Quality Assurance Project Plan

Groundwater Monitoring Well Installation 2020-2021: Washington State Department of Ecology and the National Groundwater Monitoring Network

March 2021

Publication 21-03-104

Publication information

Each study conducted by the Washington State Department of Ecology must have an approved Quality Assurance Project Plan (QAPP). The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the final report of the study to the Internet.

This Quality Assurance Project Plan is available on Ecology's website at https://apps.ecology.wa.gov/publications/SummaryPages/2103104.html

This plan was prepared by a licensed hydrogeologist. A signed and stamped copy of the report is available upon request.

Data for this project are available in Ecology's EIM Database. Study ID: NGWMN.

The Activity Tracker Code for this study is 17-026.

This QAPP was written using QAPP Template Version 1.0. Revision date: 8/27/2018.

Contact information

Publications Coordinator
Environmental Assessment Program
P.O. Box 47600, Olympia, WA 98504-7600
Phone: (360) 407-6764

Washington State Department of Ecology – https://ecology.wa.gov

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Union Gap 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

Quality Assurance Project Plan

Groundwater Monitoring Well Installation 2020-2021: Washington Department of Ecology and the National Groundwater Monitoring Network

March 2021

by Eugene Freeman

Approved by:

Signature:	Date:
Eugene Freeman, Author/Project Manager, EAP	
Signature:	Date:
Pam Marti, Author/Project Managers Unit Supervisor, EAP	
Signature:	Date:
Jessica Archer, Project Managers Section Manager, EAP	
Signature:	Date:
Stacy Polkowske, Section Manager for Project Study Area, EAP	
Signature:	Date:
Alan Rue, Director, Manchester Environmental Laboratory	
Signature:	Date:
Arati Kaza, Ecology Quality Assurance Officer	

Signatures are not available on the Internet version.
EAP: Environmental Assessment Program

1.0 Table of Contents

List of Figures and Tables

2.0 Abstract

The Washington State Department of Ecology (Ecology) entered into a cooperative agreement with the United States Geological Survey (USGS) to become a data provider to the National Groundwater Monitoring Network (NGWMN). The NGWMN uses existing federal, state, and local groundwater monitoring programs to establish a national groundwater quantity and quality database. Data are accessible through the NGWMN Data Portal. The NGWMN public portal can be accessed at https://cida.usgs.gov/ngwmn/ .

To address concerns about water supply and water quality, long-term groundwater level monitoring and water quality monitoring can be used to assess developing trends in the water resource. With regards to groundwater withdrawals, a downward trending water level indicates depletion of the groundwater reservoir. Since shallow groundwater and surface water are typically hydraulically coupled, a decline in groundwater levels would equate to a reduction in available surface water. Degradation of water quality can also affect water supply such that the water does not meet safe drink water standards for human consumption.

In 2018, Ecology was granted funding from the U.S. Geological Survey (USGS) to install 13 long-term groundwater monitoring wells in select areas of Western Washington that lack groundwater monitoring coverage. This will enhance Ecology's existing groundwater monitoring and assessment capabilities. The wells will be used for measuring water levels and groundwater quality.

The objective of this study is to install 13 dedicated, long-term groundwater monitoring wells. All 13 wells will be used to monitor water levels; six of these wells will also be used to measure water quality parameters. Data from these wells are intended to provide seasonal and long-term trends that will be used to identify evolving water supply issues and assist water managers in preserving available water resources.

3.0 Background

3.1 Introduction and problem statement

In 2016, the Washington State Department of Ecology (Ecology) entered into a cooperative agreement with the United States Geological Survey (USGS) to become a data provider to the National Groundwater Monitoring Network (NGWMN). The goal of the NGWMN is to establish a national long-term groundwater quantity and quality monitoring network of principal aquifers by using existing federal, state, and local groundwater monitoring programs. The NGWMN provides access to the data over a network interface called the Data Portal. The charter, program elements, and data requirements are described in "A National Framework for Ground-Water Monitoring in the United States" (USGS, 2013).

Ecology became a data provider because it routinely collects groundwater level measurements from a series of well networks across the state that are used to support water management decisions and planning related to groundwater level status and trends. Ecology's Water Resources Program manages the water level monitoring networks. The well monitoring data that Ecology collects are managed through its Environmental Information Management database (EIM).

Data from a small subset of the Water Resources monitoring wells are linked to the NGWMN Data Portal.

In 2018, Ecology received funding from the USGS to install 13 long-term groundwater monitoring wells in selected areas of Western Washington in order to measure water levels and groundwater quality. The wells will be placed in areas that lack groundwater monitoring coverage; this will enhance Ecology's existing groundwater monitoring and assessment capabilities.

Seven of the new wells will be used to monitor water levels under natural variability of aquifer recharge and discharge. The wells will be measured at a frequency that will provide data on seasonal and long-term trends. Four of the wells will be placed in USGS climate zones that do not have a representative groundwater monitoring well.

The remaining six wells will be placed in Whatcom County, adjacent to the U.S.-Canadian border, to supplement Ecology's long-term nitrate monitoring effort in the Sumas-Blaine Aquifer (SBA). Groundwater nitrate has been studied in the SBA by State and Federal agencies for more than 20 years (Erickson, 1998; Cox and Kahle, 1999). However, the wells sampled in this area are private domestic water supply wells and are not necessarily available for follow up sampling. The six water quality wells proposed for this project are intended to serve as a dedicated monitoring well network that would provide a continuous record for seasonal and long-term trend assessment.

3.2 Study area and surroundings

Ecology plans to install 13 monitoring wells in three geographic areas of Western Washington:

- Seven in Northwest Washington (Whatcom County)
- Three on the Olympic Peninsula
- Three in Southwest Washington

Proposed well locations are shown in Figure 1.

Northwest Washington wells

The seven Northwest Washington wells are located in Whatcom County (Figure 2).

Six of the wells are in north central Whatcom County in the Puget Lowlands physiographic province, west of the Cascade Mountain Range. The land use near the wells is predominantly irrigated agriculture consisting of raspberries, blue berries, hay, and corn. All six wells are a distance of 3,000 feet or less from the Canadian border to the north. Precipitation for this area is 35 to 60 inches annually. Precipitation falls mainly during October through March.

These six Whatcom County wells are located in the regional SBA. The hydrogeology of this aquifer is summarized in Cox and Kahle (1999). Wells are to be completed in the upper unconfined aquifer called the Sumas Aquifer which consists of a glacial outwash deposit. Soil texture of the upper unconfined aquifer is silt loam to gravelly loam. Based on driller's logs, the depth to water in the aquifer ranges from 8 feet to 40 feet below ground surface.

The seventh Whatcom County well is located east of the town of Glacier, along the west front of the Cascade Mountain Range, within the North Cascade physiographic province. Land use in this area is forest and some residential development. Average annual precipitation for this area is 60 inches. Precipitation falls mainly during October through March.

The geology in this area consists of Tertiary intrusive volcanic rocks, mass wasting deposits, and alluvial deposits. The geologic material in the area near the town of Glacier is identified as mass wasting deposits and some alluvial deposits from the nearby North Fork Nooksack River. Soil texture in nearby wells is primarily clay and gravel with some sand. Groundwater flow direction is expected to be to the southwest, toward Glacier Creek which is a distance of 600 feet from the well site.

Olympic Peninsula wells

Three monitoring wells are located on the Olympic Peninsula near the towns of Sequim, Sekiu, and Clearwater. The wells are in the Olympic Mountains physiographic province.

Land use near Sequim is scattered residential lots and agriculture. The Sekiu location is at the Hoko River State Park, which is a former ranch that is leased for grazing, with surrounding forest areas. The Clearwater location is also used for grazing and is surrounded by forest.

Average annual precipitation levels are: near Sequim 16 inches, near Sekiu 98 inches, and near Clearwater about 116 inches. The significantly lower precipitation near Sequim is due to the rain shadow effect on this area by the Olympic Mountains to the west. Most of the precipitation falls during October through April.

For all three sites, the geologic material consists of quaternary alluvial deposits embedded within tertiary sedimentary rocks, and soil texture is predominantly silt and clay with sand stringers.

Depth to groundwater is based on driller's logs archived in Ecology's well logs database. Well logs report that water level is about 35 feet at the Sequim site, 12 feet at the Sekiu site, and 10 feet at the Clearwater site.

Groundwater flow directions are: at the Sequim site, to the southeast toward the Dungeness River; at the Sekiu site, to the west in the direction of the Hoko River; and at the Clearwater site, to the west toward the Clearwater River.

Southwest Washington wells

Three groundwater monitoring wells will be installed in southwestern Washington: one at the South Lewis County Airport, one north of the town of Trout Lake in Klickitat County, and one in Clark County. The wells are located in the South Cascade Mountains physiographic province. The Lewis County site is in an area of scattered development and farmland, and the Trout Lake site is in forest and marshes. A suitable location for a Clark County well is yet to be identified.

Average annual precipitation at the Lewis County location is about 58 inches and at the Trout Lake location is about 38 inches. Most of the precipitation falls during October through April.

The geology of the Lewis County site is quaternary glacial drift deposits. At Trout Lake the geology is quaternary alluvium overlying quaternary volcanic rocks. Based on Ecology's archived driller's logs, the soil at the Lewis County site is clay and sandy clay over a sand and gravel layer. At the Trout Lake site, the soil is slate, clay, sandstone over a washed gravel. At the Lewis County site, groundwater level is at a depth of between 20 to 35 feet and groundwater flow direction is to the south, toward the Cowlitz River. At the Trout Lake site, water-level is at a depth of between 15 to 30 feet and groundwater flow direction is to the east, toward Trout Lake Creek.

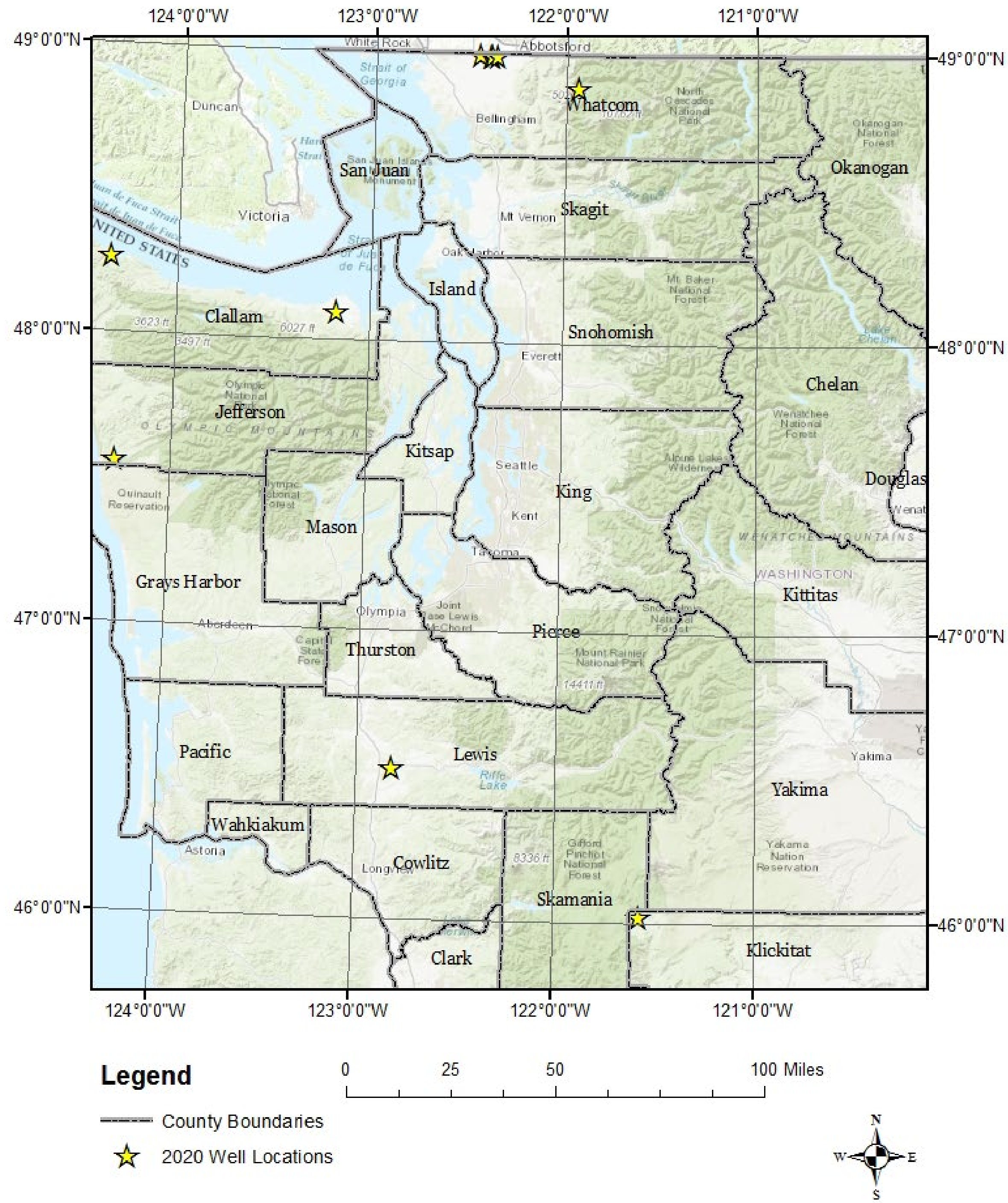

Figure 1. Map of larger study area.

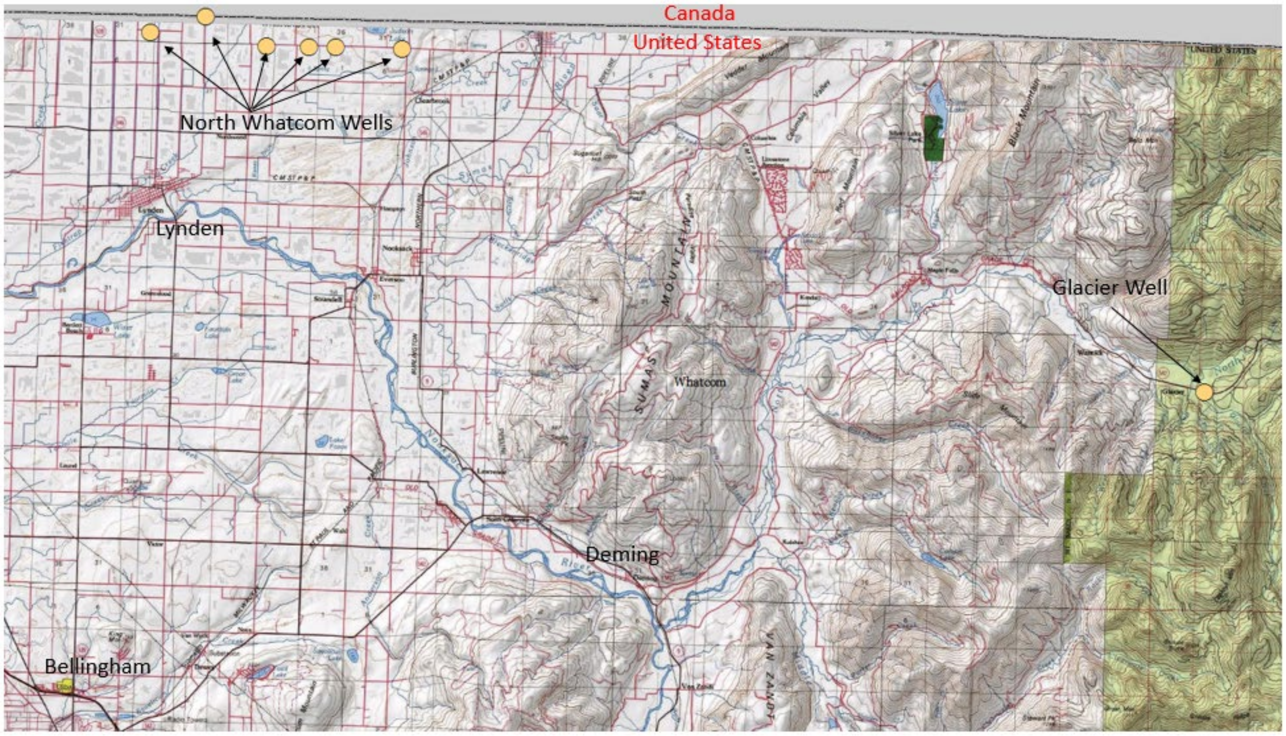

Figure 2. The six North Whatcom wells from which nitrate will be sampled.

3.2.1 History of study area

Northwest Washington wells

The area around the North Whatcom County wells primarily consists of intensive agriculture. Crop types in the area include raspberries, blueberries, hay, and corn. Concerns about nitrate contamination to groundwater have been ongoing for the past 20 years (Erickson, 1998; Cox and Kahle, 1999; Carey, 2017). Throughout these 20 years the groundwater monitoring activities have been dependent on access to private domestic water supply wells. Access to these wells has been intermittent and, therefore, the ability to maintain a continuous record of water quality throughout the aquifer has been difficult. The purpose for these wells is to provide the beginnings of a dedicated, long-term monitoring network for assessment of water quality and water-level trends in the Sumas-Blaine Aquifer.

The area near the Glacier well is primarily forest and some residential development. The purpose for this well is to provide a dedicated water-level monitoring station in an area that is not currently covered by Ecology's existing well network.

Olympic Peninsula wells

There are many wells in the Washington State groundwater monitoring network in the area near the cities of Sequim and Port Angeles. Most of these wells provide domestic or municipal water supply. This area is undergoing urban development; therefore, water withdrawals from domestic wells are increasing. In recent years, the area has exhibited trending water-level declines. A dedicated groundwater monitoring well was installed at the unincorporated community of Carlsborg in 2007. This well is completed in a lower aquifer of a three-aquifer stratified sequence. The objective of this current project is to complete the well in the upper of the three aquifers. This will provide a comparison of water-level changes occurring within the upper and lower aquifers.

The Sekiu and Clearwater wells are located in fields that are used to produce hay and are occasionally used for cattle grazing. The area around these two sites is primarily forested. There are no groundwater monitoring wells near either of these areas. Therefore, the purpose of these wells is to provide dedicated, long-term monitoring at these two locations on the Olympic Peninsula.

Southwest Washington wells

The Lewis County well is located at the South Lewis County Airport. Land use for the area surrounding the airport primarily consists of hay fields with some limited development. There have been no groundwater monitoring wells currently or in the past in this area. The purpose of this well is to provide a dedicated, long-term monitoring well in Southwest Washington that is in an area that is not subject to significant groundwater withdrawals.

The Trout Lake well is located in south-central Washington (Klickitat County) at a natural area preserve. The topographic location is identified as marshes. The ground can be saturated in some areas during the spring but dries out in the summer. The area surrounding the site is forest. There are no current or past groundwater monitoring wells in this area. Therefore, the purpose of this well is to establish a dedicated, long-term water-level monitoring well.

A suitable location for a Clark County well is yet to be identified.

3.2.2 Summary of previous studies and existing data

Northwest Washington wells

The six proposed wells in north-central Whatcom County will be sampled for water quality parameters. Elevated groundwater nitrate concentrations have been observed for over 40 years in the SBA (see Table 1). The percentage of wells not meeting the 10 mg/L nitrate-N drinking water standard in these studies has ranged from 19 to 64%.

Environment and Climate Change Canada has a network of 60 monitoring wells near the Canada-U.S. border with a 30-year nitrate record. Until 2018, about 30 wells were sampled quarterly, including in March 2018 (Suchy, 2018). As of the end of 2018, the Canadian nitrate monitoring program has been discontinued.

The Glacier well is in an area that has not hosted any groundwater monitoring wells in the past or present; therefore, there are no data available.

Table 1. Previous groundwater nitrate studies in the Sumas-Blaine aquifer (SBA).

Dates	Number of wells	Wells exceeding 10 mg/L nitrate-N (%)	Reference
1970-1973	100	19	Obert (1973)
1990	27	26	Erickson and Norton (1990)
Spring 1997	248	21	Erickson (1998)
1990-1991	230	21	Cox and Kahle (1999)
June 1999	53	50	Erickson (2000)
2002-2004	26	64	Mitchell (2005)
2003-2005	35	26	Redding (2008)
2009-2016	25	24	Carey (2017)

Olympic Peninsula wells

Groundwater levels in the Sequim area have been significantly affected by human activities (PGG, 2009). Irrigation starting in the mid-19th century caused reduced baseflow to the Dungeness River during the summer months and caused increased baseflow to small streams. Recently, there has been a shift to increase baseflow to the Dungeness River. This has resulted in less recharge to the aquifer, resulting in declining water levels. In addition, increased urbanization in the area has resulted in increased withdrawals from domestic wells, causing further declines in the groundwater.

The Sekiu and Clearwater wells are in areas that have not supported a groundwater monitoring network; therefore, there are no data available.

Southwest Washington wells

Neither of the wells at Lewis County or Trout Lake are in areas that have an existing groundwater monitoring network; therefore, there are no data available.

3.2.3 Parameters of interest and potential sources

Following are the principle parameters of interest for the six north-central Whatcom County wells and their potential sources, although the sources are not identified:

- Nitrate-N – Animal and human waste, inorganic fertilizer. Nitrate will be analyzed as nitrite+nitrate-N because nitrite-N is typically negligible in natural waters (Sawyer and McCarty, 1978)
- Ammonia-N – Animal and human waste, inorganic fertilizer
- Chloride – Can be associated with animal or human waste
- Specific conductance – Conductance of higher ionic levels can be associated with many wastes, including animal and human waste
- Dissolved oxygen (DO) – Important for interpreting water chemistry
- Oxidation/reduction potential (ORP) – Important for interpreting water chemistry
- pH – Important for interpreting water chemistry

Groundwater levels will also be monitored at these six wells.

3.2.4 Regulatory criteria or standards

The Washington State Ground Water Quality Standards (GWQS) (Chapter 173-200 WAC) apply to all groundwater of the state. The primary water quality parameter of interest for this study at six North Whatcom County wells is nitrate, with an upper limit of 10 mg/L-N. This limit corresponds with the federal maximum contaminant level for nitrate-N in drinking water (40CFR Part 41).

4.0 Project Description

This 2020-2021 project will build on activities Ecology has performed in the past as a data provider to the NGWMN.

For this project, Ecology received matching funds from the USGS to support NGWMN program objectives. This includes installation of 13 monitoring wells at selected locations in Western Washington that are not covered by Ecology's current well network. The wells will be instrumented with data loggers/pressure transducers to provide continuous water-level measurements. A subset of six wells will also be incorporated into the long-term nitrate monitoring effort in the Sumas-Blaine aquifer. The 13 new wells will provide water-level and water quality data that will be submitted to the NGWMN database.

4.1 Project goals

The goal of this project is to establish a set of 13 purpose-built, groundwater monitoring wells in Western Washington to be used for long-term water-level and water quality monitoring. Water-level data will be used to monitor seasonal and climate variability in areas of the state that are outside of the existing Ecology groundwater monitoring networks. Water quality data will supplement an existing monitoring study in the Whatcom County portion of the Sumas-Blaine aquifer.

4.2 Project objectives

The project objectives are to:

- Install 13 purpose-built groundwater monitoring wells and equip them with transducers to conduct long-term, water-level measurements in order to evaluate seasonal and climate variability over time.
- Collect water quality samples on an annual basis from a subset of six wells in Whatcom County. Samples will be collected for nitrate-N and other parameters associated with the Sumas-Blaine long-term ambient groundwater monitoring.
- Compare water quality analyte concentrations to the Washington State groundwater quality standards (chapter 173-200 WAC).
- Conduct specific capacity and/or slug tests in monitoring wells to determine the hydraulic conductivity of the aquifer.

4.3 Information needed and sources

Information on the location and construction of existing wells near the proposed well construction sites will be obtained from Ecology's Water Resources Program Well Log system, https://ecology.wa.gov/Water-Shorelines/Water-supply/Wells .

Groundwater quality SBA data are available from several studies listed in Section 3.2.2 of this Quality Assurance Project Plan (QAPP). Existing data include groundwater quality (nitrate-N, ammonia-N, and chloride), water levels, and aquifer characteristics. The current groundwater monitoring network consists of private wells that are not necessarily available for long-term monitoring. The six Whatcom County wells will serve as a dedicated, purpose-built groundwater monitoring network in support of long-term monitoring.

Water-level measurements from an existing groundwater monitoring network in the Sequim area provide water-level data. Most of the existing monitoring network consists of water supply wells. The Sequim well will be installed in the upper regional aquifer next to an existing dedicated monitoring well completed in the lower regional aquifer.

4.4 Tasks required

Project tasks fall into three categories: well construction, water-level monitoring, and water quality sampling.

Well construction

- Identify potential well locations to install 13 groundwater monitoring wells in surficial aquifers at select sites in Western Washington.
- Contact landowners and negotiate well installation agreement.
- Submit application to install well to public agencies.
- Prepare and submit well drilling contracting bid information to state-contracted well drillers.
- Contract and schedule a well drilling contractor.
- Oversee drilling and well installation operations.
- Wells will meet or exceed requirements of Minimum Standards for Construction and Maintenance of Wells (Chapter 173-160 WAC).
- Survey well measuring points using GPS instrumentation. Use GIS elevation coverage to tie into local elevation datum.
- Write a report documenting well drilling and sample collection results for submission to the NGWMN (USGS).

Water level monitoring

- Calibrate and install pressure transducers in each monitoring well for continuous water level measurements.
- Conduct quarterly manual water-level measurements and perform downloads of transducers for a period of 25 years.
- Enter data into Ecology's Environmental Information Management (EIM) system that will be linked to the NGWMN database.

Water quality sampling

- Coordinate sample collection with SBA project manager.

- Schedule sample analysis with Ecology's Manchester Environmental Laboratory.
- Collect annual water quality samples for nitrate-N and other parameters associated with the SBA long-term monitoring from the six north-central Whatcom County wells.
- Evaluate results for quality assurance (QA) using EAP QA procedures.
- Compare analytical data to Washington State groundwater quality standards (chapter 173-200 WAC).
- Enter data into Ecology's EIM system that will be linked to the NGWMN database.
- Include water quality data in SBA project reports.

4.5 Systematic planning process

This QAPP serves as the planning document for the project.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 2. Organization of project staff and responsibilities.

Staff[1]	Title	Responsibilities
Eugene Freeman Groundwater/Forests & Fish Unit (GFFU) Statewide Coordination Section (SCS) Phone: 360-407-6818	Project Manager /Licensed Hydrogeologist	Writes the QAPP. Oversees well installation and field activities. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes draft and final reports.
Jacob Carnes GFFU/SCS Phone: 360-407-6498	Field Assistant	Helps collect samples and records field information.
Eric Daiber GFFU/SCS Phone: 360-407-7169	Field Assistant	Helps collect samples and records field information.
Pam Marti GFFU/SCS Phone: 360-407-6768	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Jessica Archer SCS Phone: 360-407-6698	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Stacy Polkowske Western Operations Section Phone: 360-407-6730	Section Manager for the Study Area	Reviews and approves the final QAPP.
Alan Rue Manchester Environmental Laboratory Phone: 360-871-8801	Manchester Lab Director	Reviews and approves the final QAPP.
Arati Kaza Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

[1]All staff are from EAP.
EIM: Environmental Information Management database.
EAP: Environmental Assessment Program
QAPP: Quality Assurance Project Plan

5.2 Special training and certifications

A licensed driller will be used for all monitoring well installations (Chapter 18.104 RCW; WAC 173-160).

A hydrogeologist license is required for the person overseeing hydrogeologic studies (Chapter 18.220.020 RCW).

All field staff involved with this project have relevant experience following Ecology's Standard Operation Procedures (SOPs) or will be trained by senior staff who do. Field staff who lack the necessary skills and experience to work independently will be paired with staff mentors who will oversee and verify their work and also provide the necessary training to enable them to work proficiently and independently.

See Section 8 for a list of SOPs and practices that will be following during this project.

5.3 Organization chart

See Table 2.

5.4 Proposed project schedule

Tables 3 – 5 list key activities, due dates, and lead staff for this project.

Table 3. Proposed schedule for completing well construction and progress report.

Well Construction	Due date	Lead staff
Field work completed	August 2021	Eugene Freeman
EIM data loaded (well logs)	September 2021	Eugene Freeman
Draft report due to supervisor	September 2021	Eugene Freeman
Draft due to peer reviewer	September 2021	Eugene Freeman
Final (all reviews done) due to publications team	October 2021	Eugene Freeman
Final report due to client	November 2021	Eugene Freeman

Table 4. Proposed schedule for completing water-level monitoring.

Water Level Field Work	Due date	Lead staff
Field work completed	January/April/July/October (yearly)	Eugene Freeman
EIM Study ID	NGWMN	
EIM data loaded (water level data)	June (annually)	Eric Daiber
EIM QA	July (annually)	Eugene Freeman
EIM complete	August (annually)	Eric Daiber

Table 5. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Water Quality Sampling and Laboratory Work	Due date	Lead staff
Field work completed	March (annually)	Eric Daiber
Laboratory analyses completed	May (annually)	Eugene Freeman
Environmental Information Management (EIM) database		
EIM Study ID	NGWMN	
EIM data loaded	June (annually)	Eric Daiber
EIM data entry review	July (annually)	Eugene Freeman
EIM complete	August (annually)	Eric Daiber
Final Report		
Author lead / Support staff		Eric Daiber/ Pam Marti
Draft to supervisor	October (annually)	Eric Daiber
Draft to client/peer reviewer	December (annually)	Eric Daiber
Final draft to publications team	February (annually)	Eric Daiber
Final report due on web	March (annually)	Eric Daiber

5.5 Budget and funding

This project is jointly funded by the USGS under the NGWMN program. This QAPP addresses one of five project tasks. Under the agreement between the USGS and Ecology, a total of 13 shallow, dedicated groundwater monitoring wells will be installed in Western Washington in approximate locations as shown in Figure 1.

The funds from the USGS will be matched by funds from the State of Washington as identified in Table 6. Funding for the water quality sampling will be provided by Ecology as part of its SBA annual nitrate sampling (Table 7).

Table 6. NGWMN project budget and funding.

Item	Federal ($)	Agency-in-Kind ($)	Total ($)
Salary, benefits, and indirect/overhead	126,769	132,270	259,039
Equipment	0	15,600	15,600
Travel and other	3,702	5,553	9,255
Contracts	46,370	19,873	66,243
Project Totals	176,841	173,296	350,137

Table 7. Laboratory budget for Whatcom County wells.

Parameter	Number of Samples	Number of QA Samples	Total Number of Samples	Cost Per Sample	Lab Subtotal
Nitrate-N	6	2	8	$15	$120
Ammonium-N	6	2	8	$15	$120
Chloride	6	2	8	$15	$120
				Lab Total	$360

6.0 Quality Objectives

The quality objective for this project is to collect groundwater data of known, acceptable, and documentable quality. This will be achieved by establishing measurement quality objectives (MQOs) for precision and bias (accuracy), sensitivity, completeness, comparability, and representativeness, and by testing data against these criteria.

6.1 Data quality objectives [1]

Data quality objectives (DQOs) establish acceptable quantitative criteria for the quality and quantity of the data to be collected, relative to the ultimate use of the data. DQOs serve as performance or acceptance criteria and represent the overarching quality objectives of the study. Primary DQOs for this project are:

- Install 13 purpose-built monitoring wells that meet or exceed requirements of Minimum Standards for Construction and Maintenance of Wells (Chapter 173-160 WAC).
- Collect long-term, water-level measurements to allow the evaluation of seasonal and climate variability over time.
- Collect water quality data to add to the long-term nitrate-N monitoring effort in the SBA.

6.2 Measurement quality objectives

MQOs are performance or acceptance criteria for individual data quality indicators, including quantitative factors (precision, bias, sensitivity, and completeness) and qualitative factors (comparability and representativeness).

6.2.1 Targets for precision, bias, and sensitivity

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

6.2.1.1 Precision

Precision is a measure of the variability between results of replicate measurements that is due to random error. It is usually assessed using duplicate field measurements or laboratory analysis of duplicate samples. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures).

Duplicate samples will be collected in the field by filling two sets of bottles at the same time from a pre-selected well. Precision for field and laboratory duplicate samples will be expressed as relative percent difference (RPD) as shown in Table 8. The smaller the RPD, the more precise the measurement process. Good precision is indicative of relative consistency and comparability between different samples.

---

[1] DQO can also refer to ***Decision*** Quality Objectives. The need to identify Decision Quality Objectives during the planning phase of a project is less common. For projects that do lead to important decisions, DQOs are often expressed as tolerable limits on the probability or chance (risk) of the collected data leading to an erroneous decision. And for projects that intend to estimate present or future conditions, DQOs are often expressed in terms of acceptable uncertainty (e.g., width of an uncertainty band or interval) associated with a point estimate at a desired level of statistical confidence

Table 8. Measurement quality objectives (MQOs).

Parameter	**Duplicate Samples** (*Relative % Difference)*	**Matrix Spike-Duplicates** (*Relative % Difference)*	**Verification Standards (LCS,CRM, CCV)** (% Recovery)	**Matrix Spikes** (% Recovery)	**Surrogate Standards** (% Recovery)	**MRL or Lowest Conc. of Interest**
Temperature	n/a	n/a	n/a	n/a	n/a	2°C
pH	n/a	n/a	See Table 9	n/a	n/a	6 s.u.
Specific Conductivity	n/a	n/a	See Table 9	n/a	n/a	10 uS/cm
DO	n/a	n/a	See Table 9	n/a	n/a	0.1 mg/L
ORP	n/a	n/a	See Table 9	n/a	n/a	n/a
Water Level	0.02	n/a	n/a	n/a	n/a	0.01 ft
Ammonia-N	20	n/a	20	+/-25	n/a	0.010 mg/L
Nitrate+nitrite-N	20	n/a	20	+/-25	n/a	0.010 mg/L
Chloride	20	n/a	20	+/-25	n/a	0.1 mg/L

[a] Analyte groups are listed here with the range of MQOs of each group. Appendix C lists individual analytes and MQOs. DO: Dissolved Oxygen. ORP: Oxidation Reduction Potential.

Table 9. MQOs for field parameters expressed as acceptance criteria for field instrument intermediate and post checks (SOP EAP033).

Parameter	Units	Accept	Quality	Reject
pH	Std. Units	< or = ± 0.3	> ± 0.3 and < or = ± 1.0	> ± 1.0
Conductivity	uS/cm	< or = ± 10 %	> ± 10 % and < or = ± 20 %	> ± 20 %
Temperature	°C	< or = ± 0.2	> ± 0.2 and < or = ± 1.0	> ± 1.0
Dissolved Oxygen	mg/L	< or = ± 0.3	> ± 0.3 and < or = ± 1.0	> ± 1.0
Dissolved Oxygen	% saturation	< or = ± 5 %	> ± 5 % and < or = ± 15 %	> ± 15 %
Oxidation Reduction Potential	mv	< or = ± 5 %	> ± 5 % and < or = ± 15 %	> ± 15 %

6.2.1.2 Bias

Bias is defined as the difference between the sample value and true value of the parameter being measured. Bias is usually addressed by calibrating field and laboratory instruments, and by analyzing lab control samples, matrix spikes, and standard reference materials (see Table 8). Bias in field measurements and samples will be minimized by strictly following Ecology’s measurement, sampling, and handling protocols.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as a detection limit. In a regulatory setting, the method detection limit (MDL) is often used to describe sensitivity. Targets for lab measurement sensitivity required for the project are listed in Table 8.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Comparability expresses the confidence with which one set of data can be compared to another. Comparability will be ensured to the extent possible by implementing standardized procedures for sampling and analysis. SOPs to be used during this project are listed in Section 8.2.

The Olympic Peninsula and Southwest Washington wells are being installed in areas with limited data available on water-level conditions. Available data to compare to is limited to static water levels recorded on area well logs,

Water-level and water quality data collected from the Whatcom County wells will be compared to data collected in previous studies conducted in this area, specifically Erickson (2000, 1998), Redding (2008), and Carey (2017).

6.2.2.2 Representativeness

Representativeness expresses the degree to which data accurately and precisely represent the actual site conditions. Groundwater measurements and samples will be collected using industry standard methods, which will help ensure that representative samples are collected.

Transducers that record measurements continually (every 6 hours) will allow Ecology to observe changes in water levels that might occur over shorter timeframes than would be observed by quarterly manual measurements.

Water quality samples from the Whatcom County wells will be collected in the spring (March/April) to represent the same season and conditions as those used for samples collected in comparable studies (Redding, 2009; Carey, 2018).

6.2.2.3 Completeness

Completeness establishes whether a sufficient amount of valid measurements were obtained to meet project objectives. The number of samples and results expected establishes the comparative basis for completeness.

The completeness goal for this project is to collect and analyze 100% of the measurements and samples. However, problems occasionally arise during sample collection that cannot be controlled; thus a completeness of 95% is acceptable. Examples of potential problems that may be encountered are site access issues, equipment failure, or sample container shortages.

6.3 Acceptance criteria for quality of existing data

Existing data will be accepted if they were collected with standardized sampling, analytical, and quality assurance (QA) methods that can be documented and that are comparable to those outlined in this study.

Nitrate-N results collected from the six newly installed Whatcom County wells will be compared with data previously collected by Ecology as part of numerous SBA studies. Existing data for the study area are in the EIM database under study IDs: SUMAS, DERI001, and mred0001. These project data have a high level of QA (Level 5).

6.4 Model quality objectives

N/A

7.0 Study Design

This study is designed to install 13 purpose-built groundwater monitoring wells in select locations in Western Washington. These wells will be used for long-term water-level and water quality monitoring. Water-level data will be used to monitor seasonal and climate variability in areas of the state that are outside of existing Ecology groundwater monitoring networks. Water quality data will supplement an existing monitoring study in the Whatcom County portion of the Sumas-Blaine aquifer.

7.1 Study boundaries

Study area boundaries are shown in Figures 1 and 2. The 13 wells will be installed at select locations in Western Washington: seven in Northwest Washington (Whatcom County), three on the Olympic Peninsula, and three in Southwestern Washington.

7.2 Field data collection

Data collection at the well sites will include logging the geologic profile during drilling, documenting well construction, installing water-level monitoring equipment in each well, and sampling nitrate, ammonium, and chloride in six of the Whatcom County wells.

All wells will be installed by licensed state-contracted well drillers. The wells will meet or exceed requirements of Minimum Standards for Construction and Maintenance of Wells (Chapter 173-160 WAC).

When drilling the borehole, a 6-inch diameter hole will be drilled by the method specified by the drilling contractor. Soil samples from drill cutting will be taken at 5-foot intervals. Drill cuttings will be used to log the geologic profile. The final well depth will be determined by the season with expected low water table in the fall and winter or high water table in the spring and early summer. The screen will be set such that it will remain submerged during low water level conditions. The completed well will be a 2-inch diameter schedule 40 PVC pipe with the lower 5-10 feet consisting of 2-inch diameter, PVC slotted screen. Six of the Whatcom County wells will be flush mount construction (Figure 3), and the remaining wells will consist of a 6-inch diameter steel protective casing extending 3 feet above ground surface and protected by steel bollards (Figure 4).

A water pressure transducer will be placed in each well such that the transducer is always below the expected range of fluctuation in the water table. Where appropriate, a barometric pressure transducer will also be placed in the well above the water table such that at no time is the pressure transducer submerged below the water table. The recording frequency for both instruments will be set to log at a common start time and interval (6 hours). Since pressure transducers are not expected to be in areas where significant groundwater withdrawals are happening, there should be no need for shorter time-steps. The longer time-step also conserves battery life and data logger storage space.

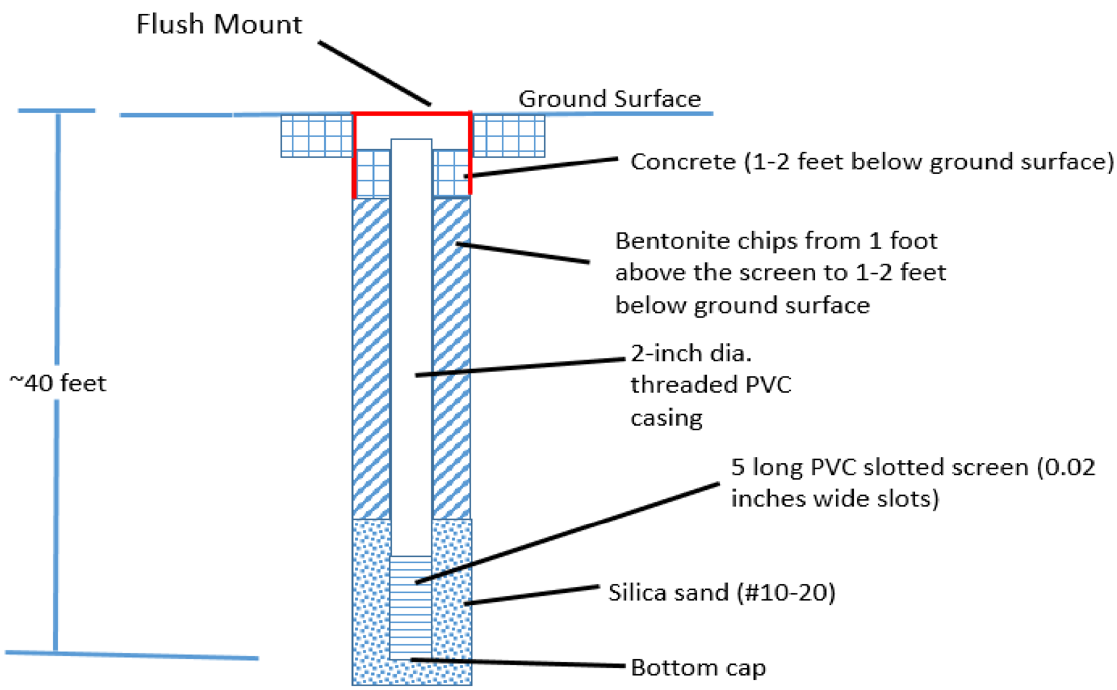

Figure 3. As-built for flush mount groundwater monitoring well design completion.

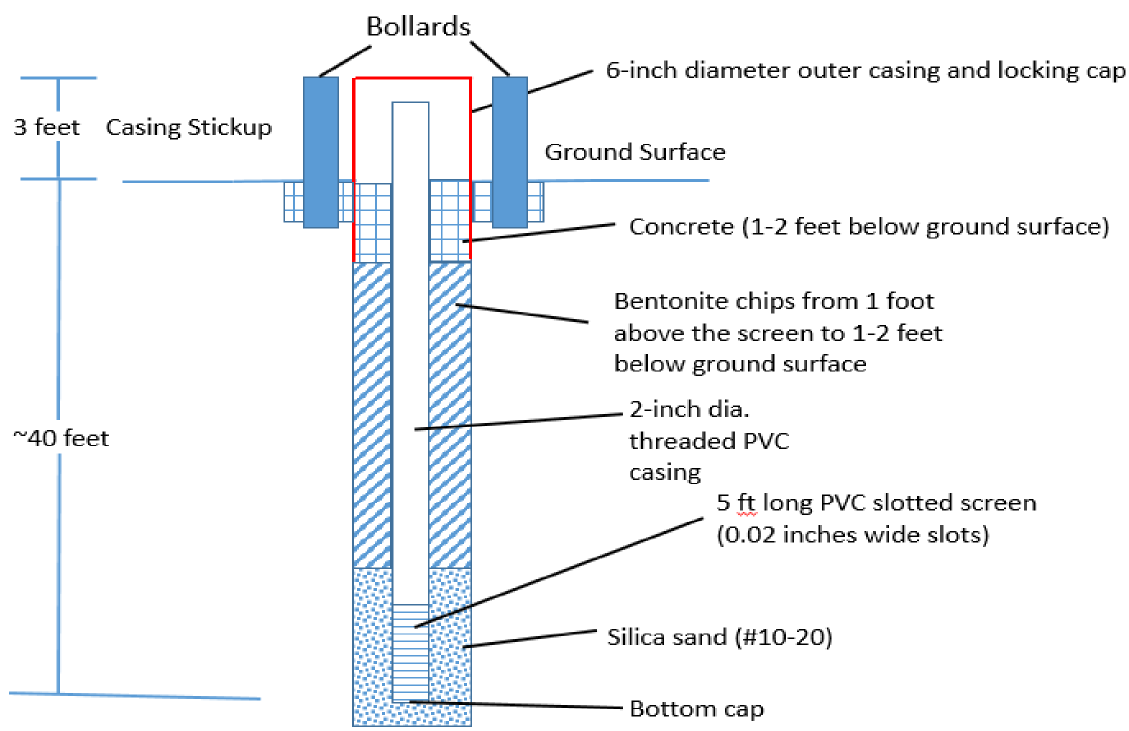

Figure 4. As-built for above-ground groundwater monitoring well design completion.

7.2.1 Sampling locations and frequency

Water-level measurements will be taken after the well is completed. Within a month after completion, data logger/pressure transducers will be installed and programmed at a regular time interval (6 hours). Each well will be visited quarterly to download data, maintain the transducers, and collect static water-level measurements. Well access agreements have been established for a period of 25 years.

Water quality samples will be collected annually in the spring for nitrate-N and other parameters associated with the SBA long-term monitoring from the six north-central Whatcom County wells

7.2.2 Field parameters and laboratory analytes to be measured

Depth to water (water levels) will be measured at all 13 installed wells.

The parameters to be measured at the six water quality wells in Whatcom County are:

- Depth to water (Field)
- Temperature (Field)
- pH (Field)
- Specific conductivity (Field)
- Dissolved oxygen (DO) (Field)
- Oxidation/reduction potential (ORP)
- Nitrite+nitrate-N (Laboratory)
- Ammonia-N (Laboratory)
- Chloride (Laboratory)

7.3 Modeling and analysis design

N/A

7.4 Assumptions underlying design

- At least a 5-foot-thick aquifer unit will be encountered in the upper unconfined aquifer during drilling.
- The lowest seasonal water level in the aquifer will not decline below the final well completion depth.
- Monitoring wells will provide information representative of site conditions.
- Access to drilling locations will not be impaired.
- Water level is not measurably affected by anthropogenic causes (addition or withdrawal) at the purpose-built, water-level monitoring wells.
- Sampling the six Whatcom County wells at the same time of year will minimize the influence of seasonal variation when comparing annual results. This assumes that seasonal climate factors (e.g., precipitation, temperature) that affect sample results are consistent each year.

7.5 Possible challenges and contingencies

The main challenges for this project are: (1) locating suitable sites for the new groundwater wells, (2) obtaining permission to install the wells from property owners and securing accesses agreements, and (3) contracting and coordinating with the well drillers.

7.5.1 Logistical problems

This project requires much logistical coordination between Ecology, property owners, and contract well drillers. Clear communications between all parties will be necessary to successfully complete the well installations. Final signatures on all access agreements will be obtained prior to drilling. Ecology will coordinate drilling activities with the drillers and property owners to ensure the well sites are clear for the drilling equipment and the areas are safe and secure.

7.5.2 Practical constraints

This project is a jointly funded venture with the USGS under the NGWMN program. Under the agreement, Ecology will match funds provided by the USGS to install 13 groundwater monitoring wells. When funding is secured, purchase requests to hire the contract drillers must be submitted and approved to meet the project schedules. Contract drillers must accept and be available to meet the project schedules.

Some practical constraints could prohibit the successful installation of the monitoring wells. The location of some underground utilities may require a proposed well to be moved or may prohibit a well from being installed.

7.5.3 Schedule limitations

Well installations have been grouped into 3 regions (Northwest Washington/Whatcom County, Olympic Peninsula, and Southwest Washington) to streamline the drilling contract process and scheduling. Well installation timelines will be coordinated with the property owners' schedules.

- Whatcom County wells must be completed by November 2020.
- The well near Clearwater, Washington must be completed by October 2020, before livestock return to the pasture where the well is located.
- Southwestern Washington wells must be completed by August 2021.

8.0 Field Procedures

8.1 Invasive species evaluation

N/A

8.2 Measurement and sampling procedures

Groundwater measurements and sampling activities for this project will follow standard operating procedures (SOPs) developed by Ecology's Environmental Assessment Program (EAP). These include the following SOPs:

- EAP052 for depth to water measurements (Marti, 2018)
- EAP074 for submersible pressure transducers (Sinclair and Pitz, 2019)
- EAP033 for measurements using a Hydrolab® (Anderson, 2020
- EAP099 for sampling monitoring wells for general chemistry (Carey, 2020)

Field measurements will be made at all sampling sites and recorded on waterproof field logs at regular intervals.

After completing a well and before leaving the site, field staff will measure static water levels in all the monitoring wells using a calibrated E-tape (SOP EAP052). Within a month of a well's completion, calibrated water-level transducers will be installed for continuous water level measurements (SOP EAP074). The transducer measurements will be compared and checked against manual water-level measurements made during quarterly field visits to download the transducer data.

Water quality samples will be collected from a subset of six Whatcom County wells as part of the SBA long-term monitoring program. Measurements for water temperature, pH, specific conductivity, dissolved oxygen (DO), and oxidation/reduction potential (ORP) will be collected using a calibrated Hydrolab MiniSonde® following Ecology's SOP EAP033 (Anderson, 2020) and manufacturer's recommendations. Field measurement methods are listed in Table 10.

Table 10. Field measurement methods.

Analyte	Sample Matrix	Expected Range of Results	Detection or Reporting Limit	Instrumental Method
Water level	Water	0-20 feet	0.1	Electrical tape
Temperature	Water	8-12°C	0.2°C	Hydrolab MS-5
pH	Water	4-8 S.U.	NA	Hydrolab MS-5
Specific conductivity	Water	50-1,000 uS/cm	5 uS/cm	Hydrolab MS-5
Dissolved oxygen	Water	0.0-10 mg/L	0.1 mg/L	Hydrolab MS-5
Oxidation/reduction potential	Water	(-300)- (+350) mv	NA	Hydrolab MS-5

Groundwater samples will be collected using a peristaltic pump and using industry-standard, low-flow sampling techniques (SOP EAP099). Wells will be purged at a rate of < 0.5-liter/minute. For purging and sample collection, each monitoring well will have dedicated tubing, silastic in the pump head, and ¼-inch diameter polypropylene for the well. The tubing will be stored in individual clean plastic bags between sample events. If water levels are beyond the peristaltic pump's range, a submersible or bladder pump will be used to purge and sample the wells.

The wells will be purged through a continuous flow cell until field parameters (pH, temperature, specific conductivity, DO, and ORP) stabilize. Samples will be collected directly from the pump discharge line after the wells are fully purged. All laboratory-bound samples will be field filtered into the appropriate containers (Table 11) using disposable in-line filters (0.45 um). Samples will be stored on ice while being transferred to Ecology's Manchester Environmental Laboratory (MEL) using standard chain-of-custody procedures.

MEL will analyze groundwater samples for the laboratory parameters of interest (Table 8).

8.3 Containers, preservation methods, holding times

Table 11 lists the sample containers, preservation, and holding times required to meet the goals and objectives of this project.

Table 11. Sample containers, preservation, and holding times.

Parameter	Matrix	Container	Preservative	Holding Time
Ammonia-N and Nitrite+nitrate-N	Water	125 mL poly, clear	H2SO4 to pH <2; Cool to 6°C or less	28 days
Chloride	Water	500 mL HDPE	Cool to 6°C or less	14 days

8.4 Equipment decontamination

Sample equipment used at more than one well, such as an E-tape, will be cleaned between sample locations. The E-tape probe will be rinsed with deionized water after each use.

Since sample tubing and filters will not be shared among the sampled wells, no equipment decontamination beyond the above is needed or warranted for this project.

Clean gloves will be worn when sampling each well. The gloves will be discarded after use at the well.

8.5 Sample ID

MEL will provide the field lead with work order numbers for all scheduled sampling dates. The work order number will be combined with a field ID number that is given by the field lead. This combination of work order number and field ID number constitute the sample ID. All sample IDs will be recorded in field logs and in an electronic spreadsheet for tracking purposes.

8.6 Chain of custody

Chain-of-custody procedures will be followed according to MEL protocol (Ecology, 2016). Once collected, samples will be properly labeled and stored in an ice-filled cooler inside the sampling vehicle. If the vehicle is left unattended, it will be locked to maintain chain-of-custody. Samples will be transported to Ecology's Operation Center in Lacey, Washington. Samples will be kept in the walk-in cooler until picked up by the laboratory courier and transported to MEL in Manchester, Washington.

8.7 Field log requirements

A field log will be maintained by the field lead and used during each sampling event. The following information will be recorded:

- Name and location of project
- Field personnel
- Sequence of events
- Any changes or deviations from the QAPP
- Environmental conditions
- Date, time, sample location, sample ID, and description of each sample
- Field instrument calibration procedures
- Field measurement results (water levels, pH, temperature, specific conductivity, DO, ORP)
- Identity of quality control (QC) samples collected
- Unusual circumstances that might affect interpretation of results
- Well depth and measurement technique

Field logs will consist of waterproof 8.5 x 11-inch field sheets pre-printed for ease of recording and kept in an enclosed metal clipboard. Permanent, waterproof ink or pencil will be used for all entries. Corrections will be made with single-line strikethroughs; initialed and dated. Electronic field logs may be used if they demonstrate equivalent security to the waterproof note system above.

8.8 Other activities

Additional activities may include:

- Any field staff new to the type of work conducted for this project will be trained by senior field staff or the project manager following relevant Ecology SOPs.
- Any maintenance needed for the Hydrolab MS-5 MiniSonde® will be performed by trained field staff following Ecology's SOP EAP033 and manufacturer instructions and recommendations.
- The Hydrolab MS-5 MiniSonde® will be calibrated at the beginning of the week and checked at the beginning of each day for calibration. If needed, mini-sondes will be re-calibrated to meet MQOs (Table 9).
- The project lead will notify the lab of any changes in scheduling.
- The project lead will work with the laboratory courier to develop a schedule for delivery of sampling containers in order to ensure that the appropriate number and type of required sample containers are available.

9.0 Laboratory Procedures

9.1 Lab procedures table

Laboratory procedures are listed in Table 12.

Table 12. Laboratory measurement methods.

Analyte	Sample Matrix[1]	Samples (Number/ Arrival Date)	Expected Range of Results (mg/L)	Detection or Reporting Limit (mg/L)	Sample Prep Method	Analytical (Instrumental) Method [2]
Ammonia-N	FW	6/annually	0.001-2.00	0.010	NA	SM 4500 NH3 H[2]
Nitrite+nitrate-N	FW	6/annually	0.01-60.0	0.010	NA	SM 4500 NO3 I[2]
Chloride	FW	6/annually	0.1-30	0.1	NA	EPA300.0[3]

[1] Filtered water

[2] Standard Methods for the Examination of Water and Wastewater, 23rd Edition, 2017. American Public Health Association [3] EPA/600/R-93/100, *Methods for the Determination of Inorganic Substances in Environmental Samples*, August, 1993

9.2 Sample preparation method(s)

Groundwater samples will be filtered in the field using clean disposable 0.45 um filters, and collected in pre-acidified bottles (nitrogen species) or non-acidified sample bottles (chloride) supplied by MEL as specified in SOP EAP099 (Carey, 2020). At least 1 liter of water will be rinsed through the filter before a sample is collected.

9.3 Special method requirements

N/A

9.4 Laboratories accredited for methods

All chemical analysis for water samples will be performed at MEL, which is accredited for all methods listed in Table 12.

10.0 Quality Control Procedures

Quality control (QC) procedures provide the information needed to assess the quality of the collected data. These procedures can also help identify problems or issues associated with data collection and analysis while the project is underway.

Total precision for field sampling and laboratory analysis will be assessed by collecting replicate samples. MEL routinely duplicates sample analyses in the lab to determine lab precision. The difference between field variability and lab variability is an estimate of the sample field variability. Field blanks, such as an equipment blank, will be used to check for sample contamination.

The primary types of QC samples used to evaluate and control the accuracy of laboratory analyses are check standards, duplicates, spikes, and blanks (Ecology, 2016). Check standards serve as an independent check on the calibration of the analytical system and can be used to evaluate bias. Duplicates are used to evaluate laboratory precision. Matrix spikes are used to check for matrix interference with detection of the analyte and can be used to evaluate bias as it relates to matrix effects. Blanks are used to check for sample contamination in the laboratory process.

10.1 Table of field and laboratory quality control

As a QC check for all installed transducers, quarterly, manual, water-level measurements will be made at each instrumented well. The check measurements will be made with a calibrated electronic well probe (E-tape) using EAP's standard protocols (Marti, 2018).

Table 13. Laboratory quality control samples, types, and frequency.

	Field		Laboratory			
Parameter	**Blanks[1]**	**Replicates[2]**	**Check Standards**	**Method Blanks**	**Analytical Duplicates**	**Matrix Spikes**
Ammonia-N	2	1	1/batch	1/batch	1/batch	1/batch
Nitrite+nitrate-N	2	1	1/batch	1/batch	1/batch	1/batch
Chloride	2	1	1/batch	1/batch	1/batch	1/batch

[1] Field blanks include 1 trip blank and 1 filter blank.
[2] Field replicate samples will be field-filtered.

Each type of QC sample in Table 13 will have MQOs associated with it (Section 6.2) that will be used to evaluate the quality and usability of the results.

10.2 Corrective action processes

QC results may indicate problems with data during the course of the project. The lab will follow prescribed procedures to resolve the problems. Options for corrective actions include the following:

- Re-calibrating the measurement equipment.
- Collecting new samples using the method described in the approved QAPP.
- Re-analyzing lab samples that do not meet QC criteria (analytical methods often state what to do when QC criteria are not met).
- Convening project personnel and technical experts to decide on the next steps needed to improve sampling or laboratory performance.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

All field data will be recorded on field logs. Before leaving each site, field notes will be checked for missing or improbable measurements. Field-generated data will be quality assured and entered into EIM as soon as practical after returning from the field. Data entry will be checked against the field notes for any errors and omissions. Missing or unusual data will be brought to the attention of the project manager for consultation.

Transducer data frequently require corrections for such factors as barometric pressure, instrument drift, or cable slippage or stretch. Data will checked and corrected before being entered into EIM.

Lab results will be checked for missing and/or improbable data. The field lead will check data received from MEL through Ecology's Laboratory Information Management System (LIMS) for omissions against the *Request for Analysis* forms. Data requiring additional qualifiers will be reviewed by the project manager.

11.2 Laboratory data package requirements

Lab-generated data reduction, review, and reporting will follow procedures outlined in the MEL *Users Manual* (Ecology, 2016). Variability in lab duplicates will be quantified using procedures outlined in the MEL *Users Manual*. Any estimated results will be qualified and their use restricted, as appropriate. For each set of samples, a standard case narrative of lab QA/QC results will be sent to the project manager.

11.3 Electronic transfer requirements

Well monitoring data that Ecology collects for this project will be managed in EIM and will be linked to the NGWMN Data Portal.

MEL will electronically transfer all lab-generated data to the project manager through the LIMS to EIM data feed. There is already a protocol in place for how and what MEL transfers to EIM through LIMS.

11.4 EIM/STORET data upload procedures

All field and lab data will be entered into EIM after data QA is complete following existing Ecology business rules and the EIM User's Manual.

11.5 Model information management

N/A

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

Field audits are always recommended for a project involving either field measurements or sampling. Currently, insufficient QA resources/personnel are likely not available for auditing activities; however, there could be a field consistency review of the project by another experienced EAP hydrogeologist. The aim of such reviews is to improve field-work consistency, improve adherence to SOPs, provide a forum for sharing innovations, and strengthen EAP's data QA program.

12.2 Responsible personnel

See Section 12.1.

12.3 Frequency and distribution of reports

A final technical report describing the work performed and results obtained during the grant period will be submitted to the USGS within 90 days after the conclusion of the project. The project schedule is shown in Table 3 of Section 5.4.

Water quality results collected from a subset of wells will be included in a SBA technical memo or report to be published according to the project schedule shown in Table 5 of Section 5.4.

12.4 Responsibility for reports

Staff responsible for the final reports are shown in Section 5.4.

13.0 Data Verification

EPA defines data verification as "the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements."

13.1 Field data verification, requirements, and responsibilities

Initial field data verification will be performed by the project manager (an EAP hydrogeologist) immediately after collecting field measurements/samples and before departing the site. This process involves checking the field logs for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be repeated.

After the sampling event, the project manager will compare all field data to determine compliance with MQOs. Values that are out of compliance with MQOs will be noted and, if necessary, equipment will be re-calibrated or wells re-sampled. At the conclusion of the study, all out-of-compliance values will be compiled and assessed for usability by the project lead.

13.2 Laboratory data verification

MEL staff will perform the lab verification following standard laboratory practices. After lab verification, a secondary verification of each data package will be performed by the project manager. This secondary verification will entail a detailed review of all parts of the lab data package, with special attention to lab QC results. If any issues are discovered, they will be resolved by the project manager.

13.3 Validation requirements, if necessary

N/A

13.4 Model quality assessment

N/A

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

After all laboratory and field data are verified, a detailed examination of the data package using statistics and professional judgment will be performed. The project manager will examine the entire data package to determine if all the criteria for MQOs, completeness, representativeness, and comparability have been met. If the criteria have not been met, the project manager will decide if affected data should be qualified or rejected based on the decision criteria from the QAPP. The project manager will decide how any qualified data will be used in the technical analysis.

14.2 Treatment of non-detects

Any non-detects will be included in the study analysis. For summary statistics, non-detects will be treated as one-half the detection limit. Nitrate-N and ammonia-N results may be non-detects.

14.3 Data analysis and presentation methods

Transducer data will be presented in graphs and tables via the NGWMN Data Portal that is linked to EIM.

Data will be presented in tabular form. The wells to be installed represent the first iteration of long-term sampling for nitrates and chloride in six Whatcom County wells. Since there are no previous data for these wells, there will be no trend or changes analysis conducted until sufficient data has been collected to make such analysis meaningful. The data will be presented in map view to show spatial distribution across the aquifer. Parameters shown will include water-levels and nitrate and chloride concentrations.

14.4 Sampling design evaluation

The sample design for the nitrate wells is based on observed nitrate concentrations in previous groundwater nitrate monitoring activities in the area (Erickson, 1998, Carey, 2017). Wells are intended to provide coverage in areas that are known to be contaminated or where there are gaps in the measurement network.

Sample design for water-level wells are intended to fill gaps in the statewide groundwater monitoring network and also show areas of natural, ambient groundwater levels.

The project manager will decide whether (1) the data package meets the MQOs, criteria for completeness, representativeness, and comparability, and (2) meaningful conclusions can be drawn from the data. If so, the sampling design will be considered effective.

14.5 Documentation of assessment

The project manager will include a section in the technical memo or report summarizing the findings of the data quality assessment.

15.0 References

Anderson, P. 2020. Standard Operating Procedure EAP033, Version 2.2: Hydrolab® DataSonde®, MiniSonde®, and HL4 Multiprobes. Publication 20-03-201. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/2003201.html. [Recertified 2019.]

Carey, B. 2017. Sumas-Blaine Aquifer Long-Term Groundwater Quality Monitoring, 2009–2016. Publication 17-03-013. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/summarypages/1703013.html.

Carey, B. 2018. Quality Assurance Project Plan: Sumas-Blaine Aquifer Nitrate Characterization, 2018. Publication 18-03-103. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/1803103.html.

Carey, B. 2020. Standard Operating Procedure EAP099, Version 1.1: Collecting Groundwater Samples for General Chemistry Parameters from Monitoring Wells. Publication 18-03-214 Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/1803214.html. [Recertified 2019.]

Cox, S., and S. Kahle. 1999. Hydrogeology, ground water quality, and sources of nitrate in lowland glacial aquifers of Whatcom County, Washington, and British Columbia, Canada. U.S. Geological Survey Water-Resources Investigations Report 98-4195. Tacoma, WA. https://pubs.er.usgs.gov/publication/wri984195.

Ecology, 2009. Quality Assurance at Ecology. Environmental Assessment Program, Washington State Department of Ecology, Olympia, WA. QA at Ecology.

Ecology, 2016. Manchester Environmental Laboratory *Lab Users Manual*, Tenth Edition. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA. http://teams/sites/EAP/manlab/LabUsers/LabUserDocs/Lab%20Manual%202016v10.pdf

Erickson, D., and D. Norton. 1990. Washington State Agricultural Chemicals Pilot Study, Final Report. Publication 90-46. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/9046.html.

Erickson, D. 1998. Sumas-Blaine Surficial Aquifer Nitrate Characterization. Publication 98-310. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/98310.html.

Erickson, D. 2000. Northcentral Sumas-Blaine Surficial Aquifer Nitrate Characterization Project—June 1999. Publication 00-03-010. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/0003010.html.

Marti, P. 2018. Standard Operating Procedure EAP052, Version 1.2: Manual Well-Depth and Depth-to-Water Measurements. Publication 18-03-215. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/1803215.html.

Mitchell, R., S. Babcock, H. Hirsch, L. McKee, R. Matthews, and J. Vandersypen. 2005. Water Quality: Abbotsford-Sumas Final Report. Western Washington University, Bellingham, WA. http://kula.geol.wwu.edu/rjmitch/Report_2005.pdf.

Obert, W.C. 1973. Nitrate in ground water, western Whatcom County, Washington. Western Washington State College Master's Thesis, 167 p.

PGG. 2009. City of Sequim 2008 Hydrogeologic Monitoring Report. Pacific Groundwater Group. sequimwa.gov.

Redding, M. 2008. Nitrate Trends in the Central Sumas-Blaine Surficial Aquifer. Publication 08-03-018. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/0803018.html.

Redding, M. 2009. Quality Assurance Project Plan: Sumas-Blaine Surficial Aquifer Long-Term Ambient Groundwater Monitoring. Publication 09-03-111. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/0903111.html.

Sinclair, K and C. Pitz. 2019. Standard Operating Procedure EAP074, Version 1.2: Use of Submersible Pressure Transducers During Groundwater Studies. Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/1903205.html.

Suchy, M., Wassenaar, L. I., Graham, G., and Zebarth, B., 2018. High-frequency NO_3^- isotope (δ^{15}N, δ^{18}O) patterns in groundwater recharge reveal that short-term changes in land use and precipitation influence nitrate contamination trends, Hydrology and Earth Systems Sciences, 22, pages 4267–4279, https://doi.org/10.5194/hess-22-4267-2018.

USGS, 2013. A National Framework for Ground-Water Monitoring in the United States" https://cida.usgs.gov/ngwmn/ .

16.0 Appendix. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Ambient: Background or away from point sources of contamination. Surrounding environmental condition.

Anthropogenic: Human-caused.

Baseflow: The component of total streamflow that originates from direct groundwater discharges to a stream.

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Groundwater: Water in the subsurface that saturates the rocks and sediment in which it occurs. The upper surface of groundwater saturation is commonly termed the water table.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Oxidation Reduction Potential: A measure of the tendency of a chemical species to acquire electrons and thereby be reduced. Each species has its own intrinsic reduction potential; the more positive the potential, the greater the species affinity for electrons and tendency to be reduced.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Specific conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Acronyms and Abbreviations

DO	(see Glossary above)
e.g.	For example
EAP	Ecology's Environmental Assessment Program
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
NGWMN	National Groundwater Monitoring Network
ORP	Oxidation/reduction potential
QA	Quality assurance
QAPP	Quality assurance project plan
QC	Quality control

RPD	Relative percent difference
RSD	Relative standard deviation
SBA	Sumas-Blaine aquifer
SOP	Standard operating procedures
USGS	United States Geological Survey
WAC	Washington Administrative Code

Units of Measurement

°C	degrees centigrade
ft	feet
mg/L	milligrams per liter (parts per million)
s.u.	standard units
umhos/cm	micromhos per centimeter

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms *precision* and *bias* be used to convey the information associated with the term *accuracy* (USGS, 1998).

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella (Kammin, 2010).

Bias: The difference between the sample mean and the true value. Bias usually describes a systematic difference reproducible over time and is characteristic of both the measurement system and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI) (Kammin, 2010; Ecology, 2004).

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process (USGS, 1998).

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured (Ecology, 2004).

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards but should be referred to by their actual designator, e.g., CRM, LCS (Kammin, 2010; Ecology, 2004).

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator (USEPA, 1997).

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator (USEPA, 1997).

Continuing Calibration Verification Standard (CCV): A quality control (QC) sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run (Kammin, 2010).

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system (Kammin, 2010; Ecology 2004).

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean (Kammin, 2010).

Data integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading (Kammin, 2010).

Data quality indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity (USEPA, 2006).

Data quality objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA, 2006).

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010).

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability, and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier – data are usable for intended purposes.
- J (or a J variant) – data are estimated, may be usable, may be biased high or low.

- REJ – data are rejected, cannot be used for intended purposes.
  (Kammin, 2010; Ecology, 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology, 2004).

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero (Ecology, 2004).

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis (USEPA, 1997).

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport (Ecology, 2004).

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples (Kammin, 2010).

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples (USEPA, 1997).

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects (Ecology, 2004).

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness (USEPA, 2006).

Measurement result: A value obtained by performing the procedure described in a method (Ecology, 2004).

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed (EPA, 1997).

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples (Ecology, 2004; Kammin, 2010).

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40 CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero (Federal Register, October 26, 1984).

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010).

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all parameters (Kammin, 2010; Ecology, 2004).

Population: The hypothetical set of all possible observations of the type being investigated (Ecology, 2004).

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator (USGS, 1998).

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data (Kammin, 2010).

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives (Kammin, 2010; Ecology, 2004).

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data (Ecology, 2004).

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled (USGS, 1998).

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator (USGS, 1998).

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population (USGS, 1998).

Sample (statistical): A finite part or subset of a statistical population (USEPA, 1997).

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit (Ecology, 2004).

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method (USEPA, 1997).

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency (USEPA, 1997).

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010).

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity (Kammin, 2010).

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin, 2010).

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning (USEPA, 2006).

References for QA Glossary

Ecology, 2004. Guidance for the Preparation of Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. https://apps.ecology.wa.gov/publications/SummaryPages/0403030.html

Kammin, B., 2010. Definition developed or extensively edited by William Kammin, 2010. Washington State Department of Ecology, Olympia, WA.

USEPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4.
http://www.epa.gov/quality/qs-docs/g4-final.pdf

USGS, 1998. Principles and Practices for Quality Assurance and Quality Control. Open-File Report 98-636. U.S. Geological Survey.
http://ma.water.usgs.gov/fhwa/products/ofr98-636.pdf