors:
Paige Haxton-Evans, Natural Resource Specialist
Dan Brown, Natural Resource Specialist

Contact:
Laboratory and Environmental Assessment Division
503-693-5700

Pictures on cover page from top left to bottom right: Malheur National Wildlife Refuge Fence Removal Panorama by Lloyd Irwin (onda.org); DEQ monitoring specialist Michael Mulvey sampling a domestic well; View of Steens Mountain by Jeff Sorn - Oregon Department of Transportation - Buena Vista Overlook (https://commons.wikimedia.org/w/index.php?curid=24374910); Field sampling picture of stock watering well; DEQ monitoring specialist Nicholas Haxton-Evans sampling a monitoring well in Virginia Valley.

Table of Contents

Executive Summary

Oregon statute's ORS 468B.155 stated objective is "to prevent contamination of Oregon's groundwater resource while striving to conserve and restore this resource and to maintain the high quality of Oregon's groundwater resource for present and future uses." To understand how Oregon is doing in meeting this goal, the Statewide Groundwater Monitoring Program received funding to begin collecting water quality data in 2015.[1] The goals of the program are to establish the status of ambient groundwater conditions, identify emerging groundwater quality problems and inform groundwater users of potential risks from contamination. Groundwater studies are conducted annually with the goal of monitoring Oregon's vulnerable aquifers over a 10-year period. Regional study areas are selected based on previously identified groundwater vulnerabilities, environmental justice concerns, nitrate data collected during real estate transactions as required by statute (ORS 448.271), time elapsed since water quality data were last collected, analysis of potential contamination sources and community interest. All studies include analysis of nitrate, arsenic, bacteria, pesticides and common ions in 60 to 100 wells. Additional analyses are added based on local risk factors and program capacity.

In 2018, the Statewide Groundwater Monitoring Program conducted a groundwater study in Harney County. Objectives of the study were:

1. To collect high-quality data on nitrate, arsenic, coliform bacteria, pesticides, pharmaceutical and personal care products, volatile organic compounds, and contaminants of local concern in groundwater throughout the study area;
2. To identify areas of groundwater contamination related to these parameters;
3. To inform well water users of the results of this study and provide information regarding potential risks to human health;
4. To identify areas needing additional investigation in order to describe the extent of contamination and focus efforts to prevent further contamination.
5. To help establish long-term trending data and describe changes over time.

Outside the scope of this study and report:

- Hydrogeologic characterization of the study area and contamination
- Investigation of the sources of contamination
- Health assessments that are based on an individual's personal risk and exposure.

Study Area Description:
This study is located in Harney County with the cities of Burns and Hines in the north and the small city of Fields in the south. This county is known for its sparse population, agricultural fields dominated by hay, grazing pastures and forested uplands. It has an arid climate and has been severely challenged with drought. A broad portion of the study area consists of the central Harney Basin Valley. This valley is considered a closed basin which means that surface water that enters the basin through snow melt and precipitation can only leave naturally by evaporation or transpiration by plants rather than flowing away toward an ocean. The hydrogeology and groundwater – surface water interactions have been poorly understood. Much of the marginal uplands to the north are a mix of marine sediments, volcanic deposits, and older basin fill, with predominantly volcanic deposits in the south uplands.

[1] DEQ had a groundwater monitoring program in the 1990s, however funding for groundwater monitoring was decreased in the 2000's to only include the Groundwater Management Areas (GWMAs) and select special studies. The three GWMAs are the Southern Willamette Valley, the Lower Umatilla Basin and the Northern Malheur Basin. The current Statewide Groundwater Monitoring Program is a new planning effort that looks at groundwater quality outside of the GWMAs. The 2013-15 Oregon Legislative Session passed a Policy Option Package funding and directing the DEQ to "monitor groundwater for contaminants of concern, including nitrates and pesticides, in two geographic regions per year. Groundwater quality throughout the state would be characterized over a ten year period. The data and information developed will be used to determine: areas of the state that are especially vulnerable to groundwater contamination; long term trends in groundwater quality; status of ambient groundwater quality; emerging groundwater quality problems; and to inform groundwater users of potential risks from contamination".

There are 28 public water systems served by around 30 groundwater wells in the Harney Basin portion of the study area. These systems serve approximately 5,800 people, in addition to visitors at recreation sites. There are no public water systems that use surface water in this area.

Ninety-one wells were selected for this study. Sixty were sampled in the spring 2018. Twenty-one of those wells were resampled in the fall along with an additional 31 new wells. Resampled wells were used to compare seasonal changes in detections.

Key findings include:

- Of the 258 analytes sampled for, 42 chemicals or water chemistry parameters were detected and measured (Table 1).

- Of the 91 wells sampled in this study 58% had one or more contaminants posing a human health concern by exceeded a maximum contaminant level or other human health-based benchmark for drinking water. These wells tap into the same groundwater system with different hydraulically connected geologic units within Harney County, and are a mix of private drinking water wells, irrigation wells, stock watering wells, and static water level monitoring wells. All of these well owners were notified of their results by DEQ staff and referred to local and state public health resources and Oregon State University Extension Agricultural resources to discuss potential risks.

- Nitrate detections were widespread but not at levels concerning to human health. Fifty-seven out of 91 wells (62%) had detections of nitrate ranging from 0.0065 - 5.48 mg/L. Seven wells had detections elevated above natural background levels of 3 mg/L. There were no wells exceeding the EPA Maximum Contaminant Level (MCL) of 10 mg/L.

- Arsenic was detected in 80% of wells tested, and in some cases at levels concerning to human health. Seventy-eight wells (80%) had detections of arsenic, widespread throughout the county. Detections ranged from 0.25 µg/L to 655 µg/L. Twenty-eight wells (31% of well sampled) exceeded the EPA Maximum Contaminant Level of 10 µg/L.

- Sixteen wells (18%) tested positive for total coliform, and three of those wells also contained *E. coli*. Detections of bacteria in groundwater wells suggest a vulnerability in the well infrastructure that may enable other sources of contamination.

- Relatively few pesticides were detected, and all detections were below applicable human health screening levels. Nine different pesticide related chemicals, derived from seven different parent pesticides, were detected in this study. A total of 137 pesticide related chemicals were analyzed in the collected samples. Eighteen wells (20%) had detections of at least one current use or legacy pesticide, and five wells had two or more pesticides detected. The most commonly detected pesticide was 2,4-D detected in nine wells, followed by atrazine compounds detected in five wells. Dieldrin was the only legacy pesticide detected. No detections of any pesticide related chemicals were close to their applicable health related screening levels[2]. 2,4-D accounted for ten out of the eleven highest pesticides detections measured.

- One pharmaceutical or personal care product, sulfamethoxazole which is a common antibiotic, was detected in one well at low levels that are not a concern for health.

[2] Atrazine and 2,4-D have USEPA Maximum Contaminant Levels (MCL). Deisopropylatrazine, desethylatrazine, and metsulfuron-methyl have USEPA non-regulatory Human Health Benchmarks. Diuron, Prometon and Dieldrin have USGS Health Based Screening Levels. 3,5-Dichlorobenzioc acid (DBA) does not have an available health screening level, but it's parent pesticides 2,6 dichlorobenzamid (BAM) and dichlobenil have non-regulatory Human Health Benchmarks of 32 µg/L and 70 µg/L, respectively. Also see Table 1.

- Out of 68 volatile organic compounds (VOCs) analyzed, five were detected in five different wells. One well sampled in the fall contained four trihalomethane VOCs which are by-products of chlorine disinfection. Two of those chemicals, bromodichloromethane and bromoform, have non-enforceable EPA Maximum Contaminant Level Goals of zero. The combination of the four trihalomethane concentrations did not exceed the EPA Maximum Contaminant Level of 800 µg/L. Chlorinated tris (TDCP), a compound used as a flame retardant, found in four wells, was the most commonly detected, but did not exceed any applicable health screening levels.

- Boron was detected in 93% of wells, with twenty-three wells exceeding the Longer Term Health Advisory Level for children of 2000 µg/L. Six wells exceeded the Lifetime Health Advisory for adults of 6000 µg/L

- Vanadium was detected in 58% of wells with only one well (118 µg/L) exceeding the EPA Maximum Contaminant Level of 86 µg/L.

- Manganese was detected in 63% of wells sampled. Eight wells had detections above the EPA Lifetime Health Advisory of 300 µg/L.

- Aluminum was detected in 24% of wells sampled. Three wells exceed the Agency for Toxic Substances and Disease Registry (ATSDR) Health-based guidance for chronic exposure in children of 7000 µg/L.

- Selenium, a new analyte to this study, was detected in 4% of wells sampled, none exceeding the EPA Maximum Contaminant Level.

- There was no statistical difference in detected concentrations of nitrate or pesticides between wells sampled in the spring versus the fall, and when comparing shallow (<100ft) and deeper wells, there was no statistical difference between detected concentrations of bacteria, nitrate or pesticides.

The results of this study can be used to inform the people of Oregon about the current condition of the state's groundwater aquifers, which are an increasingly important public natural resource, used publicly and privately at large and small scales. These results can be used to focus outreach and educational activities that encourage private well owners to routinely test wells for nitrate, bacteria, and arsenic, and encourage well protection and maintenance best practices to protect the aquifer. Regular monitoring of wells throughout Harney County and particularly in the basin's central valleys (Harney Valley, Sage Hen Valley, Silver Creek Valley, Warm Springs Valley, Blitzen Valley, and Virginia Valley) should include arsenic, bacteria, nitrate, boron, manganese, aluminum, and vanadium. It is recommended that a network of wells be established and monitored to detect any changes over time. Long-term monitoring of current use pesticides, including atrazines and 2,4-D, as well as volatile organic compounds is encouraged. Continued monitoring could be established locally, or, with continued funding, the Statewide Groundwater Monitoring Program would be able to consider addition of wells within this basin to be included in the agency's long-term monitoring network.

1. Background

1.1 Statewide Groundwater Quality Monitoring Program

Groundwater is a vital resource in Oregon. Over 600,000 Oregonians rely on private wells for their drinking water (Maupin et al., 2014). Public water systems, the agricultural community and industry all rely on groundwater to meet their operational needs. In addition, Oregon's rivers and streams depend on groundwater for the maintenance of adequate summer flows to sustain fish populations and for recreational opportunities. Groundwater is a critical water reserve that can be used when available surface water is inadequate to meet demands.

Oregon's overarching goal for groundwater quality is "to prevent contamination of Oregon's groundwater resource while striving to conserve and restore this resource and to maintain the high quality of Oregon's groundwater resource for present and future uses (ORS 468B.155)." To understand how Oregon is doing in meeting this goal, the Statewide Groundwater Quality Monitoring Program began collecting water quality data in 2015 to determine the status of ambient groundwater conditions, identify emerging groundwater quality concerns and inform groundwater users of potential risks from contamination[3].

To implement this work, DEQ conducts regional groundwater studies annually with the goal of monitoring Oregon's vulnerable aquifers over a 10-year period. The program selects areas regionally, based on previously identified groundwater vulnerabilities, nitrate data collected during real estate transactions as required by statute (ORS 448.271), time elapsed since water quality data were collected, analysis of potential contamination sources and community interest to help with recruitment of volunteer well user participants. All studies include analysis of nitrate, arsenic, bacteria, pesticides, metals and common ions in 60 to 100 wells. Additional analyses are added based on local risk factors and program capacity.

1.2 Study Area Description

1.2.1 Study Area Boundary

In the spring and fall of 2018, the Oregon DEQ collected and analyzed water samples in Harney County in southeastern Oregon. The county border defining the study area is depicted in Figure 1. The cities of Burns and Hines are in the north central part of the county at an elevation of 4,147 ft, and the small city of Fields in the south at an elevation of 4236 ft. The Burns Paiute Tribe holds native land here with tribal member residents. Within the study area boundary is the Harney Basin with Malheur, Mud, and Harney lakes at the central sink of a closed basin drainage area at 4084 ft in elevation. To the north extends the Malheur National Forest ranging from 4000 to 9000 ft. In the south of the county stands the Steens Mountain Wilderness area with a summit of 9733 ft which drops southeast down to the Alvord Desert at 4000 ft. The Harney County boundary was selected in order to capture a wide geographic area, with a diversity of residential, urban and rural wells, with varying opportunities to sample shallow and deep wells with different land uses. Most of the wells selected for sampling fall within the Greater Harney Valley, with a few wells further south and in the Alvord Desert.

---

[3] DEQ had a groundwater monitoring program in the 1990s, however funding for groundwater monitoring was decreased in the 2000's to only include the Groundwater Management Areas (GWMAs) and select special studies. The three GWMAs are the Southern Willamette Valley, the Lower Umatilla Basin and the Northern Malheur Basin. The current Statewide Groundwater Monitoring Program is a new planning effort that looks at groundwater quality outside of the GWMAs. The 2013-15 Oregon Legislative Session passed a Policy Option Package funding and directing the DEQ to "monitor groundwater for contaminants of concern, including nitrates and pesticides, in two geographic regions per year. Groundwater quality throughout the state would be characterized over a ten year period. The data and information developed will be used to determine: areas of the state that are especially vulnerable to groundwater contamination; long term trends in groundwater quality; status of ambient groundwater quality; emerging groundwater quality problems; and to inform groundwater users of potential risks from contamination".

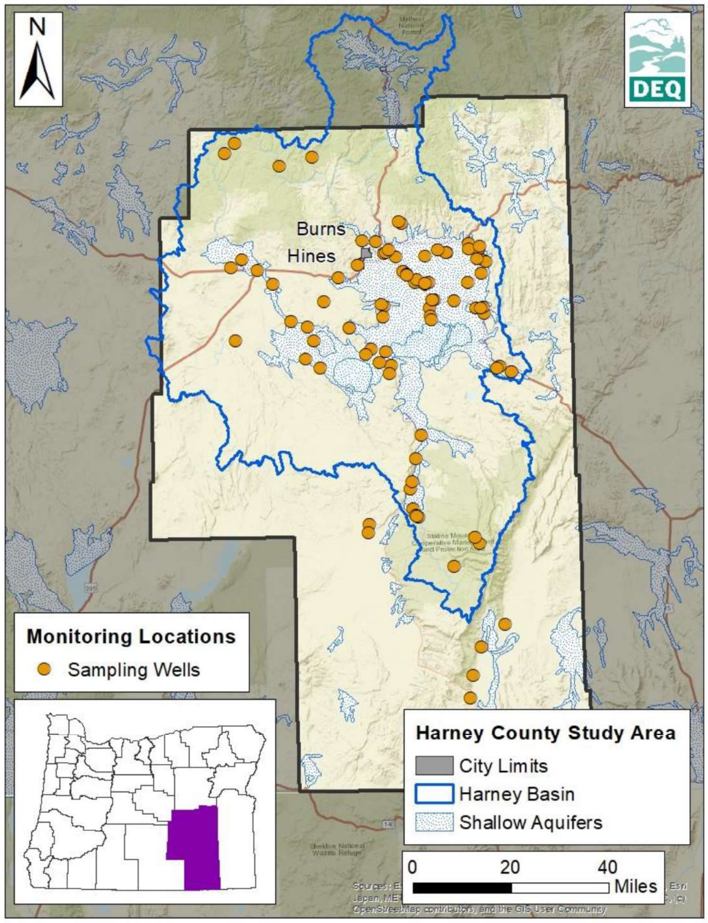


Figure 1. Study area (Harney County boundary) and well locations, with Harney Basin boundary for reference. (Shallow aquifers from Sweet et al., 1980)

1.2.2 Geology

The portion of the Harney Basin within Harney County is a high semi-arid plateau that has a low central area of playas and lake beds, alluvial plains, cinder cones, and lava fields (Piper et al.,1939) The marginal uplands consist of volcanic and pyroclastic rocks and sediments derived from volcanic rocks, as well as Mesozoic rocks of marine origin. These uplands contain numerous faults and generally slope toward the central valley basin. Unconsolidated valley-fill deposits underlie the valley floor to a depth of about 250 ft (Leonard, 1970). These layers contain clay with deposits of sand and gravel in alluvial fans derived from the contributing watershed drainages. Beneath these valley-fill deposits are consolidated rocks similar in composition to those exposed in the bordering uplands (Gonthier et al., 1977). The uplands to the south include Steens Mountain, which is predominantly a slab of west-dipping basalt with older volcanic and sedimentary outcrops exposed along the east side (Evans and Geisler, 2001).

1.2.3 Hydrogeology

Surface water from Silver Creek, Silvies River, and the Donner und Blitzen River feed the lakes at the center of Harney Basin with Harney Lake being at the lowest point. The basin is considered a closed basin which means that the surface water that enters the basin through snow melt and precipitation can only leave naturally by evaporation or transpiration by plants rather than flowing away toward an ocean. The hydrogeology and groundwater – flow system in Harney Basin remains poorly understood. In order to answer some questions regarding the ability of the groundwater resource to sustain existing and developing uses as well as future impacts to surface-water interactions, the Oregon Department of Water Resources and the US Geological Survey have developed a 4-5 year study of the groundwater – flow system in Harney Basin. Related reports are projected to be released in 2021. "The study includes determining the rates and distribution of groundwater recharge and discharge (water budget) throughout the basin, characterizing the geologic controls on groundwater flow, and identifying major hydrogeologic units. The study includes the development of a numerical groundwater-flow model to assess the conceptualization of the flow system and to provide a tool for estimating effects of proposed development scenarios on groundwater levels and surface-water depletion in the basin." (USGS Oregon Water Science Center).

1.2.4 Land use

Succeeding a broad expanse of historical inhabitance by the Paiute Tribes, the land use in the study area has a history (since the late 1800's) of livestock grazing in the valley as well as agricultural hay and crop fields and forested and grazing uplands (www.co.harney.or.us). Groundwater use includes municipal, community, domestic, commercial-industrial, agricultural, livestock, and fish and wildlife uses. Sources of anthropogenic contamination may include any fertilizers and pesticides used for hay crops. Land application of wastewater for fertilization may be another source of contamination including nitrate, bacteria and consumer use sewage related products. Septic tanks are a possible source of contamination in urban to rural transition areas that are not connected to a sewer. This concern is mainly dependent on the density of residential lots and the soil and geology used to construct septic leach-field drainages. There are five landfills in various areas of Harney County, including in the cities and towns of Diamond, Drewsey, Fields, Frenchglen, and Riley. A consideration of specific contaminants can be found below in Section 2.1.3

1.2.5 Climate

The climate in this study area is generally arid, but also varies with geography. Burns has an average annual precipitation of nearly 11 inches and 35 inches of annual snowfall (usclimatedate.com). The city of Frenchglen near Steens Mountain gets 13 inches of rain a year and 23 inches of snow. Annual average high and low temperatures in Burns are 59 and 30 degrees fahrenheit, respectively, and Frenchglen sees an average of 83 degrees in July and 21 degrees in January. The months of December through May have some of the highest precipitation and August has the lowest. In 2018, Oregon Governor Kate Brown declared a drought emergency in Harney County. Previous droughts were declared in the years of 1991, 1992, 2001, 2002, 2003, 2007, 2014, and 2015. The 2020 Pacific Northwest Water Year Impacts Assessment describes much of southern Oregon, including Harney County as "exhibiting exceptionally high levels of evaporative demand" leading to dry surface soils (Bumbaco et al., 2021).

1.2.6 Previous DEQ Monitoring

DEQ conducted a groundwater quality study in 1994 in the Burns-Hines area. The impetus for the study was the 1989 Oregon Groundwater Protection Act, ORS 468B.190, calling for the cooperation between the DEQ, OWRD and OSU to conduct an "ongoing statewide monitoring and assessment program of the quality of the groundwater sources of this state" (State of Oregon, 1989).[4] In this study, 17 wells were sampled in August in an investigation of shallow groundwater contamination. Wells were tested for volatile organic compounds (VOCs), primary and trace metals, and select pesticides. Thirty chemicals were detected including arsenic, boron, manganese, nitrates, chloride, selenium, silicon, calcium, iron, sulfate, phosphorus and vanadium. None of the wells exceeded the EPA drinking water Maximum Contaminant Level (MCL) for nitrate of 10 mg/L. One well exceeded the current MCL for arsenic of 10 µg/L[5]. One well exceeded the Boron Longer-Term Health Advisory of 2000 µg/L for children.

1.2.7 Other DEQ Monitoring in the Area

---

[4] The DEQ statewide groundwater monitoring and assessment program described here lost funding in the 2000's when DEQ's groundwater monitoring was limited to the Groundwater Management Areas (GWMAs) and select special studies. The three GWMAs are the Southern Willamette Valley, the Lower Umatilla Basin and the Northern Malheur Basin.

[5] In 2001, EPA adopted a new standard for arsenic in drinking water of 10 µg/L, replacing the old standard of 50 µg/L.

DEQ currently has five ambient surface water sampling locations in Harney County that are sampled 6 times per year. Since 2019, the DEQ statewide toxics monitoring program has two surface water sites in Harney county: Silvies River at West loop road, and Donner und Blitzen River at river mile 11.9. These sites are part of a statewide status and trending network for a wide range of toxic substances in water, sediment and fish.

In 2013, the DEQ Toxics Monitoring program conducted a regional study of the Oregon's Closed Lakes Basin, analyzing 500 chemicals at 12 locations, five of which were in Harney County: the Donner und Blitzen River at Center Patrol Road, Silvies River at West Loop Road, Donner und Blitzen River upstream of Page Springs Campground, South Fork Blitzen River at Blitzen Crossing, and Whitehorse Creek at Whitehorse Ranch Road. Eleven metals were detected in the study. Silvies River was one of the sites which accounted for the majority of the detections, with 8 metals detected. Iron also exceeded the aquatic life criterion at the Silvies River site. Detections of six brominated flame retardants occurred at two sites in the basin including the South Fork Blitzen River. These compounds may travel via airborne transport. There are no federal or state criteria developed for this chemical group, however, concern over these chemicals in humans and the environment prompted a ban on their manufacture and use. Similar to PCBs in structure, these chemicals tend to bio-accumulate in the food chain (Pillsbury et al., 2015). The laboratory measured four plant and animal sterols in the Oregon Closed Lakes Basin. All four of these sterols occur naturally in the environment but may also be enriched by humans and human activities. Beta-sitosterol and stigmastanol were detected at all locations in the Oregon Closed Lakes Basin, with the Donner und Blitzen site having the lowest values of stigmastanol. The laboratory also measured two animal sterols, cholesterol and coprostanol. Levels varied across the basin with the lowest level of coprostanol detected at the South Fork Blitzen site.

DEQ has been sampling groundwater in the nearby Northern Malheur Basin since 1989 after widespread nitrate contamination was identified and a Groundwater Management Area (GWMA) was established to develop a plan to reduce the contamination. A recent GWMA 2020 trend analysis evaluates the 35 wells sampled in the area and shows that 39% of wells have increasing nitrate trends, 51% are decreasing and 20% showed statistically insignificant trends. The area wide trend in nitrate showed statistically significant decreases from 2002 through 2019 (Richerson, 2020).

1.2.8 Real Estate Transaction Domestic Well Testing

Since 1989, Oregon statute (ORS 448.271) requires that groundwater wells that are used for domestic purposes be sampled for nitrate, arsenic and bacteria when a house is sold or transferred. The Oregon Health Authority houses this data. Real Estate Transaction data in the shallow groundwater of Greater Harney Valley show the frequent presence of arsenic at concerning levels for health (> 10 µg/L). While nitrate detections are not often above drinking water standards (10 mg/L), detections show elevated nitrate above natural groundwater levels indicating surface contamination of groundwater. There is also presence of bacteria contamination in wells throughout the basin (data pull from OHA DWTA-RET database on October 7, 2020).

1.2.9 Public Drinking Water Systems

There are three community systems served by 10 wells and 25 non-community systems served by 29 wells in the Harney Basin which is the majority of the north part of Harney County, with small portions extending into neighboring counties. These systems serve approximately 5,800 people, in addition to visitors at recreation sites. There are no public water systems that use surface water in this area.

In the Harney Basin, three community water systems include the cities of Burns (population 2,740), Hines (population 1,392), and Seneca (Grant County, population 262) (2019 Census). Non-community public water systems include the Bureau of Land Management's Burns District Office, Chickahominy Campground, Page Springs Recreation site, Burns Municipal Airport, Crane LDS Chapel, Crane Store & Café, Crane Union Highschool and Elementary, Crystal Crane Hotsprings, Diamond School District #7, Frenchglen Elementary, GH20 Inc, Horseshoe Inn, Hotel Diamond, Malheur Field Station, The Narrows, Sagehen Hill Rest Area (Department of Transportation ODOT), Frenchglen Hotel (Parks and Recreation Department OPRD), Silvies Valley Ranch, Steens Mountain Wilderness Resort, Suntex Elementary, and US Forest Service's Delintment Lake

East, Falls Campground, Idlewild Campground, Parish Cabin Campground, US Fish and Wildlife Service's Malheur Wildlife Refuge. Inactive systems are located at Novak mobile home, Highland Ranch Estates, Buchanan Springs Rest Area, Delintment Lake West, and South Steens Campground.

Six public water systems have had recent alerts for total coliform and/or *E. coli*. Nitrate alerts exceeding 5 mg/L exist for two systems and were most often detected in wells with total depth less than 100 ft.[6] The Oregon Health Authority rated public water systems in this area as high susceptibility for land use impacts to drinking water sources based on Source Water Assessments, aquifer characteristics, well locations and construction (ORDEQ, 2019).

1.2.10 Harney County Watershed Council Monitoring

DEQ worked closely with the Harney County Watershed Council (HCWC) to recruit volunteers for this study and gain access to monitoring wells to sample. The HCWC has monitored static water levels in approximately 100 wells across the basin since 2017, up to four times per year. Their monitoring showed that some wells are declining more than others. A more detailed examination of these water levels measurements and the areas of decline will be described in the 2021 USGS/OWRD Harney Basin Report.

1.2.11 Other Continued Monitoring

Since this sampling in 2018, DEQ has continued ambient surface water monitoring in Harney County. The Oregon Water Resources Department has joined in partnership with the United States Geological Survey (USGS) to conduct a basin wide groundwater study in this area from 2016-2020 and will release a report in 2021. The OWRD has a continued network of monitoring wells in Harney Basin to monitor static water levels on a quarterly basis.

1.3 Study Objectives

Informed by previous investigations and guided by the objectives of the Statewide Groundwater Monitoring Program, the goals of the 2018 Harney County groundwater study were:

1. To collect high-quality data on nitrate, arsenic, coliform bacteria, pesticides, pharmaceutical and personal care products, volatile organic compounds and other contaminants of local concern in groundwater throughout the study area;
2. To identify areas of groundwater contamination related to these parameters;
3. To inform well water users of the results of this study and provide information regarding potential risks to human health;
4. To identify areas needing additional investigation in order to describe the extent of contamination and help focus efforts to prevent further contamination;
5. To help establish long-term trending data and describe changes over time.

Outside the scope of this study and report:

- Hydrogeologic characterization of the study area and contamination
- Investigation of the sources of contamination
- Health risk assessments

[6] This analysis of water quality exceedances is from the 2019 ODEQ Drinking Water Protection (DWP) Program's Drinking Water Information in the Greater Harney Management Area summary report. This report looks at 19 out of the 28 water systems listed here, excluding some state regulated (non-EPA) systems. The ODEQ DWP focuses mapping and analysis of community and non-transient non-community systems, and transient non-community (occasional use) systems as resources allow, which is why state regulated (non-EPA) systems are occasionally excluded.

2. Study Design and Methods

2.1 Study Design

2.1.1 Study Area Selection

The Harney County study area was selected based on a consideration of available water quality data. The central Harney Valley contains a shallow and vulnerable aquifer (Sweet, 1980) making it a priority area for Oregon's Statewide Groundwater Quality Monitoring Program. Other factors considered while selecting this area for study include current available data from Real Estate Transactions, results from a previous 1994 DEQ study, results from ongoing DEQ monitoring efforts for toxic contaminants, DEQ's sampling in the nearby Northern Malheur Basin Groundwater Management Area, collaboration with groundwater studies conducted by other Oregon State agencies, detections of contaminants in Municipal Public Water Systems (PWS) that rely on groundwater in this area, and environmental justice considerations including the presence cultural minority populations. The Harney County boundary was selected in order to capture a wide geographic area, with a diversity of residential, urban and rural wells, with varying opportunities to sample shallow and deep wells with different land uses.

2.1.2 Sample Selection

Volunteers throughout the county were recruited using flyers, emails, a press release, and other announcements with the help of the Harney County Watershed Council (HCWC). Outreach also involved DEQ participation in the Community Based Water Planning (CBWP) group meetings held quarterly for a few years which were organized as part of the Oregon Water Resource Department (OWRD) place-based planning effort in the area. This group, which is still meeting monthly, involves many diverse community members including farmers, urban and rural residents, and tribal members. Participation in this group was an important part of incorporating environmental justice considerations into the outreach for well volunteer participation and ensuring that we were reaching diverse aspects of the community to provide the opportunity to participate. The study primarily relied on well users who volunteered to have their wells tested in exchange for a complete report of the analytical results from their well. Of the list of volunteered wells, wells selected were a mixture of domestic, irrigation and stock watering wells. In addition, Bureau of Land Management stock wells, US Forest Service campsite wells, and OWRD Monitoring wells were also included to incorporate a diversity of geology and well depths not represented by private wells. Many of the wells sampled in this study are also part of either the OWRD or the HCWC well network in which water level data is collected up to four times a year.

As one way to address potential environmental justice biases, the current Statewide Groundwater Quality Monitoring program, including the 2018 study in Harney County, was designed to not exclude wells that may be older or have poorer well construction, and may lack a well drilling document, also known as a well log. Many of these older wells are still in use by domestic well users. Local activities and compromised well heads are indicators of vulnerable aquifers as well as a local public health concern for those groundwater consumers. Although there may not be information about the depth, well construction, or hydrogeologic layers from wells that do not have available well logs, water quality data collected may still reveal if a contamination problem exists that needs further attention. Section 3.1 has a more detailed discussion of well logs, well characteristics of our sample selection, and discusses any water quality correlations associated with the presence or lack of a well log. Appendix A has a complete site list with well log information.

New volunteers were recruited until a sample selection of 100 wells was reached that could be feasibly sampled and that were diversified enough in the basin to be representative (Figure 1). Sample selection was limited to the availability of well users who volunteered, the accessibility of their well and the location of an untreated access point. Wells without a working pump could be included when the well head was available for the use of a submersible pump. While 100 wells were planned to be sampled, due to scheduling or technical sampling complications, only 91 wells were finally sampled for this study.

The arid climate and dominant agricultural land use prompted a sampling schedule that would capture any seasonal differences. Twenty-one wells were sampled in both the spring and fall of 2018. These wells were selected based on the availability and cooperation of the well users who volunteered as well as attention to any detections that were discovered after the spring sampling. Some wells could only be sampled once as some of the agricultural well pumps are not in operation during colder months of the year, or the well user did not give permission for a resample. Section 3.3 discusses how any water quality detections found may be correlated with seasonal sampling.

Any personal data collected from participants during this study has not been attached to the final results. The location of individual wells and an existing well log, if available, is all that identifies the water quality results with a particular well. Appendix D provides an example of the letter and laboratory report that participants receive.

2.1.3 Analyte Selection

Sample analyses included nitrate/nitrite as N (referred to as nitrate), total coliform bacteria, *E. coli* bacteria, total and dissolved arsenic, other total and dissolved metals, current use and legacy pesticides, pharmaceuticals and personal care products, volatile organic compounds (VOCs), common ions and common field parameters. In total, 258 chemicals or water quality parameters were analyzed for each well water sample tested. A complete analyte list can be found in Appendix B and the corresponding laboratory methods can be found in the Sampling and Analysis Plan (DEQ21-LAB-0012-SAP).

In addition to the standard analytes sampled by this monitoring program, personal care products and VOCS were also included in the analyte list for this study area, as allowed by laboratory capacity and local interest in these contaminants. In additional metals were analyzed for total and dissolved quantities. Dissolved solids, cations, and hardness were included as well. Selenium was added to the lists of other metals analyzed, particularly because of the interest in salt deposits found on land irrigated with groundwater. Of particular interest to landowners, as expressed in the Harney County Community Based Water Planning (CBWP) group, was a concern about high levels of boron which was an analyte already included in the analytical list.

In collaboration with the USGS, this study also involved the sampling of isotopes at a selection of wells. Measuring the concentration of certain isotopes in a sample of groundwater enables scientists to determine where and when that groundwater infiltrated into the ground and "recharged" the groundwater flow system. The isotopes included were carbon-14 (14C), tritium (3H), deuterium (2H), and oxygen-18 (18O) and were analyzed by the U.S. Geological Survey. The data and a regional analysis of the results will be included in a report that will be published by the U.S. Geological Survey in 2021, as part of their Harney Basin groundwater study and those results can also be found at USGS Water Quality Samples for USA: Sample Data.

2.2 Methods

2.2.1 Sampling Methods

DEQ water quality monitoring staff collected and processed samples according to standard procedures found in the Manual of Methods (DEQ03-LAB-0036-SOP_V3), Sampling and Analysis Plan (DEQ21-LAB-0012-SAP), and Quality Assurance Project Plan (DEQ93-LAB-0024-QAPP). In general, samples were collected from an outdoor spigot closest to the well head, whenever possible, and always before any water filtration or treatment. Some samples were collected from a pressure tank or large storage reservoir when access to water directly from the well was not available. Some wells were sampled with a submersible pump when an active pump was not available. Wells with active pumps were purged for at least five minutes and until field readings of conductivity, temperature and dissolved oxygen stabilized. Wells sampled with a submersible pump were purged three well casing volumes to ensure that stagnant water was removed, and the sample was collected from replenished groundwater. Bacteria samples were collected last, after the sample point was disinfected with isopropyl alcohol.

Confirmation that the spigot sampled was directly connected to the well head intended was determined by best available information. It was either visually clear that the spigot was plumbed to the wellhead, or the well user or well owner confirmed verbally or with written instruction that the spigot was connected to the wellhead.

Well water was tested for lead. To measure the quality of the water coming from the groundwater geologic unit(s), rather than the water sitting in the pipes, sampling procedures included a 5-10 minute flushing period before a sample was collected. If there is concern about lead contamination from plumbing, wells should be retested using the "first flush" method (Oregon.gov/DHS_ How to test your water for lead).

Methods for sampling isotopes were in concordance with instructions from USGS. Bottles were provided by USGS and samples were sealed and held at either room temperature (stable isotopes and tritium) or refrigerated (<6 degrees Celsius, for carbon-14 samples) until they were ready for analysis. Appendix C describes the methods used for isotope sampling.

2.2.2 Context for Data Interpretation

The results from this study may be interpreted in a few different contexts: first, there is a characterization of groundwater quality that establishes the ambient baseline conditions that may or may not be impacted by human use; secondly, detections of certain contaminants may suggest the impacts of human activities on groundwater quality; and thirdly, the frequency and location of measured detections can highlight the potential for human health impacts when the groundwater is used for drinking water, or agricultural impacts if the groundwater is used for irrigation or livestock watering. Many of the chemicals analyzed in this study are not found naturally in groundwater (e.g., pesticides, personal care products, volatile organic compounds), or have very low natural background concentrations (e.g., nitrate). Detection of these chemicals indicates an influence from human activities such as leaching from agricultural or residential use of fertilizers and pesticides, improperly designed or maintained septic systems, poor well construction, or leaking underground storage tanks. These contaminants, along with some naturally occurring minerals and elements, such as arsenic, may be harmful to human health when present in drinking water above certain levels.

In Oregon, there are no regulatory criteria that apply to water from private, domestic wells. However, it can be useful to compare water quality results to the criteria set by EPA for public water systems. EPA sets a maximum contaminant level goal at the concentration of a contaminant below which there is no known or expected health risk. The EPA then sets the maximum contaminant level as close to the maximum contaminant goal as feasible considering treatment technologies and cost. Maximum contaminant levels are enforceable water quality criteria for public water systems (U.S. EPA, 2012). The analytical reports sent to well owners includes information on the maximum contaminant levels for relevant contaminants. See Appendix D for an example of a laboratory report.

Many of the chemicals measured in this study do not have a maximum contaminant level. In these cases, there are several other sources of health risk information, such as the lists of Health Advisories, Human Health Benchmarks for Pesticides, and Regional Screening Levels developed by EPA (U.S. EPA, 2012; U.S. EPA, 2013; U.S. EPA, 2016). In addition, Health-Based Screening Levels are developed by the United States Geological Survey (Toccalino et al., 2014). These non-regulatory screening values are based on the available toxicological research and can be used to determine whether the concentration of a contaminant in drinking water may pose a risk to human health. In this report, results are compared to maximum contaminant level goal (MCLG) and maximum contaminant levels (MCL) when available. If no maximum contaminant level is available, the result is compared to the lowest value of the current Health Advisories, Human Health Benchmarks for Pesticides, Regional Screening Levels, or Health-Based Screening Levels. Table 1 lists health screening levels for various analytes detected.

Health screening levels for agricultural impacts to soil health, crop growth, or livestock watering are not widely available. A variety of factors play into how groundwater use may affect agricultural management. Participants in this study were referred to their local Oregon State University (OSU) Extension Service Agent to discuss the impacts that particular contaminants may have on their particular soil, crop, or livestock management.

3. Results and Discussion

3.1 Well Characteristics

3.1.1 Well Log Availability

Understanding well characteristics is often dependent on the availability of the document that describes how the well was drilled, often referred to as a well log, or a water well drilling report. The Oregon Water Resources Department has required wells logs to be submitted by well drillers since 1955. The logs provide details on well construction including a description of the geologic material drilled through and material used to case and seal the well. While understanding the depth of the well, its casing, and seal is essential to understanding what geologic unit(s) the well accesses groundwater, well logs can be difficult to locate or correlate to wells located on the ground. Some of the reasons for this include:

- A well log may never have been completed or filed with OWRD;
- The location of a well is often described only by township, range, and section on the well log, and there may be dozens of wells in any given section;
- There may be mistakes, especially in the location, that cause the well log to be misfiled and difficult to find;
- Location of a well on the ground is not enough to tie it to a well log; generally, depth, diameter and other details are needed to identify the correct well log.

With the emergence of electronic record keeping and the requirements to have new well locations tagged with a metal well tag and well ID number (since 1995), as well as latitude and longitude coordinates for exempt wells (since 2009), it is much easier to locate well logs for recently drilled wells. As one way to address potential environmental justice bias associated with older, and possibly more vulnerable wells, this study included wells with and without well logs. While the absence of some well logs limits the interpretation of the data, it also provides an opportunity to compare the results between these two groups and identify any potential bias that may be introduced when excluding wells without a well log from a study. Unlike previous studies in DEQ's recent statewide program, however, a higher percentage of wells sampled did correlate to a well log, so statistical analysis of wells without well logs is limited. Section 3.1.3 discusses possible well log bias.

Of the 91 wells sampled in this study, 79 wells have a verified well log (Figure 2) confirmed by a picture taken during sample collection of a well tag on the well casing itself, or have been confirmed by location and description in the Oregon Water Resources Groundwater Well Information System (GWIS). These include associated wells in the OWRD's Harney Basin well network. (D. Boschmann, OWRD hydrogeologist, personal communication, July 2019). Confidence in well log correlations depends on corroborating information from a variety of sources including the well ID number if present, location and well construction information, water right information, landowner interviews, and site visits by qualified personnel.

Two other wells in this study have been associated with well logs based on other related data collected by DEQ staff during communications and visits with current well owners and well users. Confidence established in these correlated well logs was based off of current well owner's personal knowledge of the well sampled and other wells that may exist on their property. This knowledge includes: the current owner or family member drilled the well themselves; the current owner received well documents from a previous owner who drilled the well; the current owner knew the name of the previous owner and well document was found with a location description that closely as possible matches the location of the well sampled, in this case it is helpful if the owner can confirm that there are no other wells on their property that match the description in the identified well drilling report. For the two wells where there is a reasonable confidence in a match, data interpretation is limited, however, those well logs are used in this report to classify wells based on depth, water bearing geology and year that the well was drilled.

Measuring the size of well casings and the depth to the bottom of a well during a physical well visit is another way to confirm a possible well log correlation, however this study did not include those measurements due to frequent inaccessibility of the well head and a desire to avoid potential introduction of contaminants to the well itself. Depths of wells were only measured when a submersible pump was needed for sampling.

A well log could not be correlated or verified for ten of the wells sampled. These wells are useful in summarizing water quality and detections of contaminants in the basin. They cannot be used to interpret the conditions of shallow or deep groundwater in the basin, but can only be characterized by their geographical location within the basin. Previous studies have only included wells with well logs. This study's inclusion of these 10 wells without well logs may reveal potential contamination issues with older wells, without logs, that may be vulnerable due to age or due to well construction standards at the time of drilling. Compared to previous studies areas in the Statewide Groundwater Program, this study has had the lowest percentage of wells with unknown or unverified well logs. This is mainly to do with the assistance from OWRD and USGS field staff who were able to collaborate on researching and verifying the well logs of the wells where samples were taken.

Of the 81 well logs evaluated, a few characteristics were particularly helpful to understand the groundwater sampled. These characteristics include the depths of the wells, the depth and lithology of the screened portion of the wells, the age of the well and/or the presence of a seal, and the depth where first water was found. An example of how this data is documented in a well log (or "Water Well Report") is included in Appendix E. Appendix A is a site list which includes some relevant information from the 81 well logs.

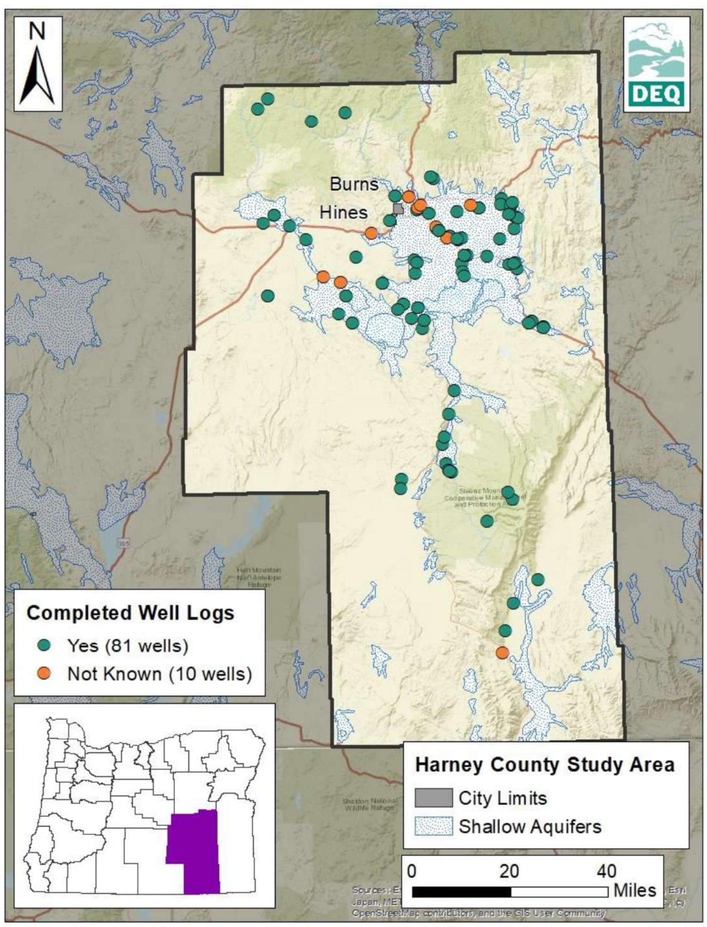


Figure 2. Distribution of wells with and without well log records. (Shallow aquifers from Sweet et al., 1980)

3.1.2 Characteristics of Wells Sampled

Of the 81 wells with associated well logs, 79 provide sufficient information for data interpretation. One well log only has a depth to the bottom of the well and another well log only has a recent static water level. Of the 79 well logs we can use for interpretation, 53 were sampled initially in the spring of 2018, 18 of which were resampled in the fall. Twenty-six wells were sampled in fall 2018 only. The depths of these 79 wells range from 40 – 800 feet below ground surface (ft bgs). Fifteen wells were drilled less than 100 ft deep and may have the potential for contamination from the surface, depending on the geology. None of these wells were drilled prior to 1955, however, the well logs from the three oldest wells show that no well seal was installed (dating 1959-1961). The deepest of these three wells was a 525 ft drilled artesian well drawing water from sandstone. Section 3.4 discusses how any water quality detections found may be correlated with these well characteristics.

Other than differences in well construction and location, other differences between the wells sampled in this study include: land use around the well, how frequently the well is used, distance of transport piping and piping material between well and faucet, whether an inline filter system was removed to take the sample, the type of faucet the sample was collected from, the presence of and/or the size of holding tank or pressure tank connected to system, and whether the well had an active working pump or if the well was sampled using a submersible pump.

3.1.3 Well Log Bias

Due to aging wells, a lack of a proper well seal, outdated construction standards, or illegally drilled wells, wells without well logs may be more vulnerable to surface contamination such as nitrate and bacteria. This study aimed to look at whether the selections of wells sampled without a well log were, in fact, more vulnerable to contamination. Figures 3 and 4 show comparisons of nitrate and bacteria detections between wells with and without wells logs. The orange symbols show wells with nitrate or bacteria detected, and the circular symbols show well without well logs. Orange circles indicate potentially vulnerable wells, however, there does not appear to be a geographical pattern to the location of those wells. A deeper analysis into land use, hydrogeology, and other well characteristics may better be able to describe these contamination occurrences, however that analysis is outside of scope of this particular report.

In addition, Kruskal-Wallis (KW) statistical analyses of these detections found that concentrations of nitrate were not significantly higher in wells without completed well logs ($H(1)=2.151$, $P=0.142$) and also no significant difference in bacteria concentrations was found between the two groups of wells ($H(1)=0.227$, $P=0.633$). These results do not support the hypothesis related to the potential vulnerability of wells without well logs. However as stated previously, the sample size of wells without well logs was small and the complexity and site-specific nature of these contamination occurrence suggest a more multi-faceted analysis is necessary. Section 3.2 will look closer at water quality detections in all wells sampled.

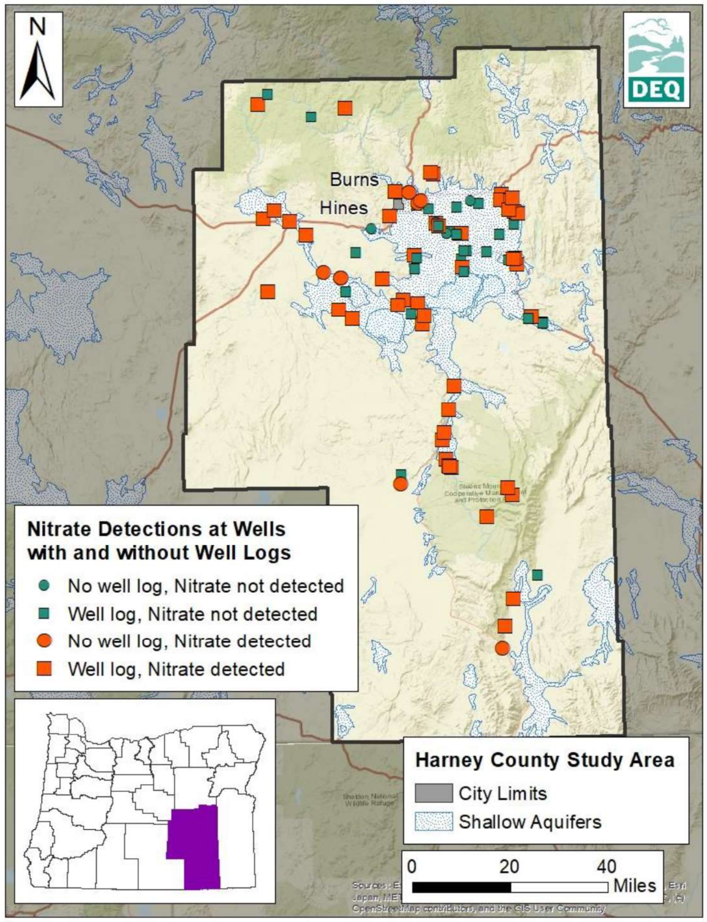


Figure 3. Comparison of the distribution of nitrate results for wells with and without well logs. (Shallow aquifers from Sweet et al., 1980)

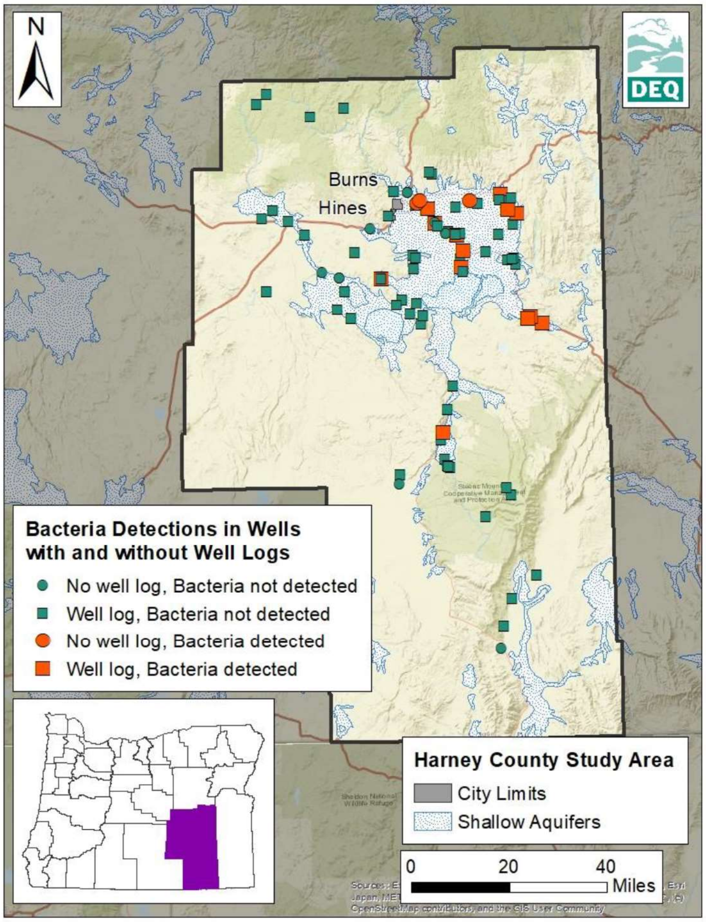


Figure 4. Comparison of the distribution of bacteria (total coliform) results for wells with and without well logs. (Shallow aquifers from Sweet et al., 1980)

3.2 Water Quality

The following sections discuss results for analytes that indicate contamination due to human activities, or present a potential health risk for people drinking the water. Comprehensive analytical reports may be obtained through the Ambient Water Quality Monitoring System (AWQMS) data portal on the DEQ web page, or by contacting the DEQ Laboratory and Environmental Assessment Division. Table 1 summarizes all 42 detected analytes out of 258 analytes sampled for, percentage of wells with detections, maximum concentrations detected, and percentages of wells exceeding application health screening levels.

A note about quantitative data summaries of analytes: due to quality assurance measures related to sampling, sample preparation, and sample analysis, some samples or analytes were downgraded to a lower data quality level (DQL). Only samples and analytes that maintained an A or B data quality level were included in the quantitative analysis described in this report. This may affect how the numbers and percentages of samples add up for each analyte quantitatively described in this report.

Table 1. Summary of 42 analytes detected, percentage of wells with detections, maximum concentrations detected, applicable health screening levels, and percentage of wells exceeding health screening levels

	% wells with detections	% detections over health screening levels	max. conc.	units	Health Screening Level*
General Water Chemistry					
Alkalinity, Total as CaCO3	100%	-	3160	mg/L	not available
Conductivity at 25°C	100%	-	7400	µmhos/cm	not available
Dissolved Oxygen	98%	-	8.7	mg/L	not available
Hardness as CaCO3	99%	-	2470	mg/L	not available
pH	100%	-	12	SU	not available
Temperature	100%	-	39.9	°C	not available
Total Dissolved Solids	100%	-	6100	mg/L	not available
Total Suspended Solids	29%	-	2130	mg/L	not available
Bacteria					
Coliform, Total	18%	18%	345	MPN/100mL	0[2]
E. Coli	3%	3%	10	MPN/100mL	0[2]
Common Ions					
Chloride	98%	-	712	mg/L	not available
Sulfate	96%	-	3520	mg/L	not available
Nutrients					
Nitrate/Nitrite as N	63%	0%	5.48	mg/L	10[1]
Phosphate, Total as P	100%	-	7.61	mg/L	not available
Consumer Product Constituent					
Sulfamethoxazole	2%	-	23	ng/L	not available
Current Use Pesticides					
Total Atrazines[#]	5%		133.4	ng/L	
Atrazine	2%	0%	13.8	ng/L	3000[1]
Deisopropylatrazine	2%	0%	4.31	ng/L	12000[3]
Desethylatrazine	5%	0%	106	ng/L	12000[3]
2,4-D	10%	0%	4700	ng/L	70000[1]
3,5-Dichlorobenzoic acid	1%	-	0.3	µg/L	not available
Diuron	3%	0%	15.6	ng/L	20000[4]
Metsulfuron Methyl	1%	0%	9.01	ng/L	1600000[3]
Prometon	1%	0%	51.7	ng/L	300000[4]
Legacy Pesticides					
Dieldrin	1%	0%	0.0836	ng/L	300
Metals[%]					
Aluminum	24%	3%	52,600	µg/L	7000[5]
Arsenic	86%	31%	655	µg/L	10[1]
Boron	93%	25%	10200	µg/L	2000[6]
Calcium	100%	-	363	mg/L	not available
Iron	54%	-	44,400	µg/L	not available
Lead	40%	0%	13.3	µg/L	15[1]
Magnesium	95%	-	380	mg/L	not available
Manganese	63%	9%	2880	µg/L	300[7]
Potassium	100%	-	45.6	mg/L	not available
Selenium	4%	0%	11.3	µg/L	50[1]
Sodium	100%	-	1710	mg/L	not available
Uranium	62%	0%	6.09	µg/L	30[1]
Vanadium	58%	1%	118	µg/L	86[1]
Volatile Organic Compounds					
Total Trihalomethanes&		0%		µg/L	800[1]
Bromodichloromethane	1%	1%	2.16	µg/L	0[2]
Bromoform	1%	1%	4.21	µg/L	0[2]
Chloroform	1%	0%	0.93	µg/L	70[2]
Dibromochloromethane	1%	0%	5.02	µg/L	60[2]
Tris (1,3-dichloro-2-propyl) phosphate (TDCP)	4%	-	126	ng/L	not available

*If more than one health screening level exists, the lowest concentration is referenced. Does not include USEPA Secondary Maximum Contaminant Levels (SMCL) affecting aesthetic quality only: Chloride and Sulfate (250 mg/L); Aluminum (50-200 µg/L); Iron (300 µg/L); Manganese (50 µg/L).
#includes atrazine, deisopropylatrazine, and desethylatrazine
%Higher of either total or dissolved concentration used
&USEPA MCL pertains to total concentration of all trihalomethanes including bromodichloromethane, bromoform, chloroform, and dibrimochloromethane. Detections of total trihalomethanes did not exceed MCLs in this study.
[1]USEPA Maximum Contaminant Level
[2]USEPA Maximum Contaminant Level Goal - non-enforceable public health goal
[3]USEPA non-regulatory Human Health Benchmark
[4]USGS Health-based Screening Level
[5]ATSDR Health-based guidance for chronic exposure in children
[6]EPA Longer-term Health Advisory for children
[7]EPA Lifetime Health Advisory
reference: https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations#one

3.2.1 Nitrate

While nitrate is a natural and necessary nutrient found in soil and surface water, human activities can enrich the level of nitrate found in the environment. Nitrate enriched water can leach into aquifers from areas of fertilizer use, manure storage or application, or improperly designed or maintained septic systems (Powers and Schepers, 1989). While background concentrations of nitrate in groundwater may only be up to 1 mg/L (Nolan and Hitt, 2003), this report will consider values of 3 mg/L or greater as elevated, which is consistent with USGS interpretations. This represents a level sufficiently above background to indicate an impact from human activities on groundwater quality. Drinking water with high nitrate may cause serious health problems for infants, pregnant women and nursing mothers. To protect the public from these health risks, the EPA has set the maximum contaminant level for nitrate at 10 mg/L. Fifty-seven out of ninety-one wells had detections of nitrate, ranging from 0.0065 mg/L to 5.48 mg/L. Seven wells (8%) had nitrate concentrations above what are considered natural background levels (higher than 3 mg/L; Figure 5). These detections were spread throughout the county. There were no wells above the maximum contaminant level (10 mg/L; Figure 6).

As mentioned previously, nitrate in this study was measured as nitrate/nitrite as N. While nitrite is rarely found in groundwater at significant levels due to geochemical conditions, these results represent a conservative measurement of nitrate. More information on nitrate risks and recommendations can be found in DEQ's Fact Sheet: Nitrate in Drinking Water.[7]

[7] https://www.oregon.gov/deq/FilterDocs/nitratedw.pdf or in Spanish (en español) https://www.oregon.gov/deq/FilterDocs/NitrateSpanishVersion.pdf

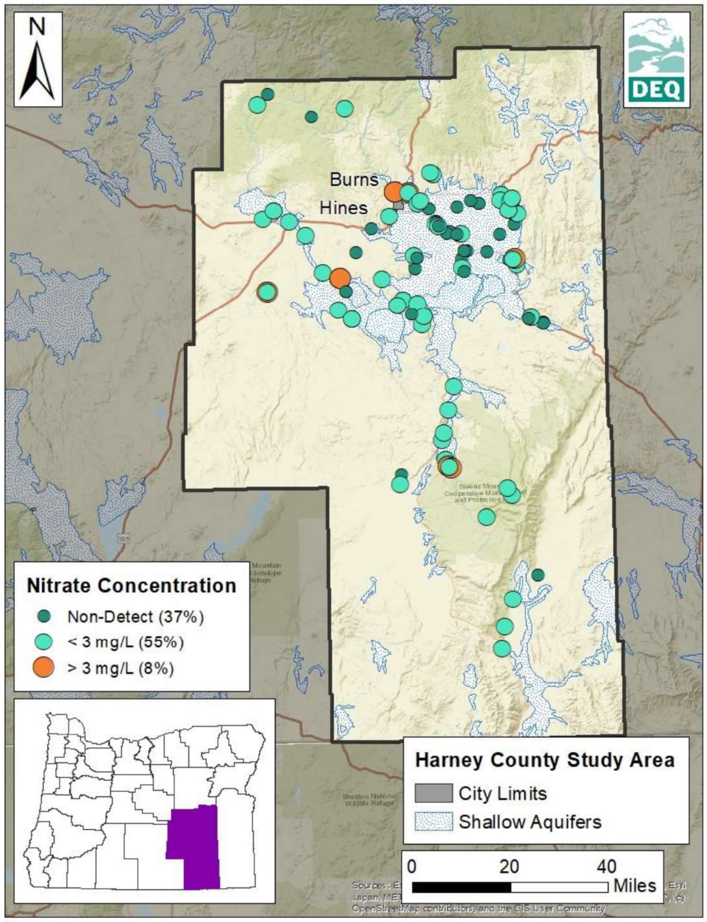


Figure 5. Nitrate concentrations detected in sampled wells. Results higher than 3 mg/L are considered elevated due to human activities. The maximum contaminant level (MCL) for nitrate in drinking water is 10 mg/L. None of the detected concentrations exceeded the MCL. (Shallow aquifers from Sweet et al., 1980)

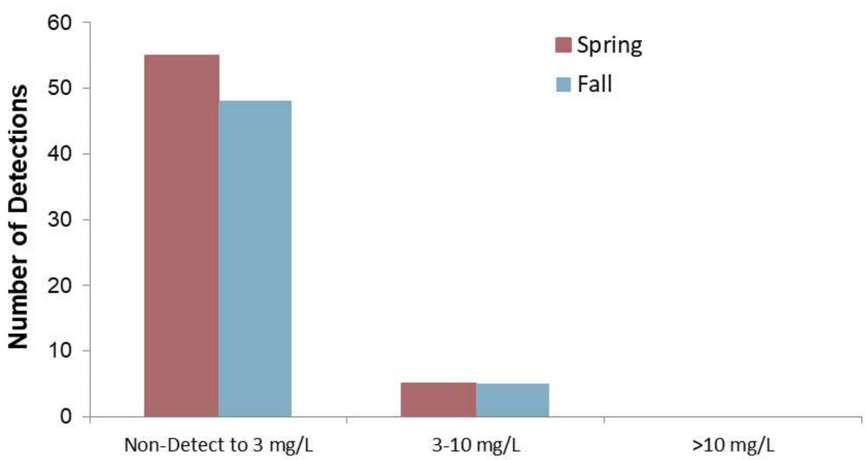


Figure 6. Nitrate concentration in number of sampled wells. Spring results are on the left, fall results are on the right. Results higher than 3 mg/L are considered elevated due to human activities. The maximum contaminant level (MCL) for nitrate in drinking water is 10 mg/L.

3.2.2 Arsenic

Arsenic is a naturally occurring element found in the earth's crust. It is found in groundwater throughout Oregon, often associated with volcanic geology. Past uses included agricultural application, especially in orchards, as an insecticide and as embalming fluids prior to 1945, indicating historic cemeteries as potential sources of arsenic. Arsenic geochemistry is complex and several factors may influence the mobility of arsenic from these sources into shallow groundwater (Welch et al., 2000). Most arsenic in groundwater is a result of dissolution of arsenic-containing minerals in soil and rock. Arsenic in drinking water is a health hazard and EPA has established a maximum contaminant level for total arsenic at 10 µg/L. However, the maximum contaminant level goal is zero. Arsenic concentrations in the wells sampled ranged from 0.25 µg/L to 655 µg/L. Seventy-eight wells out of 91 had detections of arsenic. Twenty-eight wells had arsenic concentration at or above the MCL of 10 µg/L (31% of wells). These detections were spread throughout the county (Figure 7).

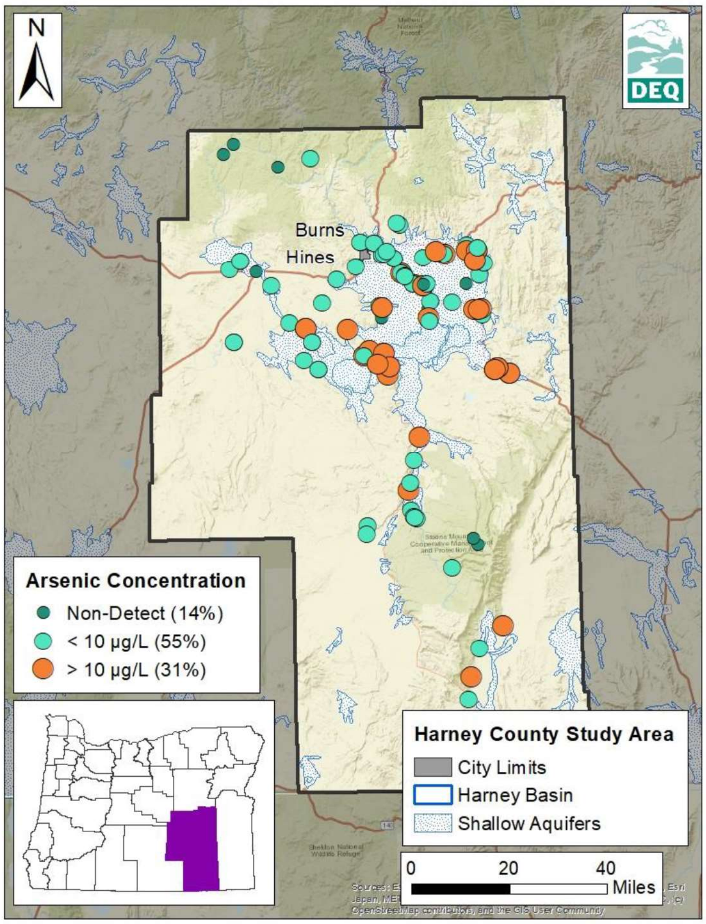


Figure 7. Arsenic results detected in sampled wells. The maximum contaminant level (MCL) for arsenic in drinking water is 10 µg/L. (Shallow aquifers from Sweet et al., 1980)

3.2.3 Coliform Bacteria and *E. coli*

Coliform bacteria are a group of closely related bacteria that are typically not harmful to humans. However, coliform bacteria are a useful indicator to determine if similar, disease-causing microorganisms (e.g., bacteria, viruses) may be present in water bodies. *E. coli* is a specific class of coliform bacteria more commonly associated with illness. Presence of coliform bacteria may indicate a problem with the integrity of a well's construction allowing contamination from surface or soil sources into the well. Bacterial contamination may also affect shallow groundwater through improperly designed or maintained septic systems, or leaching from areas where manure or biosolids are spread. The maximum contaminant level goal for coliform bacteria is zero.

Coliform bacteria were detected in 16 of 91 wells (18%), and *E. coli* was detected in 3 of those wells. There was no significant difference (Kruskal-Wallis) between detections of coliform bacteria in the spring vs the fall ($H(1)=0.52$, $P=0.820$). Detections were primarily in the central Harney Basin valley, with a few wells in the Alvord desert (Figure 8). Public health officials recommend testing well water for coliform bacteria annually and the prevalence of coliform bacteria detected in this study strongly supports that recommendation.

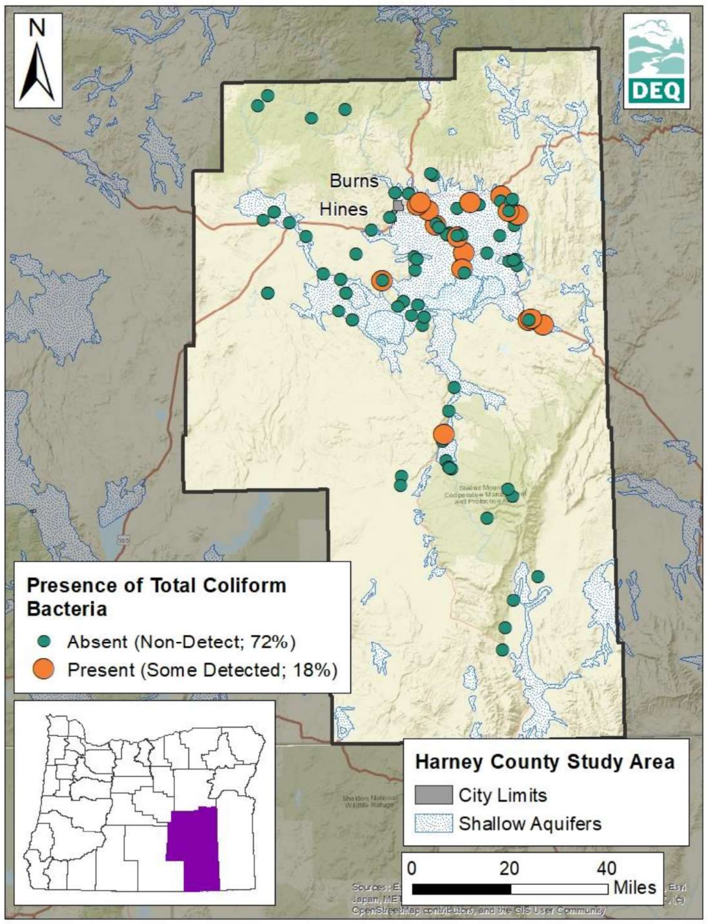


Figure 8. Total coliform bacteria detected in sampled wells. (Shallow aquifers from Sweet et al., 1980)

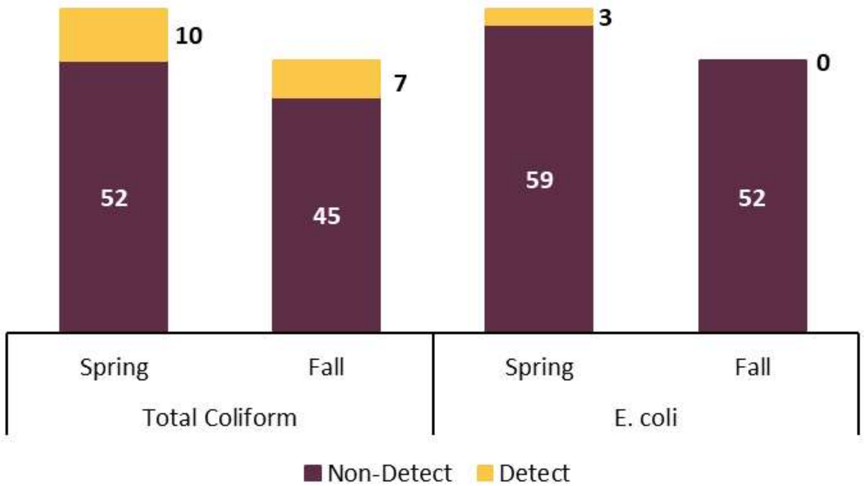


Figure 9. Total coliform and *E. coli* results for all samples collected in 2018. Non-detect is below, detect is above.

3.2.4 Pesticides

Pesticides are a broad class of chemicals that includes insecticides, herbicides and fungicides. Pesticides that are currently used and those no longer in use (legacy) are both included in the study. Legacy pesticides refer to chlorinated insecticides, such as DDT, which are banned in the United States. This study also measured several chemicals that are breakdown products of pesticides. Physical processes, such as photo-degradation by sunlight, or biological processes, such as metabolism by bacteria, can break parent pesticides down into different chemicals that may be more soluble and travel more easily into groundwater. In general, less information is known about the potential health impacts of these breakdown products than the parent pesticide. It is common to detect the breakdown product of a pesticide in a water sample, but not the parent pesticide, due to differences in solubility and other chemical properties.

Of the 137 pesticides analyzed, 104 were current use pesticides and 33 were legacy pesticides. Nine different pesticide-related chemicals were detected in this study, representing seven different parent pesticides (Table 1). At least one current use or legacy pesticide related chemical was detected in 18 of the 91 wells, or 20% of the wells sampled in this study.

The most commonly detected pesticide was 2,4-D, detected in nine wells ranging from 100 – 4700 ng/L. These detections account for 10 out of the 11 highest pesticide concentrations detected in this study. Atrazine and its breakdown products were detected in five wells, ranging from 3.49 to 106 ng/L.

2,4-D (2,4-Dichlorophenoxyacetic Acid) is used as an herbicide for the control of broad-leaf weeds in agriculture, and for control of woody plants along roadsides, railways, and utilities rights of way. Some people who drink water containing 2,4-D in excess of the MCL for many years could experience problems with their kidneys, liver, or adrenal glands (EPA Pesticide Fact Sheet for 2,4-D). The EPA has established a MCL of 70,000 ng/L for 2,4-D in drinking water. The highest detection of 2,4-D in this this study was 4700 ng/L.

Atrazine is an herbicide used to control grasses and broadleaf weeds on corn (field and sweet), sorghum, wheat, conifer forests, Christmas tree farms, sod farms, golf courses, and lawns. Atrazine is also used in Oregon on range grasses to establish permanent grass cover on range and pasture land. Atrazine is known to disrupt normal hormone signaling in the body and can be harmful to health (NPIC – Atrazine Factsheet). The maximum detection of total atrazines detected in any well was 57.45 ng/L. The EPA has established a maximum contaminant level (MCL) of 3,000 ng/L for atrazine in drinking water. The detections of atrazine and all of its breakdown products were well below this MCL. These breakdown products are more water-soluble than the parent chemical and readily leach into groundwater. There have been very few studies on the toxicity of these breakdown products, however the available data indicate that they are no more toxic than the parent chemical (EPA, Memorandum 2016).

There was detection of DBA at 300 ng/L in one well sampled in the spring, and it was not detected when resampled in the fall. This is first detection of 3,5-dichlorobenzoic acid (DBA) in groundwater sampled in the statewide groundwater program since 2015. DBA acid can be formed by degradation of 2,6-dichlorobenzamide (BAM) and dichlobenil. Dichlobenil is used for selective weed control in cranberry bogs, nurseries, fruit orchards, vineyards, forest plantations, public green areas, and for total weed control (industrial sites, railway lines, under asphalt, etc.). It can also be used to control weeds in non-flowing water. There is not a Maximum Contaminant Level for DBA however the EPA has calculated a non-regulatory Human Health Benchmark for 2,6-dichlorobenzamide (BAM) at 32,000 ng/L and for dichlobenil as 70,000 ng/L (Jensen et al., 2009).

The only legacy pesticide detected was dieldrin, in one well (0.0836 ng/L). Aldrin and dieldrin are insecticides with similar chemical structures. Aldrin quickly breaks down to dieldrin in the body and in the environment. Pure aldrin and dieldrin are white powders with a mild chemical odor. Neither substance occurs naturally in the environment. From the 1950s until 1970, aldrin and dieldrin were widely used pesticides for crops like corn and cotton. Because of concerns about damage to the environment and potentially to human health, EPA banned all uses of aldrin and dieldrin in 1974, except to control termites. In 1987, EPA banned all uses. The EPA limits the amount of aldrin and dieldrin that may be present in drinking water to 1000 ng/L and 2000 ng/L, respectively, for protection against health effects other than cancer (ATSDR.cdc.gov).

All detected pesticide related chemicals were well below any known human health screening level. Five of the wells had two or more pesticide chemicals detected (Figure 10), and three wells had chemicals from more than one parent pesticide detected (Figure 11). Very little research has been done on the combined effects of chemical mixtures on human health. A common practice is to add the concentration of all related chemicals (parents and their breakdown products, or pesticides with similar structures or modes of action) and compare that concentration to the lowest screening level of those chemicals. This method assumes that the combined effect of the chemicals is no worse than the most toxic of the individual chemicals (WHO, 2017). Using this method, the results for total atrazines and are still far below a level that may cause any health risk (Table 1).

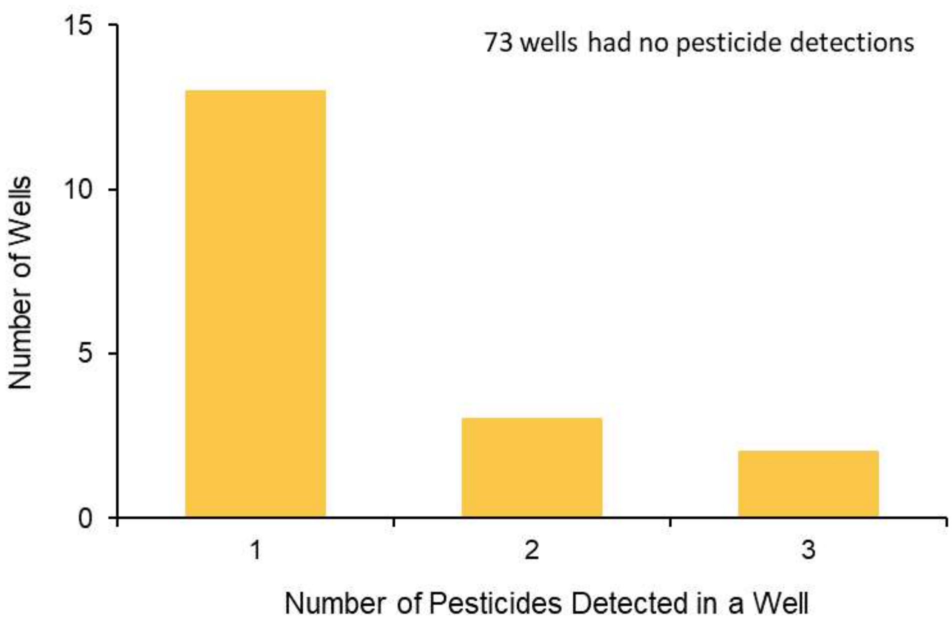


Figure 10. Histogram of total number of pesticides detected in individual wells.

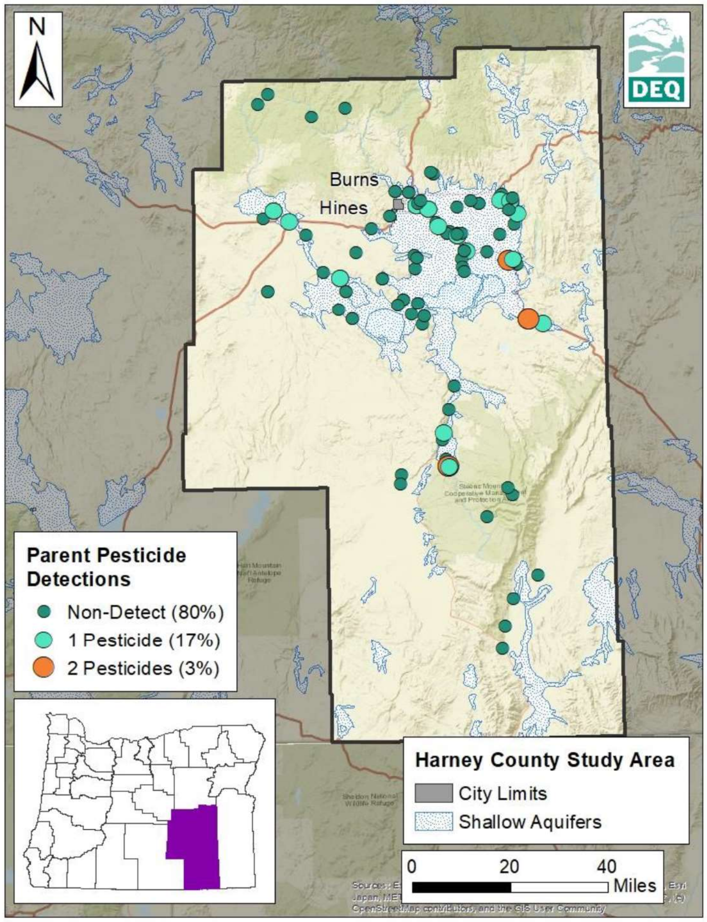


Figure 11. Number of parent pesticides detected in sampled wells. (Shallow aquifers from Sweet et al., 1980)

3.2.5 Consumer Product Constituents

Consumer product constituents include fragrances, pharmaceuticals, insect repellants and other products found in everyday household chemicals, cleaning products, beauty products, clothing, and medications. One of the goals for this Statewide Groundwater Monitoring Program was to investigate emerging groundwater quality problems. Consumer product constituents detected in groundwater are considered indicators of nearby on-site wastewater treatment systems that are not primarily designed to function as treatment for pharmaceuticals and personal care products (PPCPs) (Phillips et al., 2015).

Examples of commonly detected consumer products in other studies include the insect repellant DEET, the stimulant caffeine, and the antibiotic sulfamethoxazole. These constituents likely make their way into the water through wastewater discharges and septic systems. Although detected levels are significantly lower than a human pharmaceutical dose, presence of these chemicals in aquatic systems may lead to aquatic life impacts (Gagne et al., 2006). Detections of these chemicals in groundwater wells indicates a potential aquatic life impact through possible surface and groundwater interactions. No water quality criteria or benchmarks currently exist for most of these compounds. Only one of the 11 compounds in this group was detected during this study. Sulfamethoxazole was detected in one well sampled in the spring and fall of 2018 (Figure 12).

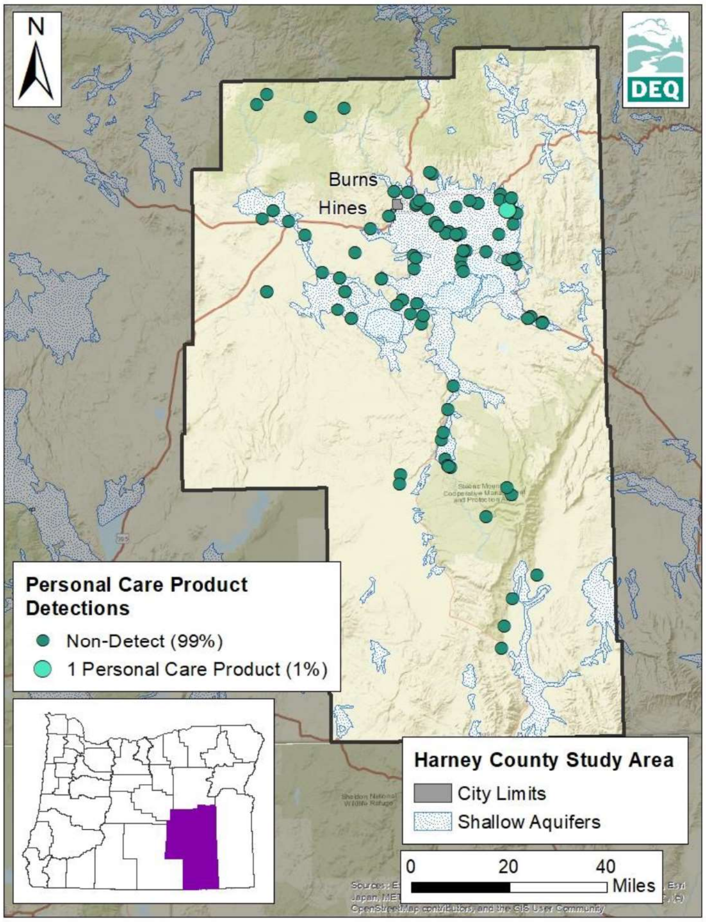


Figure 12. Number of personal care products detected in sampled wells. (Shallow aquifers from Sweet et al., 1980)

3.2.6 Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are a class of chemical compounds that share two main properties: (1) they evaporate easily from water into the air and (2) they contain carbon. They are associated with products such as plastics, adhesives, paints, gasoline, fumigants, refrigerants, and dry-cleaning fluids. Biological sources of VOCs include trees, cows and termites (methane), and cultivation. Crude oil tanking can also release VOCs into the atmosphere. When spilled or improperly disposed of, VOCs may be released into the environment and may reach groundwater through many sources and pathways, including exhaust from gasoline engines, industrial air emissions, leaking storage tanks, landfills, infiltration of urban runoff and wastewater, septic systems, and injection through wells. Factors that influence the likelihood of contamination include: 1) proximity of the well to the source of contamination; 2) the amount of VOCs that are spilled or discarded; 3) depth of the well (shallow wells are affected by surface spills more quickly and more severely than deep wells); 4) local geology (groundwater that is protected by thick, dense soils is less vulnerable to contamination); and 5) time (groundwater moves slowly, so it can take months or years after a spill before contamination reaches wells). (https://pubs.usgs.gov/circ/circ1292/pdf/circular1292.pdf and VOCs_Wellcare_Updated_May_2007). Some VOCs are known or suspected human carcinogens and their concentrations in drinking water from public water systems are regulated by the EPA.

Out of the 68 VOCs analyzed in this study five were detected in five different wells (6% of wells). One well sampled in the fall contained four different trihalomethane VOCs (Figure 13). Trihalomethanes are formed as a byproduct when chlorine is added to drinking water to kill disease-causing organisms. Two of those chemicals, bromodichloromethane and bromoform, have non-enforceable EPA Maximum Contaminant Level Goals

(MCLG) of zero. They were detected at low concentrations of 2.16 µg/L and 4.21 µg/L, respectively. The other two trihalomethane chemicals, chloroform and dibromochloromethane have MCLG levels of 70 µg/L and 60 µg/L, respectively, neither detections exceeding those levels. The combination of the four trihalomethane concentrations did not exceed the EPA Maximum Contaminant Level of 800 µg/L.

Chlorinated tris (TDCP) was the most commonly detected, found in four wells ranging in concentration from 51.8 ng/L to 126 ng/L. Chlorinated tris is the common name for Tris (1,3-dichloro-2-propyl) phosphate (TDCP). This chemical belongs to the family of organophosphate flame retardants (OPFRs). TDCP may be used as flame retardants in flexible PUR foams found in baby mattresses, car safety seats, baby slings, and residential upholstered furniture. Dust is found to be a major source of exposure to many flame retardants and young children have been found to be among the most highly exposed. Traces of TDCP have been detected in sewage effluent, river water, seawater, drinking water, sediment, and in fish throughout the world. In laboratory animal studies, TDCP has been associated with cancer of the liver, kidney, brain and testis. It has also been found to cause other harmful effects in the liver, kidney, bone marrow, and testis (Natural Resources Defense Council, 2010). The Environmental Protection Agency has not set a health-based standard or a maximum contaminant level for this contaminant. The California Environmental Health Agency proposed that the no significant risk level (NSRL) for TDCP is 5.4 µg/d based on carcinogenicity research in rodents in 2012 (Wang, et al., 2020). TDCP was not detected at levels in this study that are expected to contribute to health concerns.

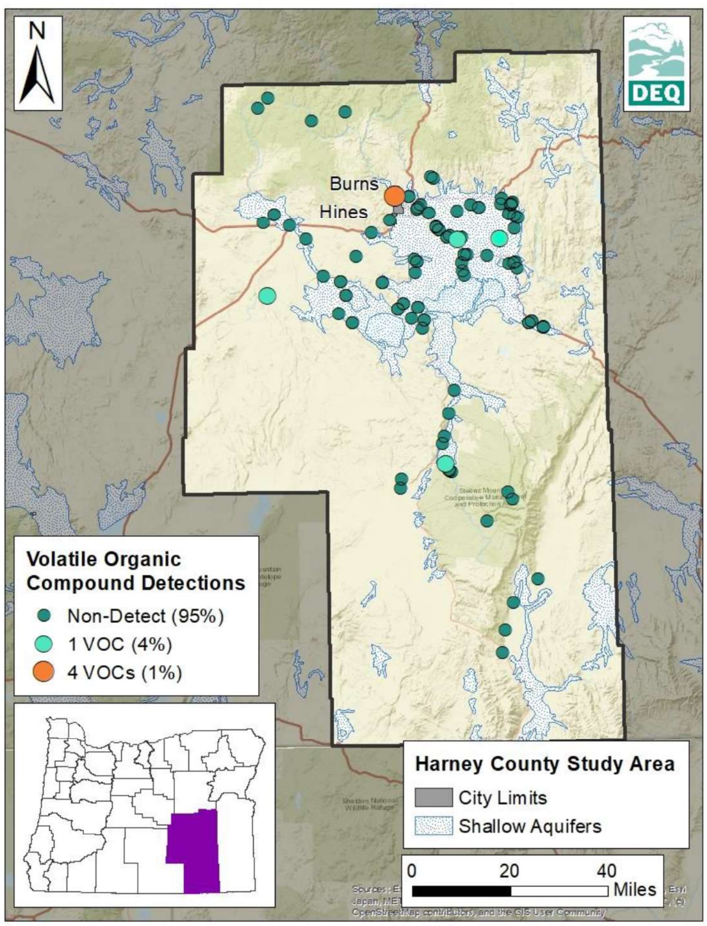


Figure 13. Number of volatile organic compounds detected in sampled wells. (Shallow aquifers from Sweet et al., 1980)

3.2.7 Boron

Boron was detected in 85 wells (93%), with concentrations ranging from 20.9 µg/L to 10200 µg/L. Twenty-three wells exceeded the Longer Term Health Advisory Level for children of 2000 µg/L. Six wells exceeded the Lifetime Health Advisory for adults of 6000 µg/L (Figure 14).

Boron is a non-metallic, naturally-occurring, element found in rocks, soil, and water. Boron does not exist as a pure element but is combined with oxygen as borate minerals and various boron compounds such as boric acid, borax, and boron oxide. Boron compounds are used primarily in the production of glass and ceramics, pesticides, fire retardants, plus insulation-grade- and textile-grade-glass fibers. Boron can be present in commercial plant foods and fertilizers. Boron compounds are often found in household laundry and cleaning products. Boron gets into drinking water from both naturally-occurring and man-made sources. Some areas in the western United States (California, Nevada, Oregon) have high concentrations of boron in some of their soils. Contamination of water can come directly from industrial wastewater and municipal sewage, as well as indirectly from air deposition and soil runoff. Natural weathering processes, burning of coal in power plants, chemical plants, and manufacturing facilities release boron into the air; and fertilizers, herbicides, and industrial wastes are among the sources of soil contamination. Boron is found in soil and is taken up by plants. It is found naturally in fruits, legumes, nuts, vegetables, and grains. Dietary levels can be as high as 5-6 mg/day for some individuals.

An acute boron overdose to infants has caused diarrhea, vomiting, signs of irritability, redness in the diaper area, a mild red rash on the face and neck, a pus-like discharge or mild congestion of the eye, and possibly convulsive seizures. In adults, an acute overdose causes nausea, vomiting, redness of the skin, difficulty swallowing due to ulcers in the throat, and a non-bloody diarrhea. In animals, acute excessive exposure has caused lethargy, rapid respiration, eye inflammation, swelling of the paws, shedding of the skin on the paws and tails, excitation during handling, and changes in the cells of the forestomach (EPA Health Advisory for Boron and Compounds, 2008).

The EPA has set a One-Day and Ten-Day Health Advisory at 3000 µg/L and a Longer-Term Health Advisory of 2000 µg/L for children. A Lifetime Health Advisory (HA) for adults is set at 6000 µg/L. Water containing boron at levels above the HA should not be used to prepare food or formula for infants and children.

The levels of boron found in this study also may indicate challenges for irrigated lands. Plants have tolerance levels for boron in irrigation water. Low tolerance indicates those plants that prefer boron levels no greater than 500-1000 µg/L. Moderate tolerance plants prefer a range of 1000-2000 µg/L. High tolerance plants should tolerate levels in the 2000-10,000 µg/L range (Food and Agriculture Organization (FAO)).

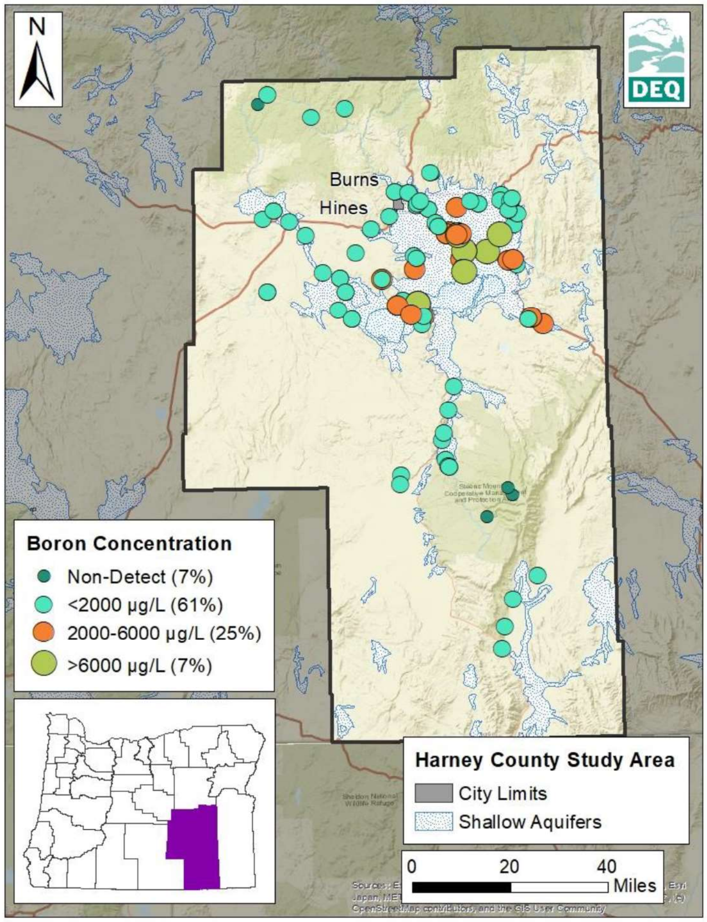


Figure 14. Boron results in sampled wells. The EPA Longer Term Health Advisory 2000 µg/L and the Lifetime Health Advisory is 6000 µg/L. (Shallow aquifers from Sweet et al., 1980)

3.2.8 Manganese

Manganese is an element found in many soils, rocks and minerals. In areas with manganese-containing minerals, manganese may be present in the groundwater under low-oxygen conditions. At high concentrations, manganese has been associated with neurological disease. EPA has set a secondary drinking water standard for manganese at 50 µg/L to avoid discoloration, staining and a metallic taste. Water above the secondary drinking water standard is usually not palatable for drinking without treatment, but it does not have concerning health effects. EPA also has calculated a Lifetime Health Advisory for manganese in drinking water at 300 µg/L. Manganese was detected in 57 of the wells (63%) sampled in this study at concentrations ranging from 2.04 µg/L to 2880 µg/L. Thirty-four wells were detected at levels below the 50 µg/L secondary drinking water standard and 23 were above 50 µg/L. Eight wells (9%) were above the 300 µg/L Lifetime Health Advisory (Figure 15).

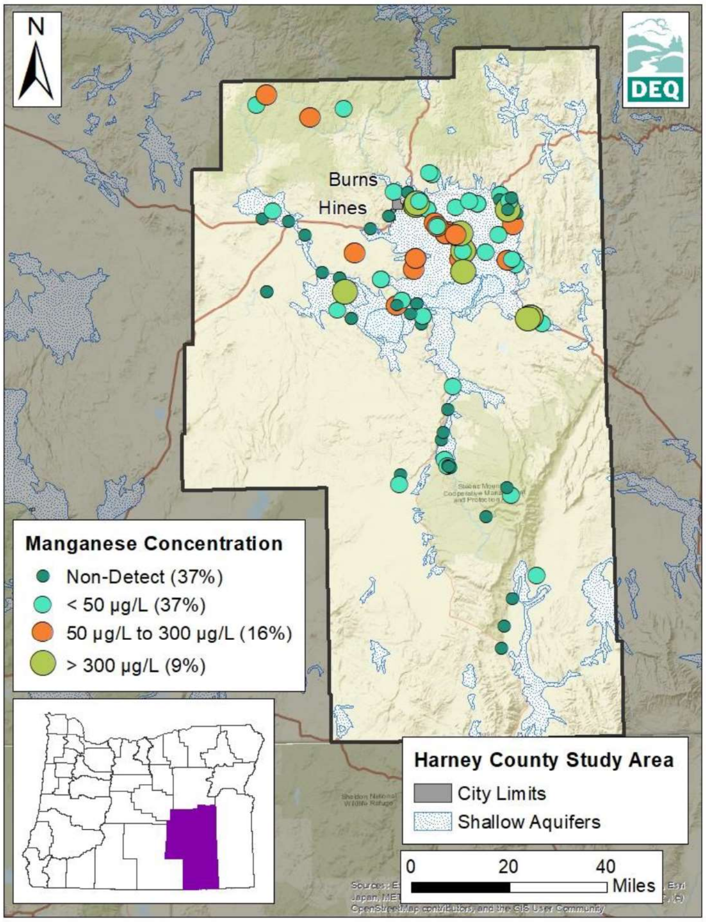


Figure 15. Manganese results in sampled wells. The secondary drinking water standard for manganese is 50 µg/L and the Lifetime Health Advisory is 300 µg/L. (Shallow aquifers from Sweet et al., 1980)

3.2.9 Uranium

Uranium is a natural element found throughout the environment. Uranium in water comes mainly from rocks and soil as water passes over them. Nearly all naturally occurring uranium is non-radioactive (OHA, 2007). EPA has established a maximum contaminant level of 30 µg/L for uranium in drinking water. Low concentrations of uranium were detected in 56 of the 91wells (62%) sampled in this study. The maximum concentration measured was 6.09 µg/L, below the maximum contaminant level.

3.2.10 Vanadium

Vanadium is found in many different minerals as well as in coal and other fossil fuels. Vanadium may be released to the environment through the combustion of fossil fuels, or through natural weathering processes of rocks and soils. Nausea, mild diarrhea, and stomach cramps have been reported in people who have been exposed to some vanadium compounds. A number of negative health effects have been found in animals ingesting vanadium compounds, including decreases in the number of red blood cells, increased blood pressure, and mild neurological effects. There is no federal or state regulatory standard for vanadium in drinking water. However, EPA has set a Regional Screening Level for resident tap water of 86 µg/L for vanadium. Vanadium was detected in 53 of the 91 study wells (58%). Only one well exceeded the Regional Screening Level, with a maximum concentration of 118 µg/L.

3.2.11 Lead

Lead was detected in 37 of the 91 wells (41%) sampled in this study ranging for 0.2 to 13.3 µg/L, none exceeding the MCL. Lead, like manganese and arsenic, can end up in groundwater due to the erosion of natural deposits, however, the most common source of lead in drinking water is from the corrosion of household plumbing systems. Lead is typically tested using the “first flush” method, which collects water that had been sitting in the pipes. For this study, however, DEQ staff flushed each well for 5-10 minutes prior to sampling. This ensures that stagnant water has been flushed and that samples indicated background lead levels present in the groundwater rather than water that may have contained lead due to corrosion from sitting in the pipes. The EPA has established a Maximum Contaminant Level (MCL) of 15 µg/L for lead in drinking water.

3.2.12 Aluminum

Aluminum was detected in 24% of wells sampled. Three wells exceed the Agency for Toxic Substances and Disease Registry (ATSDR) Health-based guidance for chronic exposure in children of 7000 µg/L. Aluminum is the most abundant metal in the earth’s crust and small amount of aluminum can be found dissolved in water. It is light in weight and used for beverage cans, pots and pans, airplanes and foil. It is often mixed with other metals to form aluminum alloys which are stronger and harder. Aluminum compounds can be found in consumer products such as antacids, astringents, buffered aspirin, food additives, cosmetics and antiperspirants. You can be exposed to aluminum through food, water, and air and in small amounts from vaccinations. Exposure is usually not harmful, but high levels can affect the health of your nervous system. The EPA has recommended a Secondary Maximum Contaminant Level (SMCL) of 0.05-0.2 mg/L (50-200 µg/L) for aluminum in drinking water. That level is set based on changes to the color of the water and it is not associated with any health effects in humans or animals. EPA doesn’t have a health-based standard for aluminum. The Agency for Toxic Substances and Disease Registry (ATSDR) has a health-based guidance for chronic exposure in children (the chronic child ‘environmental media evaluation guidelines’ or EMEG) of 7000 µg/L.

3.2.13 Selenium

Selenium was added to the analyte list for this study out of local landowner concern about salt deposits on irrigated land. Selenium was detected in 4% of the wells sampled ranging from 2.2 µg/L to 11.3 µg/L, none of them exceeding the EPA Maximum Contaminant Level for drinking water set at 50 µg/L. This concentration range detected in this study also indicates that selenium is unlikely contributing to salt deposits on irrigated land in the area (Albasel et al., 1989). Selenium is a trace mineral needed in small amounts for good health. It is a metal that is found in natural deposits such as ores containing other elements. The major sources of selenium in drinking water are discharge from petroleum and metal refineries; erosion of natural deposits; and discharge from mines. Some people who drink water containing selenium well in excess of the maximum contaminant level (MCL) for many years could experience neurological effects, brittle hair, deformed nails, numbness in fingers or toes, or problems with their circulation (ATSDR, 2003).

3.3 Seasonal Differences

Twenty-one wells were sampled during both the spring (March-April 2018) and fall (October-November 2018) sampling events in an effort to capture the seasonal variability of results. Resampled wells were chosen based on availability for sampling and geographic distribution within the study area. When analyzing for contaminants that leach through shallow soils and are seasonally applied, such as nitrate and pesticides, there were no statistically significant differences (Kruskal-Wallis) between the wells sampled in the spring and the fall (pesticides ($H(1)=0.141$, $P=0.707$; nitrate ($H(1)=0.049$, $P=0.825$)). Figure 16 displays the average concentration of detected pesticides in spring and fall. Figure 17 displays the average concentration of detected nitrate in spring and fall.

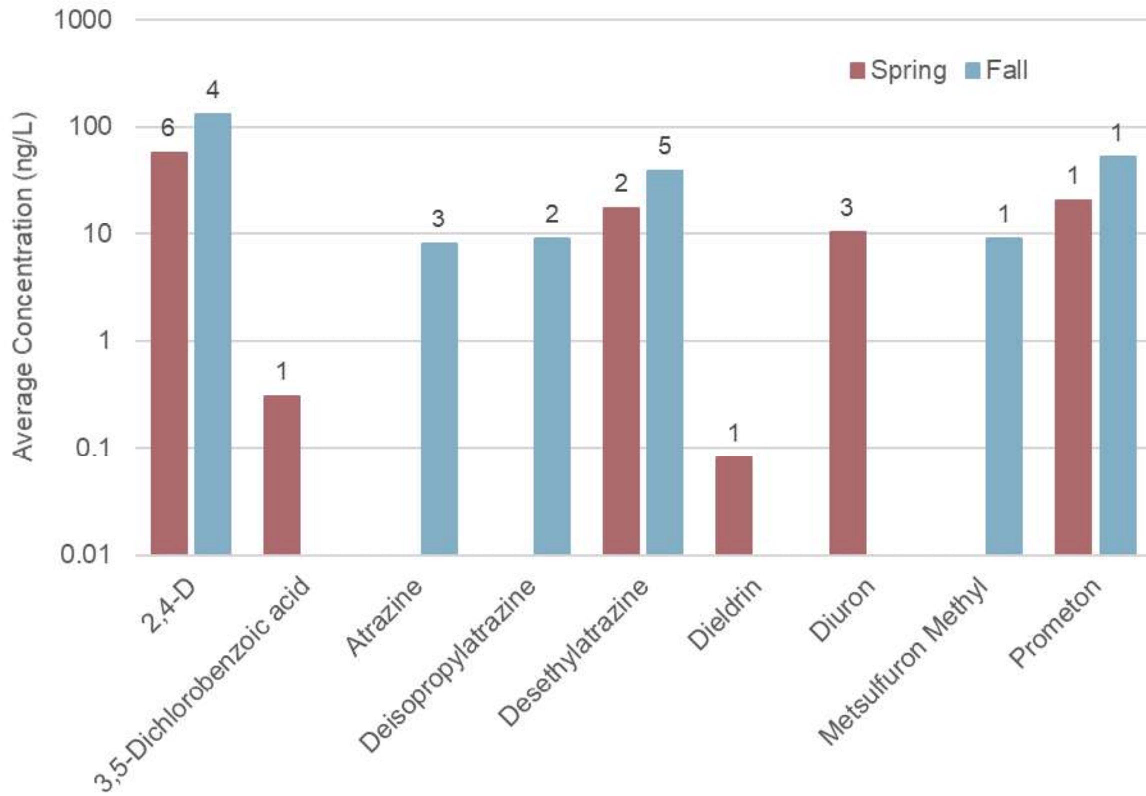


Figure 16. Average pesticide concentrations detected by season. The number on top of the columns indicates the number of detections included in the average concentration. Spring results are on the left, and fall results are on the right of each paired column.

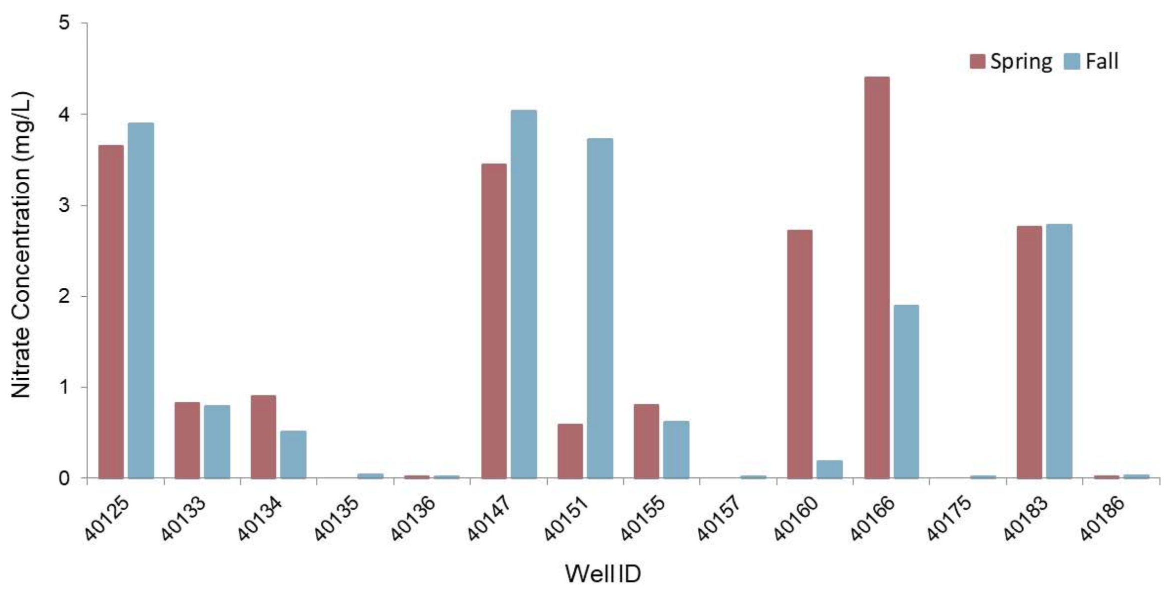


Figure 17. Nitrate concentrations in wells sampled during both the spring and fall 2018 sampling events. Nitrate was detected in either spring or fall in 14 out of the 21 resampled wells. The five digit numbers represent the DEQ

sampling station ID of individual wells. Spring results are on the left, and fall results are on the right of each paired column.

3.4 Effects of Well Characteristics on Water Quality

Well depth data was available for 80 of the 91 wells sampled and shows that well depths ranged from 13 feet below ground surface (bgs) to 800 ft bgs. Seventeen wells were 100 ft or shallower in depth. When analyzed (Kruskal-Wallis) for the presence of bacteria ($H(1)=0.054$, $P=0.816$), nitrate ($H(1)=1.855$, $P=0.173$), and total pesticide concentrations by depth ($H(1)=0.003$, $P=0.953$), there were no significant differences between wells under 100 ft and those over 100 ft in depth.

4. Summary

The 2018 Harney County groundwater study met its objectives in the following ways:

1. *To collect high-quality data on nitrate, arsenic, coliform bacteria, pesticides, pharmaceutical and personal care products, volatile organic compounds and other contaminants of local concern in groundwater throughout the study area;*
   Groundwater quality data for 91 wells within the study area are available. This represents the largest quality-controlled groundwater investigation in the area since 1994 (ODEQ). This data may be used in future analyses of specific groundwater issues or to support and focus outreach activities. The data collected here is also able to inform other studies, such as the joint USGS and OWRD study that is using isotopic data combined with water chemistry data to develop a conceptual groundwater-flow model in the Harney Basin.

2. *To identify areas of groundwater contamination related to these parameters*
   Arsenic is widespread in groundwater in Harney County, and frequently at concerning levels for human health. There are elevated detections of nitrate throughout the county that suggest anthropogenic contamination, but none detected at levels concerning for human health. Bacteria detections found through the county are also of a concern for human health. Boron contamination is widespread, including levels that are a concern for human health. There are detections of pesticides that suggest vulnerable aquifers, although none are at a level that are a concern for human health.

3. *To inform well water users of the results of this study and provide information regarding potential risks to human health*
   In addition to the 16 wells with bacteria detections, there were 28 detections of arsenic, 23 detections of boron, 1 detection of vanadium, 8 detections of manganese, 3 detections of aluminum, and 2 detections of volatile organic compounds that exceeded a maximum contaminant level or other health-based benchmark. These detections account for a total of 53 wells (58%) with at least 1 contaminant exceeding health standards. All of these well owners were notified of these results by DEQ staff and referred to local and state public health resources to discuss potential risks. While current use and legacy pesticides were detected in 18 wells, all results were well below any health-based benchmark and not expected to pose a health risk.

4. *To identify areas needing additional investigation in order to describe the extent of contamination and help focus efforts to prevent further contamination.*
   This study confirmed widespread and elevated levels of arsenic and boron throughout the county attributed to the geologic qualities of the area. There are also elevated levels of bacteria and nitrate that should be monitored. Hydrogeologic analyses and investigations into the sources of contamination were outside the scope of this study.

5. *To help establish long-term trending data and describe changes over time.*
   This study established baseline ambient conditions of wells throughout Harney County, with data on 258 different analytes. With extended permission, many of the wells sampled in this study, including BLM and OWRD monitoring wells have the potential to be established as long-term monitoring sites to track the changes in these analytes over time.

5. Recommendations

Prevention Efforts: Groundwater contamination is a long-lasting problem and reversing the impacts of contamination in groundwater is neither straightforward nor easy. Steps should be taken to reduce any further negative impacts from human activity and continue to test and monitor for contamination so that it does not go undetected for very long. Additional analysis of data from this study, as well as data from previous studies, and the Oregon Health Authority's Real Estate Transaction Act (ORS 448.271) data can further refine the extent of groundwater contamination and contribute to identifying the sources of nitrate, pesticide and bacterial contamination. With this information, strategies can be developed to help prevent further degradation of groundwater quality.

Continued Monitoring in a Well Network: Long-term monitoring of arsenic, boron, manganese, aluminum, vanadium, nitrate, bacteria, volatile organic compounds, and pesticides, particularly 2,4-D and atrazine degradates, is recommended to prevent vulnerable wells and groundwater from being subjected to unmonitored contamination. While concentrations of bacteria, arsenic, boron, manganese, aluminum and vanadium exceeded their respective maximum contaminant levels in some wells, levels of all contaminants may change over time. A network of wells should be established and monitored to detect any changes over time. Continued monitoring could be established locally, or, with continued funding, the Statewide Groundwater Monitoring Program would be able to consider addition of wells within this basin to be included in the agency's long-term monitoring network.

Outreach and Education: Results from this study can be used to focus public health outreach in areas where contamination exists. There is no state regulatory oversight of water quality criteria when using water from private wells, and regulations only require wells to be tested at the point of sale. OHA recommends that private well owners get their wells tested annually for nitrate and bacteria, and to test the well at least once for arsenic. Despite this recommendation, many well owners are unaware of their water quality. Overall results of this study, and the on-going statewide monitoring program, can be used to better understand the threats to and quality of the groundwater resources of Oregon. Oregon's Statewide Groundwater Quality Monitoring Program intends to stay connected with future groundwater monitoring efforts in Harney County and to look for opportunities to establish long-term monitoring stations around the state. To stay up to date and learn more about what Oregon is doing to monitor groundwater quality, visit DEQ's Groundwater Protection webpage.

Resources: There are many resources available to help domestic well owners in Oregon. As part of the recommendations of this Harney County Groundwater Report, the following list of resources is provided to well owners:

- The *Oregon Domestic Well Safety Program* (www.healthoregon.org/wells) focuses on improving local and state capacity to assess and manage risks associated with private wells. DWSP partners with local health departments and water information providers to further promote domestic well safety. *Note: the Oregon Domestic Well Safety Program is without continued funding at the writing of this report (March 2021).*

- The Oregon Water Resources Department and Oregon Health Authority publish a brochure, "Water Well Owner's Handbook: A guide to water wells in Oregon" which provides general information on groundwater, water wells, well construction, operation, maintenance and abandonment information (https://www.oregon.gov/OWRD/WRDPublications1/Well_Water_Handbook.pdf).

- DEQ's Drinking Water Protection Program has developed many tools for public water systems that can be readily used for domestic wells:
  - Basic Tips for Keeping Drinking Water Clean and Safe https://www.oregon.gov/deq/FilterDocs/dwpBasicTips.pdf
  - Groundwater Basics for Drinking Water Protection https://www.oregon.gov/deq/wq/programs/Pages/GWP-Basics.aspx

6. References

Albasel, N., Pratt P.F., and Westcot D.W., 1989. Guidelines for Selenium in Irrigation Waters. Journal of Environmental Quality.

ATSDR. ToxFAQs. ToxFAQs™ - Letter A | Toxic Substance Portal | ATSDR (cdc.gov)

Agency for Toxic Substances and Disease Registry. 2003. Selenium ToxFAQs™. Available at https://www.atsdr.cdc.gov/toxfaqs/tfacts92.pdf Accessed on Feb 2, 2020.

Bumbaco, K.A., Raymond C.L., O'Neill L.W., and Hoekema D.J., 2021. 2020 Pacific Northwest Water Year Impacts Assessment. A collaboration between the Office of the Washington State Climatologist, Climate Impacts Group, Oregon State Climatologist, Idaho Department of Water Resources, and NOAA National Integrated Drought Information System.

Evans, J.G., Geisler, T.M., 2001. Geologic field-trip to Steens Mountain Loop Road, Harney County Oregon. USGS Bulletin 2183.

Food and Agriculture Organization (FAO). http://www.fao.org/DOCREP/003/T0234E/T0234E05.htm

Gonthier, Joseph B., Collins, C.A., and Anderson, David B., 1977. Groundater-data for the Drewsey Resource Area, Harney Malheur counties, Oregon. USGS Open-File Report 77-741.

Jensen, G.G., Björklund, E., Simonsen, A., and Halling-Sørensen, B., 2009. Determination of 2,6-dichlorobenzamide and its degradation products in water samples using solid-phase extraction followed by liquid chromatography-tandem mass spectrometry. J. Chromatogr. A 2009, 1216, 5199–5206.

Leonard, A.R.,1970. Ground-water Resources in the Harney Valley, Harney County, Oregon. State of Oregon Groundwater Rerpot No 16.

MacNish, R.D., Mayers, D.A., and Barker, R.A., 1973. Appraisal of Groundwater Availability and Management Projections, Walla Walla River Basin, Washington and Oregon. Water Supply Paper Bulletin No. 37. Washington State Department of Ecology, in cooperation with the U.S. Geological Survey.

Maupin, M. A., Kenny J.F., Hutson S.S., Lovelace J.K., Barber N.L., and Linsey K.S., 2014. Estimated use of water in the United States in 2010: U.S. Geological Survey Circular 1405, 56 p., (http://dx.doi.org/10.3133/cir1405).

Natural Resources Defense Council, 2010. https://www.nrdc.org/sites/default/files/flameretardantsFS.pdf

Newcomb, R.C., 1965. Geology and Groundwater Resources of the Walla Walla River Basin, Washington – Oregon. Water Supply Bulletin No. 21. Washington State Department of Conservation, Division of Water Resources in cooperation with the U.S. Geological Survey.

Nolan, B. T., and Hitt, K. J., 2003. Nutrients in Shallow Ground Waters Beneath Relatively Undeveloped Areas in the Conterminous United States. U.S. Geological Survey Water-Resources Investigations Report 02-4289, Denver, Colorado.

Oregon Department of Environmental Quality (ORDEQ). 2003. Lower Umatilla Basin Groundwater Management Area Synoptic Sampling Event Report.

Oregon Department of Environmental Quality (ORDEQ). 2014. Water Quality Monitoring Mode of Operations Manual, Volume 3: Field Collection Methods. *Standard Operating Procedure, DEQ03-LAB-0036-SOP_V3*, Version 3.5.

Oregon Department of Environmental Quality (ORDEQ). 2015. Statewide Groundwater Monitoring Plan. *Quality Assurance Project Plan, DEQ93-LAB-0024-QAPP*, Version 2.0.

Oregon Department of Environmental Quality (ORDEQ). 2019. Drinking Water Information in the Greater Harney Management Area.

Oregon Health Authority (formerly Department of Human Services). 2007. Technical Bulletin – Health Effects Information: Uranium. Oregon Department of Human Services, Office of Environmental Health, January 2007.

Phillips, P.J., Schubert, C., Argue, D., Fisher, I., Furlong, E.T., Foreman, W., Gray, J., and Chalmers, A., 2015. Concentrations of hormones, pharmaceuticals and other micropollutants in groundwater affected by septic systems in New England and New York: Science of the Total Environment, 512-513, 43-54.

Pillsbury, L., Goodwin, K., and Brown, D., 2015. DEQ Basin Summary Reports: Supplement to the Statewide Water Quality Toxics Assessment Report.

Piper, Arthur M., Robinson, T. W, Park, C. F., Jessup, L. T., 1939. Geology and ground-water resources of the Harney Basin, Oregon, with a statement on Precipitation and tree growth. US DOI Water-Supply Paper 841.

Powers, J. F., and Schepers, J. S., 1989. Nitrate Contamination of Groundwater in North America. Agriculture, Ecosystems and Environment; v. 26, p. 165-187.

Richerson, P. 2020. DEQ Memo: Northern Malheur County Groundwater Management Area Area-Wide Trend Analysis.

State of Oregon, 1989. Groundwater Protection Act of 1989. House Bill 3515, Section 17 through 66. (Oregon Revised Statutes 468B. 150 through 468B.185)

Sweet, H. R., C. E. Wells, and Maxwell, J., 1980. Surface Impoundment Assessment for the State of Oregon. Report to the U.S. Environmental Protection Agency for Oregon Department of Environmental Quality. Sweet, Edwards & Associates, Inc., Kelso, Washington.

Toccalino, P. L., Gilliom, R. J., Lindsey, B. D., and Rupert, M. G., 2014. Pesticides in Groundwater of the United States: Decadal-Scale Changes, 1993-2011. Groundwater; v. 52 (S1), p. 112-125.

Usclimatedata.com. https://www.usclimatedata.com/climate/milton-freewater/oregon/united-states/usor0222

United States Environmental Protection Agency (U.S. EPA), 2008. Drinking Water Health Advisory for Boron and Compounds. Prepared by Health and Ecological Criteria Division (HECD), Office of Science and Technology (OST), Office of Water (OW) for Office of Groundwater/Drinking Water (OGWDW), OW, U.S. EPA.

United States Environmental Protection Agency (USEPA), Office of Water, 2012 Edition of the Drinking Water Standards and Health Advisories. EPA Report 822-S-12-001, Washington, D. C.

United States Environmental Protection Agency (USEPA), Office of Water, Human Health Benchmarks for Pesticides: Updated 2013 Technical Document, 2013. (https://www.epa.gov/sites/production/files/2015-10/documents/hh-benchmarks-techdoc.pdf).

Unites States Environmental Protection Agency (USEPA), Office of Pesticide Programs, Aquatic Life Benchmarks, 2014. (https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/aquatic-life-benchmarks-pesticide-registration).

United States Environmental Protection Agency (USEPA), Office of Water, Regional Screening Levels (RSLs) – Generic Tables (May 2016), 2016. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016.

United States Environmental Protection Agency (USEPA), Memorandum 2016. Refined Ecological Risk Assessment for Atrazine. https://www.biologicaldiversity.org/campaigns/pesticides_reduction/pdfs/AtrazinePreliminaryERA.pdf

United States Geological Survey (USGS), Oregon Water Science Center, Harney Basin Groundwater Study. https://www.usgs.gov/centers/or-water/science/harney-basin-groundwater-study?qt-science_center_objects=0#qt-science_center_objects (accessed February 2021).

Wang, C., Chen, H., Li, H., Yu, J., Wang, X., and Liu, W., 2020. Review of emerging contaminant tris(1,3-dichloro-2-propyl)phosphate: Environmental occurrence, exposure, and risks to organisms and human health. Environmental International. Volume 143, October 2020, 105946W

Welch, A. H., Westjohn, D. B., Helsel, D. R., and Wanty, R. B., 2000. Arsenic in Ground Water of the United States: Occurrence and Geochemistry. Ground Water; v. 38 (4), p. 589-604.

World Health Organization, 2017. Chemical mixtures in source water and drinking-water. https://apps.who.int/iris/bitstream/handle/10665/255543/9789241512374-eng.pdf?sequence=1

Appendix A – Complete Site List

Well ID	Harney County Groundwater Study Site ID	Type of Well	Latitude	Longitude	Well Log	Depth to bottom of well (ft bgs)	Water-bearing Geology	Spring or Fall 2018 Sampling	Year Well Completed
40130	**HC 003**	**domestic**	43.4287	-118.9900	HARN_52586, HARN_1103	160	gravel medium water bearing	Spring and Fall	2016
40131	**HC 004**	**irrigation**	43.5299	-118.9101	HARN_2073	180	fractured black sandstone	Spring	1995
40133	**HC 006**	**domestic**	43.2495	-119.2536	HARN_50079	46	sand fine	Spring and Fall	1995
40134	**HC 007**	**domestic**	43.3042	-119.0459	HARN_50399	110	black cinders wet	Spring and Fall	1999
40135	**HC 008**	**domestic**	43.2938	-118.9869	HARN_51086	60	brown clay/ black cinder	Spring and Fall	2004
40136	**HC 009**	**domestic**	43.5923	-118.6019	HARN_51013	320	rock broken/obsidian	Spring and Fall	2004
40137	**HC 010**	**stock**	43.5944	-118.5994	HARN_51205	165	pumice gray, obsidian black	Spring	2005
40138	**HC 011**	**domestic**	43.5216	-118.5914	HARN_51416	225	clay brown	Spring	2007
40139	**HC 012**	**domestic**	43.5848	-118.7328	HARN_52479	230	gray clay/ fine sand	Spring	2016
40140	**HC 013**	**domestic**	43.5046	-118.8551	HARN_52671	100	sand layers in gray clay	Spring	2017
40141	**HC 014**	**domestic**	43.4428	-118.7052	HARN_50179	323	clay greenish blue	Spring	1997
40142	**HC 015**	**domestic**	43.4023	-118.5844	HARN_1287	130	coarse sand gravel and water	Spring	1959
40143	**HC 016**	**domestic**	43.5847	-118.9862	HARN_458	49	gravel and brown clay and water	Spring and Fall	1969

40144	**HC 017**	**domestic**	43.5736	-118.9384	HARN_51319 and HARN_52061	300	gravel med	Spring and Fall	2006
40145	**HC 018**	**domestic**	43.3961	-118.9961	HARN_1124	110	blue claystone	Spring	1980
40146	**HC 019**	**domestic**	43.5524	-119.0970	HARN_51646	285	clay cinders	Spring	2009
40147	**HC 020**	**domestic**	43.6251	-119.0747	HARN_50027	67	sand fine, brown	Spring and Fall	1996
40148	**HC 021**	**stock**	43.4463	-118.7867	HARN_52152	223	Clay-tan	Spring	2015
40149	**HC 022**	**stock**	43.4221	-118.8064	HARN_52676	200	clay- gray, sand medium black	Spring	2017
40150	**HC 023**	**domestic**	42.8273	-118.8869	HARN_1650	100	gravel, coarse	Spring	1988
40151	**HC 024**	**domestic**	42.8083	-118.8775	HARN_1651	40	lava rock	Spring and Fall	1968
40152	**HC 025**	**domestic**	43.5847	-118.7331	HARN_645	118	white sandstone	Spring	1974
40153	**HC 026**	**domestic**	43.2779	-119.3116	HARN_52452	unknown	unknown	Spring	unknown
40154	**HC 027**	**domestic**	43.3304	-119.2794	HARN_52425(deepening), HARN_50497(new)	380	cinder, black/ clay, yellow	Spring and Fall	2015
40157	**HC 028**	**domestic**	43.2537	-118.9643	HARN_50077	160	sharp coarse sand, white pink brown	Spring and Fall	1996
40155	**HC 029**	**stock**	43.3341	-119.5970	HARN_52487	200	black cinder WB	Spring and Fall	2015
40158	**HC 031**	**monitoring**	43.4460	-118.7950	HARN_52234	76	sand	Spring	2015
40159	**HC 032**	**domestic**	43.4913	-118.8209	HARN_52315	180	unknown	Spring and Fall	1959
40160	**HC 033**	**domestic**	43.5740	-119.5663	HARN_244	175	sandstone w/clay layers	Spring and Fall	1987
40161	**HC 034**	**domestic**	43.5492	-119.6117	HARN_253	200	black and gray gravel	Spring	1973
40162	**HC 035**	**monitoring**	43.2268	-118.4817	HARN_52608	145	reddish brown basalt	Spring	2016
40163	**HC 036**	**domestic**	43.4201	-118.5888	HARN_51004	115	brown sand	Spring	2003

40164	**HC 037**	**domestic**	43.4934	-118.6495	HARN_51689	305	sand fine black, black cinder pumice	Spring	2010
40165	**HC 038**	**domestic**	43.5766	-118.8216	HARN_1975	95	broken claystone	Spring	1992
40167	**HC 040**	**monitoring**	43.4358	-119.0011	HARN_52629	105	lt gray siltstone	Spring	2017
40168	**HC 041**	**monitoring**	43.2267	-118.4816	HARN_52607	371	reddish vesicular basalt with clay	Spring	2016
40169	**HC 042**	**monitoring**	43.4460	-118.7950	HARN_52235	496	pumice	Spring	2015
40170	**HC 043**	**domestic**	43.6735	-118.9159	HARN 50078	420	black cinder	Spring	1996
40171	**HC 044**	**stock**	43.6802	-118.9263	HARN 51704	184	clay brown	Spring	2010
40172	**HC 045**	**monitoring**	43.3679	-119.1323	HARN_52631	490	gray green claystone and basalt	Spring	2016
40173	**HC 046**	**monitoring**	43.3678	-119.1322	HARN_52630	191	sand and gravel	Spring	2017
40174	**HC 047**	**monitoring**	43.4474	-119.2353	HARN_52657	623	brown sand water bearing	Spring	2017
40175	**HC 048**	**irrigation**	43.2440	-118.5291	HARN_1495	160	blue clay	Spring and Fall	1970
40176	**HC 049**	**irrigation**	43.2387	-118.5396	HARN_1494	125	blue clay	Spring and Fall	1979
40177	**HC 050**	**irrigation**	43.4172	-118.6163	HARN_1228	300	Gravel Med	Spring	1980
40178	**HC 051**	**irrigation**	43.4178	-118.5976	HARN_50931	172	rock grey	Spring	2003
40179	**HC 052**	**irrigation**	43.5597	-118.5891	HARN_52173	800	brown sand water bearing	Spring	2015
40180	**HC 053**	**irrigation**	43.5543	-118.5740	HARN_52274	95	brown sand	Spring	2015
40181	**HC 054**	**irrigation**	43.6103	-118.6399	HARN_52029	165	sandstone brown	Spring	2014
40182	**HC 055**	**irrigation**	43.5952	-118.6430	HARN_52411	755	-	Spring	1977
40183	**HC 056**	**domestic**	43.5643	-118.6098	HARN_707	72	fine to medium gravel	Spring and Fall	1967
40184	**HC 057**	**stock**	43.3973	-118.8048	HARN_1201	13	unknown	Spring	unknown

40185	**HC 058**	**irrigation**	43.2311	-118.9732	HARN_1458	341	white yellow gravel	Spring	1976
40186	**HC 059**	**domestic**	43.2874	-119.0698	HARN_50950	65	cinders blk	Spring and Fall	2003
40187	**HC 060**	**stock**	43.3850	-118.7981	HARN_52675	380	brown clay	Spring	2017
40568	**HC 061**	**domestic**	42.4123	-118.6275	HARN_51177	145	washed gravel	Fall	2005
40570	**HC 063**	**domestic**	42.3307	-118.6631	HARN_51159	175	black, yellow, gray, and red shale fractured	Fall	2005
40571	**HC 064**	**domestic**	43.8898	-119.6296	HARN_006	104	broken black and brown rock	Fall	1984
40572	**HC 065**	**domestic**	42.4791	-118.5300	HARN_52661	160	Clay	Fall	2017
40573	**HC 066**	**domestic**	42.6558	-118.7282	HARN_51574	220	rock brown volcanic	Fall	1995
40574	**HC 067**	**domestic**	42.7192	-118.6243	HARN_1656	55	broken brown basalt	Fall	1989
40575	**HC 068**	**domestic**	42.8021	-118.8663	HARN_1900	272	mid gray basalt	Fall	1991
40576	**HC 069**	**domestic**	42.8061	-118.8738	HARN_1655	325	loose red and black cinders	Fall	1971
40577	**HC 070**	**domestic**	42.7390	-118.6420	HARN_1666	110	broken black rock	Fall	1972
40578	**HC 071**	**domestic**	43.9180	-119.5897	HARN_51298	186	black shale frac water	Fall	2006
40579	**HC 072**	**domestic**	43.8499	-119.4103	HARN_2020	120	brown clay/ broken rock	Fall	1993
40580	**HC 073**	**domestic**	43.8757	-119.2728	HARN_8	200	yellow claystone	Fall	1968
40581	**HC 074**	**stock**	43.2614	-119.0146	HARN_1455	525	sandstone	Fall	1961
40583	**HC 076**	**stock**	43.6002	-118.5961	HARN_51618	660	rock black	Fall	2009
40584	**HC 077**	**stock**	43.0446	-118.8495	HARN_52440	125	rock brown, pumice gray	Fall	2015
40585	**HC 078**	**stock**	42.8870	-118.8991	HARN_50612	105	rock brn	Fall	2000
40589	**HC 082**	**domestic**	43.5416	-119.5039	HARN_1935	137	gravel fine, sand medium	Fall	1992

40590	**HC 083**	**stock**	43.5217	-118.8965	HARN_50698	75	clay gray, gravel sand	Fall	2001
40591	**HC 084**	**domestic**	43.5206	-118.8963	HARN_52532	156	sand fine black with clay strips	Fall	2016
40592	**HC 085**	**stock**	42.9078	-118.8915	HARN_50598	110	sand stone water bearing broken rock tan	Fall	2000
40593	**HC 086**	**domestic**	43.4967	-118.8071	HARN_52714	65	sand med gravel	Fall	2018
40594	**HC 087**	**domestic**	43.4953	-118.8230	HARN_51138	72	clay gray	Fall	2005
40595	**HC 088**	**domestic**	43.5006	-119.4399	HARN_51428	185	sandstone conglom	Fall	2008
40596	**HC 089**	**stock**	42.9751	-118.8727	HARN_1603	240	black fine sand	Fall	1963
40597	**HC 090**	**stock**	42.7835	-119.0669	HARN_52545	525	basalt blk fract. w/broken claystone water bearing	Fall	2016
40598	**HC 091**	**stock**	42.7582	-119.0703	HARN_1640	251	sand, gravel, shale brown	Fall	1975
40125	**HC 001**	**domestic**	43.3723	-119.3012	-	-	-	Spring and Fall	-
40129	**HC 002**	**domestic**	43.3889	-119.3693	-	-	-	Spring	-
40132	**HC 005**	**domestic**	43.4984	-118.8645	-	-	-	Spring and Fall	-
40156	**HC 030**	**domestic**	43.5152	-119.1735	-	-	-	Spring	-
40166	**HC 039**	**domestic**	43.6213	-119.0180	-	-	-	Spring and Fall	-
40569	**HC 062**	**domestic**	42.2635	-118.6764	-	-	-	Fall	-
40582	**HC 075**	**domestic**	43.5303	-118.9095	-	-	-	Fall	-
40586	**HC 079**	**domestic**	43.5937	-118.7675	-	-	-	Fall	-
40587	**HC 080**	**domestic**	43.5888	-118.9797	-	-	-	Fall	-
40588	**HC 081**	**domestic**	43.5969	-118.9695	-	-	-	Fall	

Appendix B – Full Analyte List

Analyte group, *Analyte sub-group*, Analyte name	
Bacteria	**Current Use Pesticides, cont'd**
Total Coliform	*Herbicides*
E. Coli	Alachlor
Consumer Product Constituents	Ametryn
Acetaminophen	Aminocarb
Caffeine	Atrazine
Carbamazepine	Bromacil
Codeine	Butachlor
Cotinine	Butylate
DEET	Chlorpropham
Diphenhydramine	Cyanazine
Ibuprofen	Cycloate
Sulfamethoxazole	Dacthal (DCPA)
Triclosan	DCPA acid metabolites
Venlafaxine	Deisopropylatrazine
Current Use Pesticides	Desethylatrazine
Fungicides	Dichlobenil
Azoxystrobin	Dichloroprop
Chlorneb	Dimethenamid
Chlorothalonil	Dinoseb
Etridiazole	Diphenamid
Fenarimol	Diuron
Pentachlorophenol	EPTC
Propiconizole	Fluometuron
Pyraclostrobin	Fluridone
Triadimefon	Hexazinone
Tricyclazole	Imazapyr
Trifloxystrobin	Linuron
Herbicides	MCPA
2,4,5-T	MCPP
2,4-D	Metolachlor
2,4-DB	Metribuzin
2,6-Dichlorobenzamide (DBA)	Metsulfuron Methyl
Acetochlor	Molinate
Acifluorfen	Napropamide

Analyte group, *Analyte sub-group*, Analyte name	
Current Use Pesticides, cont'd	**Current Use Pesticides, cont'd**
Herbicides	*Insecticides*
Neburon	Fenvalerate+Esfenvalerate
Norflurazon	Imidacloprid
Oxyfluorfen	Malathion
Pebulate	Methiocarb
Pendimethalin	Methomyl
Picloram	Methyl paraoxon
Prometon	Mevinphos
Prometryn	Mexacarbate
Pronamide	Oxamyl
Propachlor	Parathion-ethyl
Propazine	Parathion-methyl
Pyraflufen ether	Permethrin
Siduron	Pyriproxyfen
Simazine	Terbufos
Simetryn	Tetrachlorvinphos (Stirophos)
Sulfometuron-methyl	**Legacy Pesticides**
Tebuthiuron	2,4,5-TP (Silvex)
Terbacil	Aldrin
Terbutryn (Prebane)	Chlorobenzilate
Terbutylazine	Dieldrin
Triclopyr	Endosulfan I
Trifluralin	Endosulfan II
Vernolate	Endosulfan sulfate
Insecticides	Endrin
3,5-Dichlorobenzoic acid	Endrin aldehyde
Acetamiprid	Endrin ketone
Azinphos-methyl (Guthion)	Endrin+cis-Nonachlor
Baygon (Propoxur)	Heptachlor
Bifenthrin	Heptachlor epoxide
Carbaryl	Methoxychlor
Carbofuran	Mirex
Chlorpyrifos	*BHC-Technical (HCH)*
Diazinon	alpha-BHC
Dicamba	beta-BHC
Dichlorvos	delta-BHC
Dimethoate	gamma-BHC (Lindane)
Ethoprop	*Chlordane*
Fenamiphos	alpha-Chlordane

Analyte group, *Analyte sub-group*, Analyte name	
Legacy Pesticides, cont'd	**Field Parameters, cont'd**
cis-Chlordane	pH
cis-Nonachlor	Temperature
gamma-Chlordane+trans-Nonachlor	Turbidity
Oxychlordane	**Volatile Organic Compounds**
trans-Chlordane	1,1,1,2-Tetrachloroethane
trans-Nonachlor	1,1,1-Trichloroethane
Total DDT	1,1,2,2-Tetrachloroethane
2,4´-DDD	1,1,2-Trichloroethane
2,4´-DDE	1,1-Dichloroethane
2,4´-DDT	1,1-Dichloroethylene
4,4´-DDD	1,1-Dichloropropene
4,4´-DDE	1,2,3-Trichlorobenzene
4,4´-DDT	1,2,3-Trichloropropane (TCP)
Metals (Dissolved and Total Recoverable)	1,2,4-Trichlorobenzene
Aluminum	1,2,4-Trimethylbenzene
Arsenic	1,2-Dibromo-3-chloropropane (DBCP)
Boron	1,2-Dibromoethane (EDB)
Calcium	1,2-Dichlorobenzene
Iron	1,2-Dichloroethane (EDC)
Lead	1,2-Dichloropropane
Magnesium	1,2-Dimethylbenzene
Manganese	1,3,5-Trimethylbenzene
Potassium	1,3-Dichlorobenzene
Sodium	1,3-Dichloropropane
Uranium	1,4-Dichlorobenzene
Vanadium	1,4-Dimethylbenzene + 1,3-Dimethylbenzene
Standard Parameters	2,2-Dichloropropane
Alkalinity, Total as CaCO3	2-Butanone (MEK)
Chloride	2-Chlorotoluene
Hardness as CaCO3, Dissolved	4-Chlorotoluene
Hardness as CaCO3, Total Recoverable	4-Isopropyltoluene
Nitrate/Nitrite as N	4-Methyl-2-pentanone (MIBK)
Phosphate, Total as P	Acetone
Sulfate	Benzene
Total Dissolved Solids	Bromobenzene
Total Suspended Solids	Bromochloromethane
Field Parameters	Bromomethane
Conductivity	Carbon disulfide
Dissolved Oxygen	Carbon tetrachloride

Analyte group, *Analyte sub-group*, Analyte name	
Volatile Organic Compounds, cont'd	**Volatile Organic Compounds, cont'd**
Chlorobenzene	n-Propylbenzene
Chloroethane	sec-Butylbenzene
Chloroform	Styrene
Chloromethane	tert-Butylbenzene
cis-1,2-Dichloroethene	Tetrachloroethylene
cis-1,3-Dichloropropene	Toluene
Dibromochloromethane	trans-1,2-Dichloroethene
Dibromomethane	trans-1,3-Dichloropropene
Dichlorodifluoromethane (Freon 12)	Trichloroethylene
Dichloromethane	Trichlorofluoromethane (Freon 11)
Ethylbenzene	Trimethylsilyl fluoride
Hexachloro-1,3-butadiene	Tris (1,3-dichloro-2-propyl) phosphate (TDCP)
Isopropylbenzene (Cumene)	
Methyl tert-butyl ether (MTBE)	Tris (2-chloroethyl) phosphate (TCEP)
Naphthalene	Vinyl chloride
n-Butylbenzene	Xylenes, total

Appendix C – Methodology for Sampling Isotopes

Collection tips

- You will need a roll of black electrical tape.
- When filling the bottle, you ideally will have a uniform stream of water with low turbulence and a flow rate that is low enough so it does not introduce a lot of air into the sample when filling the bottle.
- Handling bottle caps
    - Have someone hold the cap by the edge or set upside down on a clean surface.
    - If a cap gets dirty (falls on the ground, splashed with mud, etc) just rinse it off with native well water.
- If you feel you have not collected a good sample, just dump the water out of the bottle and start over.
- Do not sample downstream of sand filter or water softener
- Stable isotopes and tritium CAN be sampled downstream from a pressure tank
- Stable isotopes and tritium CAN be sampled downstream from a cistern
- Do not sample C14 downstream from a pressure tank
- Do not collect C14 unless you have direct access to the well

Collecting the samples

Carbon-14: 1-liter coated glass bottle, filtered sample

The number one enemy of a carbon-14 sample is the modern atmosphere. Minimize the introduction of air into the sample. Minimize turbulence.

- *Small degassing bubbles coming through the line are normal*
- *Do not collect sample if the well is blowing air, e.g. due to too much drawdown*

1. Sample should be filtered through a 0.45 µm filter. Attach a length of flexible tubing to the outlet of the filter that will reach the bottle of the bottle.

    If you cannot attach a length of tubing, you can still collect the sample, but need to pump water into the bottle at an angle, like pouring a beer to minimize foam. This is not ideal, but better than not sampling. Please include a note if sample was not bottom filled.
2. Begin filling the bottle. Count or measure the time it takes to fill the bottle.
3. Continue filling the bottle, allowing it to overflow for the same length of time it took to initially fill it. The goal is to displace most of the water that first went into the bottle because it was in contact with the air in the bottle and may have entrained some modern atmospheric CO_2.

4. With the water still pumping, slowly withdraw the sampling tube from the bottle, leaving a meniscus on top. Cap the bottle and check for air bubbles. You are looking for a bubble of atmospheric air introduced due to improper filling or capping; small bubbles from natural degassing are normal. The small bubbles will coalesce into a large one after sitting for a while, so don't be surprised to find a large bubble in the bottle later in the day.
5. Store sample on ice or refrigerator. Take care not to freeze or it will break -- hotel refrigerators are notorious for freezing samples.

Tritium: 1-liter plastic bottle, raw water sample

1. Fill the bottle all the way to the top. Attempt to cap with no head space, but a small amount will not disturb the analysis.
2. Sample can be stored at ambient temperature. Chilling is fine and will not hurt it. Avoid excessive heat and freezing.

Stable Isotope: 20-mL bottle, raw water sample

1. Follow the same steps as for tritium.

<u>After collecting the samples</u>

1. Dry each bottle (otherwise the labels won't stick).
2. Label each bottle with the well ID, sample date, time, and the depth of the sampling interval. Use a Sharpie and waterproof labels. Pencil, ballpoint pens, and felt tip pens will smudge and potentially make the sample unusable if the date, time, or interval is lost.
3. Use black electrical tape to seal the gap between the cap and the bottle neck. Two to three wraps in a clockwise direction usually does the trick. Take care not to cover the label with electrical tape.

Appendix D – Example of Results Letter and Laboratory Report

Oregon

Kate Brown, Governor

Department of Environmental Quality
Laboratory and Environmental Assessment Division
3150 NW 229th, Suite 150
Hillsboro, OR 97124
Voice & TTY (503) 693-5700
FAX (503) 693-4999

August 2019
[redacted]
Station Description: 40145 - Harney County Groundwater Well 018
Well Address: [redacted]
Well Location: [redacted]
Well ID: [redacted]

Dear [redacted],

Thank you for volunteering to have your well tested in Spring 2018 as part of the Statewide Groundwater Monitoring Program in Harney County. Your test results will help us develop a better understanding of the quality of Oregon's groundwater resources, including any potential health concerns in Harney County. With this letter, we have included a report of your well water analytical test results.

We would like to assist you with the following:

- Understanding how the report is presented
- Providing the Analytical Report for your records
- Understanding what your results mean for your health
- Explaining the terms and definitions used in the report

Should you or other members of the household have health concerns that you feel may be related to your domestic well, we encourage you to talk with your physician or contact the Oregon Health Authority's (OHA) Domestic Well Safety Program (DWSP) at **971-673-0977**.
For additional questions about:

- Your **report**, call DEQ at **503-693-5736**
- **Water treatment options,** call the Public Health Drinking Water Program:
  Bill Goss
  william.h.goss@state.or.us
  541-966-0900
- For **agricultural questions** related to livestock watering or irrigation, call your local OSU Extension service at **541-573-2506**

Your well is one of many we tested in Harney County. A summary of the complete project will be available on our website once all the sampling and analysis is complete. We will email study participants to let them know when this is posted.

A note about lead results: Your well water was tested for lead. However, in order to measure the quality of the water coming from the groundwater aquifer, rather than the water sitting in the pipes, our sampling procedures include a 5-10 minute flushing period before we collect a sample. If you are concerned about lead contamination from your plumbing you should retest your water using the "first flush" method.

1

A note about radiochemistry: Radionuclides occur naturally as trace elements in rocks and soils from the radioactive decay of uranium-238 and thorium-232. Breathing air or drinking water contaminated with radionuclides can have health effects. This study did not have the capacity to sample for radiochemistry in groundwater, however, if you are concerned about radionuclides in your well water, please visit these webpages to learn more.

>> https://www3.epa.gov/radtown/private-wells.html
>> http://wellowner.org/water-quality/radionuclides/

A note about isotopes: A few wells in this study were tested for isotopes in partnership with the U.S. Geological Survey. These samples will help to determine where and when that groundwater infiltrated into the ground and "recharged" the groundwater flow system. The data will inform a regional analysis of groundwater aquifers for the Harney Basin which will be included in a report that will be published by the U.S. Geological Survey by December 2020 as part of the Harney Basin groundwater study. *If your well was sampled for isotopes, you will receive a separate letter explaining where you can access those results. All well users in Harney County will be able to learn about this data by accessing the USGS report at the end of 2020.*

Understanding your Report

The Analytical Report is organized so that the chemicals that were detected in your well water are **highlighted in bold** and at the top of the list. Many of these are basic parameters used to characterize the groundwater aquifer (under the headings *Nutrients, General Chemistry, Total Metals by Inductively Coupled Mass Spectrometry and General Field Parameters*). Bacteria (coliform, total and *E. coli*) are also listed (*Microbiology*). The last few sections contain the results for the pesticides, pharmaceuticals and volatile organic compounds (VOCs) tested. These analytes are sorted by laboratory method. If there was a detection of any of these pesticides in your water it will be listed in bold at the top of the report, all other analytes are considered non-detect, designated by "<". Additionally, if there were any detections of contaminants known to have a potential health risk (such as bacteria, nitrate, arsenic, lead, manganese, pesticides or VOCs), we provided a brief description of the chemical, compared your result to the known risk levels, and made recommendations for follow-up testing or treatment at the end of the report. These recommendations are provided with cooperation from OHA. You may also reference the packet of materials we provided when we came to test your well to learn more about well maintenance and common contaminants.

There are also some online tools you may find helpful in understanding your results:
Drinking Water Interpretation Tool: http://www.psiee.psu.edu/water/dwit.asp
Well Water Interpretation Tool: http://ohiowatersheds.osu.edu/know-your-well-water/well-water-interpretation-tool

We are available to answer questions you may have about this analytical report or to provide additional resources on groundwater quality. Please feel free to contact us at:
groundwater.monitoring@deq.state.or.us or **503-693-5736**

If we do not know the answer, we will direct you to health professionals at OHA or technical experts at your local health authority to assist you.

Our partners at the Domestic Well Safety Program (DWSP) want to hear from you! The DWSP wants to learn how well services and resources can better serve private well users. Please take a moment to fill out the survey and provide your feedback. Link: https://www.surveymonkey.com/r/YTJXHXC

Thank you again for participating in this study!

Sincerely,

Paige Haxton-Evans
Statewide Groundwater Monitoring
Oregon Department of Environmental Quality
Laboratory Environmental Assessment Program
groundwater.monitoring@deq.state.or.us
503-693-5736

Understanding and Accessing USGS Isotope Results

Samples of groundwater were collected for the analysis of carbon-14 (^{14}C), tritium (^{3}H), deuterium (^{2}H), and oxygen-18 (^{18}O) and analyzed by the U.S. Geological Survey. All four analytes are formed naturally in small quantities in the upper atmosphere. Precipitation reaching the earth's surface contains trace amounts of these analytes, and when it infiltrates, carries them into the groundwater system. The presence of these analytes in your drinking water has no effect on your health. Measuring the concentration of these analytes in a sample of groundwater enables scientists to determine where and when that groundwater infiltrated into the ground and "recharged" the groundwater flow system. The following information explains how scientists use the data and provides a link for you to access the results for your well. Most wells only have analyses of ^{2}H and ^{18}O. The data and a regional analysis of the results will be included in a report that will be published by the U.S. Geological Survey by December 2020 as part of the Harney Basin groundwater study.

^{14}C can be used to estimate the age of groundwater that recharged between 500 and 45,000 years ago. ^{3}H can be used to estimate the age of groundwater has recharged since 1950. Because water samples collected from wells typically are a mixture of waters that recharged at various times in the past, trained scientists use samples of ^{14}C and ^{3}H in combination to estimate the distribution of recharge times contained in a sample of groundwater.

Without specialized training, it is possible to obtain a general understanding of the relative proportion of old and young groundwater in a well sample by comparing the values of ^{14}C and ^{3}H. ^{14}C is used to estimate the amount and age of the old fraction of water in a sample. Values of ^{14}C typically range from 0 to 105 percent modern. Smaller values of ^{14}C within this range are evidence that the sample contains a larger fraction of old water. Similarly, ^{3}H is used to estimate the amount and age of the young fraction of water; values range from undetectable to more than 100 picoCuries per liter (pCi/L). If ^{3}H is not detected, most of the water in the sample was recharged prior to 1950. Generally, larger amounts of ^{3}H indicate a larger fraction of water recharged after 1950. Groundwater recharged in the last 10 years generally will have a ^{14}C value between 95 and 105 percent modern and a ^{3}H value between 5 and 20 pCi/L.

Interpretation of ^{2}H and ^{18}O requires many samples from across a region. The results from a single well without a regional context are not particularly meaningful. The sample from your well will inform a regional analysis of ^{2}H and ^{18}O for the Harney Basin which will be included in the report mentioned earlier.

The analyses for your well can be accessed from the U.S. Geological Survey National Water Information System (NWIS) using the following link:

HC018 -
https://nwis.waterdata.usgs.gov/nwis/qwdata?site_no=432346118594601&format=html_table

Questions about these data can be sent to Hank Johnson at the U.S. Geological Survey Oregon Water Science Center at hjohnson@usgs.gov.

DEQ Laboratory and Environmental Assessment Program

Analytical Report

Station: 40145
Station Description: Harney County Groundwater Well 018
Sampled Date/Time: 3/21/2018 3:32:00PM
Laboratory ID: 1803077-06
Sample Type: Grab Sample::GS

Analysis Summary

Analyte Name	Result:	Units:	DQL:
Nutrients			
Phosphate, Total as P	**0.36**	mg/L	A
General Chemistry			
Alkalinity, Total as CaCO3	**516**	mg/L	A
Chloride	**712**	mg/L	A
Sulfate	**170**	mg/L	A
Total Dissolved Solids	**1980**	mg/L	A
Total Metals by Inductively Coupled Plasma Mass Spectrometry			
Boron, Total recoverable	**3410**	µg/L	A
Calcium, Total recoverable	**17.7**	mg/L	A
Hardness as CaCO3, Total recoverable	**126**	mg/L	A
Magnesium, Total recoverable	**19.8**	mg/L	A
Manganese, Total recoverable	**71.0**	µg/L	A
Potassium, Total recoverable	**18.4**	mg/L	A
Sodium, Total recoverable	**677**	mg/L	A
General Field Parameters			
Conductivity at 25°C	**3353**	µmhos/cm	A
Dissolved Oxygen	**5.3**	mg/L	A
pH	**8.2**	pH Units	A
Temperature	**12.1**	°C	A
Dissolved Metals by Inductively Coupled Plasma Mass Spectrometry			
Boron, Dissolved	**3380**	µg/L	A
Calcium, Dissolved	**17.5**	mg/L	A
Hardness as CaCO3, Dissolved	**122**	mg/L	A
Magnesium, Dissolved	**19.0**	mg/L	A
Manganese, Dissolved	**69.6**	µg/L	A
Potassium, Dissolved	**17.7**	mg/L	A
Sodium, Dissolved	**670**	mg/L	A
Microbiology			
Coliform, Total	< 1	MPN/100 mL	A
E. Coli	< 1	MPN/100 mL	A
Nutrients			
Nitrate/Nitrite as N	< 0.0119	mg/L	A
General Chemistry			
Total Suspended Solids	< 1	mg/L	A
Total Metals by Inductively Coupled Plasma Mass Spectrometry			
Aluminum, Total recoverable	< 100	µg/L	A
Arsenic, Total recoverable	< 1.25	µg/L	A

DEQ Laboratory and Environmental Assessment Program

Analytical Report

Station: 40145
Station Description: Harney County Groundwater Well 018
Sampled Date/Time: 3/21/2018 3:32:00PM
Laboratory ID: 1803077-06
Sample Type: Grab Sample::GS

Analysis Summary

Analyte Name	Result:	Units:	DQL:
Total Metals by Inductively Coupled Plasma Mass Spectrometry			
Iron, Total recoverable	< 250	µg/L	A
Lead, Total recoverable	< 1.00	µg/L	A
Selenium, Total recoverable	< 10.0	µg/L	A
Uranium, Total recoverable	< 0.50	µg/L	A
Vanadium, Total recoverable	< 10.0	µg/L	A
Low Level Analysis of Pesticides by Gas Chromatography/Mass Spectrometry			
2,6-Dichlorobenzamide	< 43.3	ng/L	A
4,4´-DDD	< 43.3	ng/L	A
4,4´-DDE	< 43.3	ng/L	A
4,4´-DDT	< 43.3	ng/L	A
Acephate	< 86.5	ng/L	B
Aldrin	< 43.3	ng/L	A
alpha-BHC	< 43.3	ng/L	A
Azoxystrobin	< 43.3	ng/L	A
beta-BHC	< 43.3	ng/L	B
Bifenthrin	< 43.3	ng/L	A
Bromacil	< 43.3	ng/L	A
Butachlor	< 43.3	ng/L	A
Butylate	< 43.3	ng/L	A
Chlorobenzilate	< 43.3	ng/L	A
Chloroneb	< 43.3	ng/L	A
Chlorothalonil	< 43.3	ng/L	A
Chlorpropham	< 43.3	ng/L	A
Chlorpyrifos	< 43.3	ng/L	A
cis-Chlordane	< 43.3	ng/L	A
Cyanazine	< 43.3	ng/L	A
Cycloate	< 43.3	ng/L	A
Dacthal (DCPA)	< 43.3	ng/L	A
delta-BHC	< 43.3	ng/L	A
Diazinon	< 43.3	ng/L	A
Dichlobenil	< 43.3	ng/L	A
Dichlorvos	< 43.3	ng/L	A
Dieldrin	< 43.3	ng/L	A
Dimethenamid	< 43.3	ng/L	A
Dimethoate	< 43.3	ng/L	B
Diphenamid	< 43.3	ng/L	A
Endosulfan I	< 43.3	ng/L	A

DEQ Laboratory and Environmental Assessment Program

Analytical Report

Station: 40145
Station Description: Harney County Groundwater Well 018
Sampled Date/Time: 3/21/2018 3:32:00PM
Laboratory ID: 1803077-06
Sample Type: Grab Sample::GS

Analysis Summary

Analyte Name	Result:	Units:	DQL:
Low Level Analysis of Pesticides by Gas Chromatography/Mass Spectrometry			
Endosulfan II	< 43.3	ng/L	A
Endosulfan sulfate	< 43.3	ng/L	A
Endrin	< 43.3	ng/L	A
Endrin aldehyde	< 43.3	ng/L	A
EPTC	< 43.3	ng/L	A
Ethoprop	< 43.3	ng/L	A
Etridiazole	< 43.3	ng/L	A
Fenamiphos	< 108	ng/L	A
Fenarimol	< 43.3	ng/L	A
Fenvalerate+Esfenvalerate	< 433	ng/L	A
Fluridone	< 43.3	ng/L	A
gamma-BHC (Lindane)	< 43.3	ng/L	A
Heptachlor	< 43.3	ng/L	A
Heptachlor epoxide	< 43.3	ng/L	A
Hexazinone	< 43.3	ng/L	A
Malathion	< 43.3	ng/L	A
Methoxychlor	< 43.3	ng/L	A
Methyl paraoxon	< 43.3	ng/L	A
Mevinphos	< 43.3	ng/L	A
MGK 264	< 43.3	ng/L	A
Mirex	< 43.3	ng/L	A
Molinate	< 43.3	ng/L	A
Napropamide	< 43.3	ng/L	A
Norflurazon	< 43.3	ng/L	A
Oxyfluorfen	< 43.3	ng/L	A
Parathion-ethyl	< 43.3	ng/L	A
Parathion-methyl	< 43.3	ng/L	A
Pebulate	< 43.3	ng/L	A
Pendimethalin	< 43.3	ng/L	A
Permethrin	< 86.5	ng/L	A
Pronamide	< 43.3	ng/L	A
Propachlor	< 43.3	ng/L	A
Pyraflufen ethyl	< 43.3	ng/L	A
Pyriproxyfen	< 216	ng/L	A
Tebuthiuron	< 43.3	ng/L	A
Terbacil	< 43.3	ng/L	A
Terbufos	< 43.3	ng/L	A

DEQ Laboratory and Environmental Assessment Program

Analytical Report

Station: 40145
Station Description: Harney County Groundwater Well 018
Sampled Date/Time: 3/21/2018 3:32:00PM
Laboratory ID: 1803077-06
Sample Type: Grab Sample::GS

Analysis Summary

Analyte Name	Result:	Units:	DQL:
Low Level Analysis of Pesticides by Gas Chromatography/Mass Spectrometry			
Tetrachlorvinphos (Stirophos)	< 108	ng/L	A
trans-Chlordane	< 43.3	ng/L	A
trans-Nonachlor	< 43.3	ng/L	A
Triadimefon	< 43.3	ng/L	A
Tricyclazole	< 108	ng/L	B
Trifloxystrobin	< 43.3	ng/L	A
Trifluralin	< 43.3	ng/L	A
Tris (1,3-dichloro-2-propyl) phosphate (TDCP)	< 86.5	ng/L	A
Tris (2-chloroethyl) phosphate (TCEP)	< 43.3	ng/L	A
Vernolate	< 43.3	ng/L	A
Pesticides by Liquid Chromatography/Tandem Mass Spectrometry			
Acetamiprid	< 4.33	ng/L	A
Acetochlor	< 10.8	ng/L	A
Alachlor	< 10.8	ng/L	A
Ametryn	< 4.33	ng/L	A
Aminocarb	< 4.33	ng/L	A
Atrazine	< 4.33	ng/L	A
Azinphos-methyl (Guthion)	< 21.6	ng/L	A
Baygon (Propoxur)	< 4.33	ng/L	A
Carbaryl	< 5.41	ng/L	A
Carbofuran	< 4.33	ng/L	A
DEET	< 32.4	ng/L	A
Deisopropylatrazine	< 4.33	ng/L	A
Desethylatrazine	< 4.33	ng/L	A
Diuron	< 4.33	ng/L	A
Fluometuron	< 4.33	ng/L	B
Imazapyr	< 43.3	ng/L	A
Imidacloprid	< 21.6	ng/L	A
Linuron	< 4.33	ng/L	A
Methiocarb	< 4.33	ng/L	A
Methomyl	< 4.33	ng/L	A
Metolachlor	< 10.8	ng/L	A
Metribuzin	< 4.33	ng/L	A
Metsulfuron Methyl	< 4.33	ng/L	B
Mexacarbate	< 4.33	ng/L	B
Neburon	< 5.41	ng/L	A
Oxamyl	< 4.33	ng/L	A

DEQ Laboratory and Environmental Assessment Program

Analytical Report

Station: 40145
Station Description: Harney County Groundwater Well 018
Sampled Date/Time: 3/21/2018 3:32:00PM
Laboratory ID: 1803077-06
Sample Type: Grab Sample::GS

Analysis Summary

Analyte Name	Result:	Units:	DQL:
Pesticides by Liquid Chromatography/Tandem Mass Spectrometry			
Prometon	< 4.33	ng/L	A
Prometryn	< 4.33	ng/L	B
Propazine	< 4.33	ng/L	A
Propiconazole	< 21.6	ng/L	A
Pyraclostrobin	< 4.33	ng/L	A
Siduron	< 4.33	ng/L	A
Simazine	< 4.33	ng/L	A
Simetryn	< 4.33	ng/L	A
Sulfometuron-methyl	< 4.33	ng/L	A
Terbutryn (Prebane)	< 4.33	ng/L	A
Terbutylazine	< 4.33	ng/L	A
Phenoxy Herbicides by Electron Capture Detector			
2,4,5-T	< 0.3	µg/L	A
2,4,5-TP (Silvex)	< 0.1	µg/L	A
2,4-D	< 0.1	µg/L	A
2,4-DB	< 0.6	µg/L	A
3,5-Dichlorobenzoic acid	< 0.3	µg/L	A
Acifluorfen	< 0.2	µg/L	A
DCPA acid metabolites	< 0.6	µg/L	B
Dicamba	< 0.3	µg/L	A
Dichloroprop	< 0.3	µg/L	A
Dinoseb	< 0.3	µg/L	A
MCPA	< 20.4	µg/L	A
MCPP	< 61.2	µg/L	A
Pentachlorophenol	< 0.1	µg/L	A
Picloram	< 0.6	µg/L	A
Triclopyr	< 0.3	µg/L	B
Pesticides by High Resolution Mass Spectrometry			
2,4´-DDD	< 0.0642	ng/L	B
2,4´-DDE	< 0.0642	ng/L	B
2,4´-DDT	< 0.0642	ng/L	B
4,4´-DDD	< 0.0642	ng/L	B
4,4´-DDE	< 0.0642	ng/L	B
4,4´-DDT	< 0.0642	ng/L	B
Aldrin	< 0.0642	ng/L	B
alpha-BHC	< 0.0642	ng/L	B
alpha-Chlordane	< 0.0642	ng/L	B

DEQ Laboratory and Environmental Assessment Program

Analytical Report

Station: 40145
Station Description: Harney County Groundwater Well 018
Sampled Date/Time: 3/21/2018 3:32:00PM
Laboratory ID: 1803077-06
Sample Type: Grab Sample::GS

Analysis Summary

Analyte Name	Result:	Units:	DQL:
Pesticides by High Resolution Mass Spectrometry			
beta-BHC	< 0.0642	ng/L	B
cis-Nonachlor	< 0.0642	ng/L	B
delta-BHC	< 0.0642	ng/L	B
Dieldrin	< 0.0642	ng/L	B
Endosulfan I	< 0.161	ng/L	B
Endosulfan II	< 0.161	ng/L	B
Endosulfan sulfate	< 0.161	ng/L	B
Endrin ketone	< 0.642	ng/L	B
Endrin+cis-Nonachlor	< 0.128	ng/L	B
gamma-BHC (Lindane)	< 0.0642	ng/L	B
gamma-Chlordane+trans-Nonachlor	< 0.128	ng/L	B
Heptachlor	< 0.0642	ng/L	B
Heptachlor epoxide	< 0.0642	ng/L	B
Hexachlorobenzene	< 0.803	ng/L	B
Methoxychlor	< 0.257	ng/L	B
Mirex	< 0.0642	ng/L	B
Oxychlordane	< 0.0642	ng/L	B
Trifluralin	< 0.535	ng/L	B
Dissolved Metals by Inductively Coupled Plasma Mass Spectrometry			
Aluminum, Dissolved	< 100	µg/L	A
Arsenic, Dissolved	< 1.25	µg/L	A
Iron, Dissolved	< 250	µg/L	A
Lead, Dissolved	< 1.00	µg/L	A
Selenium, Dissolved	< 10.0	µg/L	A
Uranium, Dissolved	< 0.50	µg/L	A
Vanadium, Dissolved	< 10.0	µg/L	A
Pharmaceuticals and Personal Care Products by Liquid Chromatography/Tandem Mass Spectrometry			
Acetaminophen	< 75.3	ng/L	A
Caffeine	< 75.3	ng/L	A
Carbamazepine	< 12.5	ng/L	A
Codeine	< 25.1	ng/L	A
Cotinine	< 12.5	ng/L	A
Diphenhydramine	< 12.5	ng/L	A
Ibuprofen	< 251	ng/L	A
Sulfamethoxazole	< 12.5	ng/L	A
Triclosan	< 251	ng/L	A
Venlafaxine	< 12.5	ng/L	A

DEQ Laboratory and Environmental Assessment Program

Analytical Report

Station: 40145
Station Description: Harney County Groundwater Well 018
Sampled Date/Time: 3/21/2018 3:32:00PM
Laboratory ID: 1803077-06
Sample Type: Grab Sample::GS

Analysis Summary

Analyte Name	Result:	Units:	DQL:
Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry			
1,1,1,2-Tetrachloroethane	< 0.750	µg/L	A
1,1,1-Trichloroethane	< 0.500	µg/L	A
1,1,2,2-Tetrachloroethane	< 0.500	µg/L	A
1,1,2-Trichloroethane	< 0.600	µg/L	A
1,1-Dichloroethane	< 0.500	µg/L	A
1,1-Dichloroethylene	< 0.600	µg/L	A
1,1-Dichloropropene	< 0.500	µg/L	A
1,2,3-Trichlorobenzene	< 0.500	µg/L	A
1,2,3-Trichloropropane (TCP)	< 0.750	µg/L	A
1,2,4-Trichlorobenzene	< 0.600	µg/L	A
1,2,4-Trimethylbenzene	< 0.600	µg/L	A
1,2-Dibromo-3-chloropropane (DBCP)	< 1.25	µg/L	A
1,2-Dibromoethane (EDB)	< 0.500	µg/L	A
1,2-Dichlorobenzene	< 0.500	µg/L	A
1,2-Dichloroethane (EDC)	< 0.500	µg/L	A
1,2-Dichloropropane	< 0.500	µg/L	A
1,2-Dimethylbenzene	< 0.750	µg/L	A
1,3,5-Trimethylbenzene	< 0.500	µg/L	A
1,3-Dichlorobenzene	< 0.500	µg/L	A
1,3-Dichloropropane	< 0.500	µg/L	A
1,4-Dichlorobenzene	< 0.600	µg/L	A
1,4-Dimethylbenzene + 1,3-Dimethylbenzene	< 1.00	µg/L	A
2,2-Dichloropropane	< 0.500	µg/L	A
2-Butanone (MEK)	< 50.0	µg/L	A
2-Chlorotoluene	< 0.600	µg/L	A
4-Chlorotoluene	< 0.600	µg/L	A
4-Isopropyltoluene	< 0.500	µg/L	A
4-Methyl-2-pentanone (MIBK)	< 5.00	µg/L	A
Acetone	< 40.0	µg/L	A
Benzene	< 0.600	µg/L	A
Bromobenzene	< 0.600	µg/L	A
Bromochloromethane	< 0.600	µg/L	A
Bromodichloromethane	< 0.750	µg/L	A
Bromoform	< 0.600	µg/L	A
Bromomethane	< 1.00	µg/L	B
Carbon disulfide	< 2.00	µg/L	A
Carbon tetrachloride	< 0.500	µg/L	A

Page 7 of 14

DEQ Laboratory and Environmental Assessment Program

Analytical Report

Station: 40145
Station Description: Harney County Groundwater Well 018
Sampled Date/Time: 3/21/2018 3:32:00PM
Laboratory ID: 1803077-06
Sample Type: Grab Sample::GS

Analysis Summary

Analyte Name	Result:	Units:	DQL:
Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry			
Chlorobenzene	< 0.600	µg/L	A
Chloroethane	< 0.500	µg/L	A
Chloroform	< 0.600	µg/L	A
Chloromethane	< 0.600	µg/L	A
cis-1,2-Dichloroethene	< 0.500	µg/L	A
cis-1,3-Dichloropropene	< 0.600	µg/L	A
Dibromochloromethane	< 0.750	µg/L	A
Dibromomethane	< 0.500	µg/L	A
Dichlorodifluoromethane (Freon 12)	< 0.500	µg/L	A
Dichloromethane	< 0.500	µg/L	A
Ethylbenzene	< 0.500	µg/L	A
Hexachloro-1,3-butadiene	< 0.500	µg/L	A
Isopropylbenzene (Cumene)	< 0.500	µg/L	A
Methyl tert-butyl ether (MTBE)	< 0.500	µg/L	A
Naphthalene	< 1.00	µg/L	A
n-Butylbenzene	< 0.500	µg/L	A
n-Propylbenzene	< 0.500	µg/L	A
sec-Butylbenzene	< 0.600	µg/L	A
Styrene	< 0.600	µg/L	A
tert-Butylbenzene	< 0.500	µg/L	A
Tetrachloroethylene	< 0.600	µg/L	A
Toluene	< 0.500	µg/L	A
trans-1,2-Dichloroethene	< 0.600	µg/L	A
trans-1,3-Dichloropropene	< 0.500	µg/L	A
Trichloroethylene	< 0.500	µg/L	A
Trichlorofluoromethane (Freon 11)	< 0.500	µg/L	A
Vinyl chloride	< 0.600	µg/L	A
Xylenes, total	< 1.75	µg/L	A

DEQ Laboratory and Environmental Assessment Program

Analytical Report

Station: 40145

Station Description: Harney County Groundwater Well 018

Sampled Date/Time: 03/21/2018 03:32 PM

Laboratory ID: 1803077-06

Sample Type: Grab Sample::GS

Information about your detection

Sulfate

As water moves through soil and rock formations that contain sulfate minerals, some of the sulfate dissolves into the groundwater. Minerals that contain sulfate include magnesium sulfate (Epsom salt), sodium sulfate (Glauber's salt), and calcium sulfate (gypsum). People unaccustomed to drinking water with elevated levels of sulfate, above 250 mg/L, can experience diarrhea and dehydration. Infants are often more sensitive to sulfate than adults. **As a precaution, water with a sulfate level exceeding 500 mg/L should not be used in the preparation of infant formula.** Older children and adults become accustomed to high sulfate levels after a few days.

Animals are also sensitive to high levels of sulfate. In young animals, high levels may be associated with severe, chronic diarrhea, and in few instances, death. As with humans, animals tend to become accustomed to sulfate over time. **Diluting water high in sulfate with water low in sulfate can help avoid problems of diarrhea and dehydration in young animals and animals not accustomed to drinking high sulfate water.** The ratio of water high in sulfate to water low in sulfate can be gradually increased until the animals can tolerate the high sulfate water.

If sulfate in water exceeds 250 mg/L, a bitter of medicinal taste may render the water unpleasant to drink. High sulfate levels may also corrode plumbing, particularly copper piping. In areas with high sulfate levels, plumbing materials more resistant to corrosion, such as plastic pipe, are commonly used.

Three types of treatment systems will remove sulfate from drinking water: reverse osmosis, distillation, or ion exchange. Water softeners, carbon filters, and sediment filters do **not** remove sulfate. Water softeners merely change magnesium or calcium sulfate into sodium sulfate, which is somewhat more laxative.

The EPA has established a Secondary MCL for sulfate at 250 mg/L (ppm). The concentration of sulfate in your well water was **170 mg/L**.

Up to 250 mg/L: This concentration is not expected to have any aesthetic effects or pose a significant health risk to you or your family.

DEQ Laboratory and Environmental Assessment Program

Analytical Report

Station: 40145

Station Description: Harney County Groundwater Well 018

Sampled Date/Time: 03/21/2018 03:32 PM

Laboratory ID: 1803077-06

Sample Type: Grab Sample::GS

Information about your detection

Chloride

Chloride occurs naturally in groundwater but is found in greater concentrations where seawater and run- off from road salts (salts used to de-ice icy roads) can make their way into water sources. It generally combines with calcium, magnesium, or sodium to form various salts: for example, sodium chloride (NaCl) is formed when chloride and sodium combine. Over time, sodium chloride's high corrosivity will also damage plumbing, appliances, and water heaters. There is no federally enforceable standard for chlorides in drinking water.
Although chlorides are harmless at low levels, well water high in sodium chloride can damage plants if used for gardening or irrigation, and give drinking water an unpleasant taste. Chlorides can be removed from water with either a reverse osmosis system or a distiller.

The EPA has established a Secondary MCL level of 250 mg/L to avoid salty tastes and undesirable odors.

The concentration of chloride in your well water was **712 mg/L**.

Up to 250 mg/L: This concentration is not expected to have any aesthetic effects or pose a significant health risk to you or your family.

>250 mg/L: This concentration is above the EPA SMCL and may affect the aesthetic quality of your drinking water, or corrode copper piping. It is recommended that you use bottled water from an approved source for making infant formula. Boiling your water will **not** remove the chloride. There are several water treatment options available for chloride. If you choose to treat your water, make sure your system is certified by NSF (www.nsf.org) to remove chloride.

DEQ Laboratory and Environmental Assessment Program

Analytical Report

Station: 40145

Station Description: Harney County Groundwater Well 018

Sampled Date/Time: 03/21/2018 03:32 PM

Laboratory ID: 1803077-06

Sample Type: Grab Sample::GS

Information about your detection

Manganese

Manganese is a natural mineral commonly found in groundwater. If the groundwater is oxygen poor, manganese (and iron) will dissolve more readily, particularly if the pH of the water is on the low side (slightly more acidic) and or soils are enriched with dissolved organic carbon. At high concentrations manganese can cause water to have a brown or black color and cause staining and a bitter metallic taste. To avoid these potential health effects, the EPA Lifetime Health Advisory for manganese is set at 300 µg/L. The EPA also has a 10-day exposure health advisory for children of 1000 ug/L and for bottle-fed infants under 6 months they recommend avoiding short-term exposure above 300 ug/L. These short term levels are a safe range designed to prevent effects on children's developing brains, and do not necessarily reflect a level where health effects will occur.

Total Recoverable Manganese was detected in your well water at a concentration of 71.0 µg/L and **Dissolved Manganese was detected in your well water at a concentration of 69.6 µg/L**.

For the ingestion of drinking water, the highest concentration detected of either total recoverable, or dissolved Manganese should be used to determine health risk.

>50 and <300 ug/L: This concentration may cause discoloration, staining or a metallic taste, however it is not expected to pose a significant health risk to you or your family.

DEQ Laboratory and Environmental Assessment Program

Analytical Report

Station: 40145

Station Description: Harney County Groundwater Well 018

Sampled Date/Time: 03/21/2018 03:32 PM

Laboratory ID: 1803077-06

Sample Type: Grab Sample::GS

Information about your detection

Boron

Boron is a non-metallic, naturally-occurring, element found in rocks, soil, and water. Boron does not exist as a pure element but is combined with oxygen as borate minerals and various boron compounds such as boric acid, borax, and boron oxide. Boron compounds are used primarily in the production of glass and ceramics, pesticides, fire retardants, plus insulation-grade- and textile-grade-glass fibers. Boron can be present in commercial plant foods and fertilizers. Boron compounds are often found in household laundry and cleaning products. Boron gets into drinking water from both naturally-occurring and man-made sources. Some areas in the western United States (California, Nevada, Oregon) have high concentrations of boron in some of their soils.

Contamination of water can come directly from industrial wastewater and municipal sewage, as well as indirectly from air deposition and soil runoff. Natural weathering processes, burning of coal in power plants, chemical plants, and manufacturing facilities releases boron into the air; and fertilizers, herbicides, and industrial wastes are among the sources of soil contamination. Boron is found in soil and is taken up by plants. It found naturally in fruits, legumes, nuts, vegetables, and grains. The average intake of boron in the U.S. diet ranges from 0.85 mg B/day (4-8 year old child) to 1.47 mg B/day (male vegetarian). Dietary levels can be as high as 5-6 mg/day for some individuals.

An acute boron overdose to infants has caused diarrhea, vomiting, signs of irritability, redness in the diaper area, a mild red rash on the face and neck, a pus-like discharge or mild congestion of the eye, and possibly convulsive seizures. In adults, an acute overdose causes nausea, vomiting, redness of the skin, difficulty swallowing due to ulcers in the throat, and a non-bloody diarrhea. In animals, acute excessive exposure has caused lethargy, rapid respiration, eye inflammation, swelling of the paws, shedding of the skin on the paws and tails, excitation during handling, and changes in the cells of the forestomach.

DEQ Laboratory and Environmental Assessment Program

Analytical Report

The EPA has set a One-Day and Ten-Day Health Advisory at 3.0 mg/L (3000 ppb) and a Longer-Term Health Advisory of 2.0 mg/L (2000 ppb) for children. A Lifetime Health Advisory for adults is set at 6 mg/L (6000 ppb). Water containing boron at levels above the HA should not be used to prepare food or formula for infants and children.

Total Recoverable Boron was detected in your well water at a concentration of 3410 µg/L and **Dissolved Boron was detected in your well water at a concentration of 3380 µg/L**.

For the ingestion of drinking water, the highest concentration detected of either total recoverable, or dissolved Boron should be used to determine health risk.

>2000 and <6000 ppb (2-6 mg/L): This concentration exceeds EPA Lifetime Health Advisory for children and may be a risk to children drinking the water. If children are drinking the water, it is recommended that you find a safe source of drinking water or use bottled water from an approved source. Boiling your water will **not** remove the Boron. If you choose to treat your water, make sure your system is certified by NSF (www.nsf.org) to remove Boron.

DEQ Laboratory and Environmental Assessment Program

Analytical Report

Explanation of terms and phrases used in your Analytical Report

Data Quality Levels (DQL) listed on your Analytical Report:

A = Data of known Quality; meets Quality Control (QC) limits established in a DEQ approved plan.

B = Data of known but lesser quality; Data may not meet established QC but is within marginal acceptance criteria; or data value may be accurate, however controls used to measure Data Quality Objective elements failed (e.g. batch failed to meet blank QC limit); the data is generally usable for most situations or in supporting other, higher quality data.

C= Data of unacceptable quality; Generally due to QC failures but may be related to other known information about the sample. Data should not be used for a single result but may provide information about water quality in general.

D= No data available; No sample collected or no reportable results. Samples are either voided or cancelled.

E= Data of unknown quality; Insufficient QA/QC or other information available to make determination. Data could be acceptable; however, no evidence is available to prove either way. Data is provided for Educational Use Only.

Terms

mg/L (milligrams per liter; parts per million; ppm)

Unit of concentration equivalent to one penny in $10,000; or 2 quarts (half gallon) in an Olympic sized swimming pool (- 600,000 gallons).

µg/L (micrograms per liter; parts per billion; ppb)

Unit of concentration equivalent to one second in 32 years; or 1 gallon jug of milk distributed in Detroit Lake Reservoir at it's fullest (-1.5 billion gallons). There are 1,000 µg/L in 1 mg/L.

ng/L (nanograms per liter; parts per trillion; ppt)

Unit of concentration equivalent to one 5 gallon bucket of liquid distributed in the entirety of Crater Lake (-4.6 trillion gallons). There are 1,000 ng/L in 1 µg/L and 1,000,000 ng/L in 1 mg/L.

EPA United States Environmental Protection Agency

MCL Maximum Contaminant Level defined by EPA as the maximum permissible level of a contaminant in water, which is delivered to any user of a public water system. There are no regulations for water that comes from a private, domestic well. However, the MCL set for public water systems is a very reliable health based standard for domestic wells. http://water.epa.gov/drink/contaminants

SMCL EPA has established National Secondary Drinking Water Regulations (NSDWRs) that set non-mandatory water quality standards for 15 contaminants. EPA does not enforce these "secondary maximum contaminant levels" (SMCLs). They are established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor. These contaminants are not considered to present a risk to human health at the SMCL. https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals

Human health benchmark for pesticides (HHBP), Regional Screening Level (RSL) and Health-based screening level (HBSL)

Non-Enforceable benchmark concentrations in water below which adverse health effects are not expected over a lifetime of exposure calculated by the EPA and the United States Geological Survey, respectively.
http://www.epa.gov/region9/superfund/prg/, http://water.usgs.gov/nawqa/HBSL

Breakdown product

A new chemical that results from the degradation of another (parent) chemical. Degradation may occur because of biological activity, exposure to light or air, or by another similar process.

Appendix E – Example of a Well Drilling Report (Water Well Report)

NOTICE TO WATER WELL CONTRACTOR
The original and first copy of this report are to be filed with the
WATER RESOURCES DEPARTMENT
SALEM, OREGON 97310
within 30 days from the date of well completion.

1124
Harn

WATER WELL REPORT
STATE OF OREGON
(Please type or print)
(Do not write above this line)

State Well No. 25s/31E - 15cc
State Permit No.

(1) OWNER:
Name [redacted]
Address

(2) TYPE OF WORK (check):
New Well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 12.

(3) TYPE OF WELL:
Rotary ☐ Driven ☐
Cable ☒ Jetted ☐
☐ Bored ☐

(4) PROPOSED USE (check):
Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) CASING INSTALLED: Threaded ☐ Welded ☒
8" Diam. from 0 ft. to 90 ft. Gage .250
" Diam. from ft. to ft. Gage
" Diam. from ft. to ft. Gage

(6) PERFORATIONS: Perforated? ☐ 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.

(7) SCREENS: Well screen installed? ☐ Yes ☒ No
Manufacturer's Name
Type Model No.
Diam. Slot size Set from ft. to ft.
Diam. Slot size Set from ft. to ft.

(8) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? ☒ Yes ☐ No If yes, by whom? Driller
Yield: 15 gal./min. with 7 ft. drawdown after 2 hrs.
" " " "
" " " "
Bailer test gal./min. with ft. drawdown after hrs.
Artesian flow g.p.m.
Temperature of water Depth artesian flow encountered ft.

(9) CONSTRUCTION:
Well seal—Material used cemenT
Well sealed from land surface to 20 ft.
Diameter of well bore to bottom of seal 12 in.
Diameter of well bore below seal 8 in.
Number of sacks of cement used in well seal 8 sacks
How was cement grout placed? pumped

Was a drive shoe used? ☒ Yes ☐ No Plugs Size: location ft.
Did any strata contain unusable water? ☐ Yes ☐ No
Type of water? depth of strata
Method of sealing strata off
Was well gravel packed? ☐ Yes ☐ No Size of gravel:
Gravel placed from ft. to ft.

(10) LOCATION OF WELL:
County Harney Driller's well number
SW ¼ SW ¼ Section 15 T. 25S R. 31E W.M.
Bearing and distance from section or subdivision corner

(11) WATER LEVEL: Completed well.
Depth at which water was first found 30 ft.
Static level 23 ft. below land surface. Date 4/10/80
Artesian pressure lbs. per square inch. Date

(12) WELL LOG: Diameter of well below casing 8"
Depth drilled 110 ft. Depth of completed well 110 ft.
Formation: Describe color, texture, grain size and structure of materials; and show thickness and nature of each stratum and aquifer penetrated, with at least one entry for each change of formation. Report each change in position of Static Water Level and indicate principal water-bearing strata.

MATERIAL	From	To	SWL
Soil	0	15	0
clay, blue	15	22	0
clay, green	22	35	30
clay, blue	35	90	0
claystone, blue W B	90	110	23

RECEIVED
1980
WATER RESOURCES DEPT
SALEM, OREGON

Work started 3/27 1980 Completed 3/30 1980
Date well drilling machine moved off of well 3/30 1980

Drilling Machine Operator's Certification:
This well was constructed under my direct supervision. Materials used and information reported above are true to my best knowledge and belief.
[Signed] Harold Woodruff (Drilling Machine Operator) Date 4/10, 1980
Drilling Machine Operator's License No. 1188

Water Well Contractor's Certification:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.
Name Margie I Woodruff (Person, firm or corporation) (Type or print)
Address Box 1043 Burns, Ore
[Signed] Margie I Woodruff (Water Well Contractor)
Contractor's License No. 717 Date 4/10, 1980

(USE ADDITIONAL SHEETS IF NECESSARY)
SP*45656-119