DEPARTMENT OF
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State of Washington

# Quality Assurance Project Plan

# Sumas-Blaine Aquifer Nitrate Characterization, 2018

May 2018

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## Publication Information

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

This Quality Assurance Project Plan is available on Ecology's website at https://fortress.wa.gov/ecy/publications/SummaryPages/1803103.html

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# Quality Assurance Project Plan

# Sumas-Blaine Aquifer Nitrate Characterization, 2018

May 2018

Approved by:

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

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# 2.0 Abstract

The Sumas-Blaine aquifer (SBA) is virtually the sole source of drinking water for 25,000-35,000 rural residents of northern Whatcom County. The aquifer is vulnerable to contamination due to its shallow depth, high winter rainfall, as well as overlying agricultural and residential land uses.

The purpose of this 2018 study is to resample for nitrate and other parameters at approximately 200 of the 248 wells sampled by Ecology in 1997.

Nitrate concentrations detected from monitoring across the aquifer during the 1990s indicated that more than 20% of wells had nitrate-N concentrations higher than 10 mg/L. Subsequent monitoring at a subset (25) of these wells during 2003-2016 suggests there have been statistically significant decreasing nitrate trends in 9 wells and in the average nitrate concentration for the 25 wells. During 2016, one in four sampled wells still exceeded 10 mg/L nitrate-N.

Results of the 2018 resampling will be used to assess changes in the locations and concentrations of nitrate across the aquifer since 1997. Samples will be collected for nitrate, ammonia, chloride, and field parameters during March-April to correspond with the 1997 sampling period. We will attempt to substitute equivalent wells in locations where we are unable to access previously sampled wells.

# 3.0 Background

## 3.1 Introduction and problem statement

The Sumas-Blaine aquifer (SBA) is the U.S. portion of the greater Abbotsford-Sumas aquifer (ASA) which spans the U.S.-Canada border in northern Whatcom County, WA (Figure 1). The SBA is the main drinking water source for 25,000-35,000 people in rural northern Whatcom County. Much of the land overlying the aquifer is intensively cultivated to produce dairy forage crops, berries, and other agricultural products. Residential development over the aquifer is also ongoing, including hobby farms with livestock. The area's shallow depth to water (typically less than 10 feet) and heavy winter precipitation make the aquifer especially vulnerable to nitrate contamination.

Periodic groundwater monitoring for nitrate has been conducted in the SBA since the early 1970's. Twenty-nine percent (29%) of the SBA wells sampled between 1981 and 2010 exceeded (did not meet) the drinking water/groundwater standard for nitrate of 10 mg/L-N during at least one sampling (Chapter 246-290 WAC; Chapter 173-200WAC; Carey and Cummings, 2012). In spring of 1997, 21% of 248 SBA wells sampled exceeded the drinking water limit (Erickson, 1998). Follow-up sampling at 25 of these wells between 2003 and 2016 suggests there were statistically significant decreasing trends in 9 wells, no statistical trend in 15 wells, and an increasing trend in 1 well. Despite the decreasing trend in 9 wells, 25% of sampled wells exceeded 10 mg/L nitrate-N in 2016 (Carey, 2017).

This 2018 study is being undertaken to assess potential changes in groundwater nitrate concentrations within the greater SBA since the last broad scale sampling of the aquifer in 1997.

A major goal of this study is to replicate the 1997 study as much as possible by sampling approximately 200 of the 248 wells sampled by Erickson in 1997. Results of the study will also provide current information on cross-boundary groundwater quality, due to similar groundwater sampling that took place north of the Canadian border in March of 2018.

## 3.2 Study area and surroundings

The SBA is located in the Fraser-Whatcom Lowland and is bordered by the Cascade Mountain Range to the east and the Salish Sea to the west. Most of the study area is located on the glacial outwash plain, which is bisected by the Nooksack River. Hummocky uplands are found in the northeastern and southern parts of the area.

The outwash plain consists of sand, silt, and gravel deposited by glaciers advancing and retreating from the area (Cox and Kahle, 1999). The portion of the outwash plain located north of the Nooksack River is 40-60 feet higher than the area south of the river and is called the Lynden Terrace.

The original coniferous forests have mostly been logged and the land converted to agricultural production. Dairy-related forage crops cover the most acreage, followed by berry production. Much of the cultivated land in low-lying areas is underlain by tile drains that discharge to larger drains that in turn flow into to nearby creeks and eventually to the Nooksack River (Figure 1). The Nooksack River is one of the largest tributaries of the Salish Sea. The general groundwater flow direction of the SBA is toward the Nooksack River (Tooley and Erickson, 1996).

The SBA covers about 150 square miles, with groundwater depths less than 10 feet in much of the area (Tooley and Erickson, 1996). As part of the larger ASA, the SBA is downgradient of the Canadian portion of the aquifer.

The SBA ranges from less than 25 feet in the west to over 75 feet on the eastern edges, with most aquifer areas less than 50 feet thick. The average reported hydraulic conductivity[1] of the SBA is 270 feet/day with a range of 7 to 7,800 feet/day (Cox and Kahle, 1999).

The local area has a moderate coastal climate influenced by nearby marine water to the west and coastal mountain ranges to the east. These features lead to mostly mild temperatures and an annual precipitation of 35-60 inches. Rainfall is concentrated during October-March, with very little rainfall in the summer. Occasional winter storms from the Fraser Valley to the northeast bring colder air and snow.

The combination of shallow depth to groundwater and high winter precipitation make the SBA especially vulnerable to contamination.

[1] Rate of water movement through a material at a unit gradient.

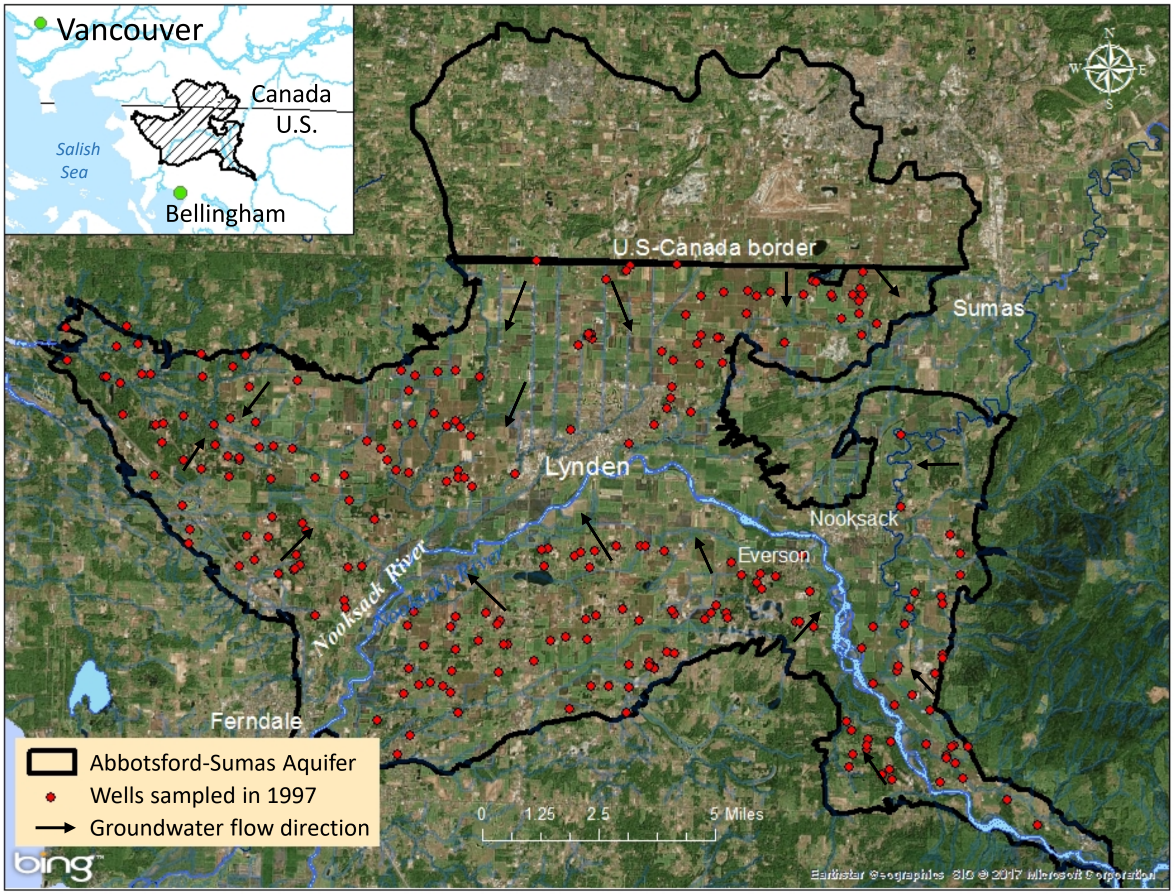


Figure 1. Map of the Abbotsford-Sumas aquifer showing sampling locations for 1997 and the generalized groundwater flow direction.

*Erickson, 1998; Tooley and Erickson, 1996*

### 3.2.1 History of study area

Approximately 115,000 acres in Whatcom County are used for farmland, with dairy farms occupying the most acreage. The earliest records posted by Whatcom Farm Friends indicate 33,000 cows in Whatcom County in 1950 (Whatcom Farm Friends, 2017). In 2014, the number of dairy cows in the county was down to 44,000 from a peak of over 67,000 in the 1990s. The number of dairies has also declined over time from approximately 1,000 in 1962 to only 104 in 2014. The average herd size in 2014 was approximately 400 animals (Whatcom Farm Friends, 2017).

Over the past 30 years, raspberries (and more recently blueberries) have been planted in many fields that were formerly used to grow grass and corn to support local dairy operations. In 2015, grass and corn crops encompassed 45,219 acres in the Whatcom County, while berries occupied 15,029 acres (Washington State Department of Agriculture, 2017).

Land conversion from agricultural and forested areas to residential development, including hobby farms, has also increased in recent years.

### 3.2.2 Summary of previous studies and existing data

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. Currently, about 30 wells are sampled quarterly, including in March 2018 (Suchy, 2018).

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

| 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) |

### 3.2.3 Parameters of interest and potential sources

The principle parameters of interest for this study and potential sources, although the study is not designed to identify sources, include:

- 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 **–** 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

### 3.2.4 Regulatory criteria or standards

The Washington State Ground Water Quality Standards (GWQS) (Chapter 173-200 WAC) apply to all groundwaters of the state. The parameter of primary interest for this study 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

A total of 248 wells distributed across the SBA were sampled in 1997 to provide a snapshot in time of nitrate concentrations (Erickson, 1998). A small subset of these wells (~25) has been sampled nearly annually since 2003. The average springtime nitrate-N concentrations in this well subset have decreased over time (Carey, 2017). Trends in individual wells for 2003 to 2016 varied: 9 wells had decreasing trends, 15 had no trend, and one well had an increasing trend. Still, the percent of wells in 2016 with nitrate-N concentrations above 10 mg/L-N was 24%.

The number of wells in the trend analysis is so small in relation to the size of the aquifer that it is likely that these results are not representative of the 150-square-mile SBA as a whole. Accordingly, this 2018 study is intended to help address this shortfall by collecting samples from 200 of the wells sampled in 1997. Results of this study will provide a more comprehensive dataset for comparison of nitrate concentrations over the entire aquifer and at the same time of year as the smaller subset.

## 4.1 Project goals

The major reasons for conducting the project are to (1) get a broad perspective on current nitrate concentrations in the aquifer compared to 1997, (2) observe the regional groundwater flow direction compared to previous studies, (3) begin to investigate nitrate influences on groundwater quality from upgradient Canadian groundwater, and (4) provide information to help develop a long-term, purpose-built groundwater monitoring network for the aquifer.

## 4.2 Project objectives

The objectives of the study are to:

- Sample approximately 200 of the SBA water supply wells sampled in 1997 by Erickson (1998) for pH, specific conductance, dissolved oxygen (DO), oxidation/reduction potential (ORP), nitrite+nitrate-N, ammonia-N, and chloride. Wells will be sampled from March through April 2018 to coincide with the timing of the 1997 sampling. If 200 formerly sampled wells are not obtained, we will substitute new water supply wells in areas where the unavailable wells are located.
- Measure the depth to water in wells, where access is possible and permission is granted in order to evaluate the direction of groundwater flow.
- Evaluate changes over time by comparing results from this study to historical data, including:
    - Mean nitrate-N concentrations between 1997 and 2018.
    - Differences in results between individual wells sampled in 1997 and 2018.
    - Trends in wells with a longer data record, including wells in the Ecology long-term nitrate trend study (Carey, 2017).
    - Nitrate results collected by Environment and Climate Change Canada in March 2018 at monitoring wells near the US-Canada border.

## 4.3 Information needed and sources

Groundwater quality data are available for the SBA from several studies listed in Section 3.2.2. Existing data include groundwater quality (nitrate-N, ammonia-N, and chloride), water levels, and aquifer characteristics.

Data from Ecology studies are available from the EIM database, https://fortress.wa.gov/ecy/eimreporting/ (Study IDs: SUMAS, DERI001, and mred0001). Data from the U.S. Geological Survey are available from the National Water Information System (NWIS) database https://waterdata.usgs.gov/nwis

## 4.4 Tasks required

The following are the main tasks for this project:

- Obtain permission from approximately 200 well owners across the SBA to sample their well water (preferably wells that were sampled in the 1997 study and secondarily wells with drilling logs near wells no longer available).
- Schedule well sampling within a 2-week to 4-week timeframe during March-April 2018.
- Measure groundwater levels, where possible, and collect samples as scheduled.
- Evaluate results for quality assurance (QA) using standard Environmental Assessment Program (EAP) QA procedures.
- Enter results into Ecology EIM database.
- Evaluate EIM data for QA according to standard EAP procedures.
- The Whatcom County Health Department will send nitrate results to the owner(s) of each well sampled.
- Map results and analyze data for changes over time including comparison with the 10 mg/L nitrate-N GWQS.
- Prepare and publish a report describing the results.

## 4.5 Systematic planning process used

This Quality Assurance Project Plan (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 (All EAP except client) | Title | Responsibilities |
|---|---|---|
| Steve Hood<br>Water Quality Program<br>Bellingham Field Office | Client | Clarifies scope of the project. Approves the final QAPP. |
| Barb Carey<br>Groundwater, Fish and Forest Unit, SCS<br>Phone: 360-407-6769 | Project Manager/Principal Investigator | Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. |
| Eric Daiber<br>Groundwater, Fish and Forest Unit. SCS<br>Phone: 360-407-7169 | Field Assistant/ Investigator | Helps collect samples and records field information. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft and final report. |
| Kirk Sinclair/ Pam Marti<br>Groundwater, Fish and Forest Unit, SCS<br>Phone: 360-407-6557 | Unit Supervisor for the Project Manager | Provides internal review of the QAPP, approves the budget, and approves the final QAPP. Reviews the draft report. |
| Jessica Archer<br>SCS<br>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. |
| Dale Norton<br>Western Operations Section<br>Phone: 360-407-6596 | Section Manager for the Study Area | Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP. |
| Alan Rue<br>Manchester Environmental Laboratory<br>Phone: 360-871-8801 | Director | Reviews and approves the final QAPP. |
| Tom Gries<br>Phone: 360-407-6327 | Acting Ecology Quality Assurance Officer | Reviews the draft QAPP and approves the final QAPP. |

EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan
SCS: Statewide Coordination Section

## 5.2 Special training and certifications

Sampling will include 5 teams of 2 people each. One member of each team will be experienced in sampling water supply wells according to Standard Operating Procedures EAP096 (Carey, 2016a), EAP052 (Marti, 2009), EAP033 (Swanson, 2010), and EAP099 (Carey, 2016b). Analysis of results will require experience with GIS mapping and data analysis.

A hydrogeologist license is required to oversee hydrogeologic studies (Chapter 18.220.020 RCW).

## 5.3 Organization chart

NA

## 5.4 Proposed project schedule

Table 3. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

| Field and laboratory work | Due date | Lead staff |
|---|---|---|
| Field work completed | April 15, 2018 | Barb Carey |
| Laboratory analyses completed | May 30, 2018 | |
| Environmental Information System (EIM) database | | |
| EIM Study ID | edai0001 | |
| Product: | Due date | Lead staff |
| EIM data loaded | June 30, 2018 | Eric Daiber |
| EIM data entry review | July 15, 2018 | Eugene Freeman |
| EIM complete | August 15, 2018 | Eric Daiber |
| Final report | | |
| Author lead / Support staff | Eric Daiber/Pam Marti | |
| Schedule: | | |
| Send results to Whatcom County Health Department for mailing to homeowners | September 30, 2018 | |
| Draft report due to supervisor | October 15, 2018 | |
| Draft report due to client/peer reviewer | December 15, 2018 | |
| Draft report due to external reviewer(s) | NA | |
| Final report (all reviews done) due to publications coordinator | February 15, 2019 | |
| Final report due on web | March 31, 2019 | |

## 5.5 Budget and funding

EAP will provide funding for the project. The itemized costs for the project are listed in Table 4.

Table 4. Project budget.

| Item | | | | | Cost |
|---|---|---|---|---|---|
| Equipment and supplies (e.g. tubing, filters, gloves, calibration standards, flow cells, field meter repairs). | | | | | $10,000 |
| Travel (10 staff for 2-3 weeks) | | | | | $14,000 |
| Laboratory (see below) | | | | | $ 10,568 |
| | | | | Total Project Cost: | $34,568 |
| Parameter | Number of Samples | Number of QA Samples | Total Number of Samples | Cost Per Sample | Lab Subtotal |
| Nitrite+nitrate-N | 200 | 50 | 250 | $14.09 | $3,523 |
| Ammonia-N | 200 | 50 | 250 | $14.09 | $3,523 |
| Chloride | 200 | 50 | 250 | $14.09 | $3,523 |
| | | | | Lab Total: | $10,568 |

# 6.0 Quality Objectives

## 6.1 Data quality objectives [2]

The main data quality objectives (DQOs) for this project are to collect approximately 200 groundwater samples representative of the SBA and analyze them for pH, specific conductivity, DO, ORP, nitrite+nitrate-N, ammonia-N, and chloride. Sampling and analysis will be done using the standard methods described in this QAPP (Sections 8.0 and 9.0). The sampling process should (1) meet the Measurement Quality Objectives (MQOs) described below and (2) ensure the results for this study are comparable to previous study results listed in Section 3.2.2.

## 6.2 Measurement quality objectives

MQOs for the data to be collected are listed in Tables 5 and 6.

### 6.2.1 Targets for precision, bias, and sensitivity

#### 6.2.1.1 Precision

Precision for laboratory duplicate samples will be expressed as relative percent difference (RPD) as shown in Table 5. Duplicate field samples will be collected by filling two bottles for each of the planned laboratory analyses. The bottle pairs for each analyte (or group of analytes) will be filled sequentially with minimal time passage between the filling of bottles. For example, we will fill one bottle to test for chloride and then quickly fill the second bottle for chloride testing. We will repeat this pattern for each constituent/bottle pair until all analytes have been collected.

#### 6.2.1.2 Bias

Bias is the difference between the population mean and the true value. Bias will be addressed by calibrating field equipment at the start of each week and checking calibration each day. If any of the field parameters do not meet the acceptance criterion, that parameter will be re-calibrated (Table 6). Laboratory instruments will be calibrated per SOPs, and both lab control samples and matrix spikes will be analyzed via standard reference materials. Targets for bias in terms of acceptable % recovery are listed in Table 5.

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[2] 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 5. Measurement quality objectives (e.g., for field and laboratory analyses of water samples).

| MQO → | Precision | | Bias | | | Sensitivity |
|---|---|---|---|---|---|---|
| Parameter | Duplicate Samples (Lab Samples) | Matrix Spike Duplicates | Verification Standards (LCS,CRM,CCV) | Matrix Spikes | Surrogate Standards | MDL or Lowest Conc. of Interest |
| | Relative Percent Difference (% RPD) | | Recovery Limits (%) | | | Concentration Units |
| Temperature | NA | NA | NA | NA | NA | 2°C |
| pH | NA | NA | See Table 6 | NA | NA | NA |
| Specific conductivity | NA | NA | See Table 6 | NA | NA | 10 umhos/cm |
| Dissolved oxygen (DO) | NA | NA | See Table 6 | NA | NA | 0.1 mg/L |
| Oxidation reduction potential (ORP) | NA | NA | See Table 6 | | | |
| Water level | 0.02 | NA | NA | NA | NA | 0.01 ft |
| Ammonia-N | 20 | NA | 20 | +/-25 | NA | 0.010 mg/L |
| Nitrite+nitrate-N | 20 | NA | 20 | +/-25 | NA | 0.010 mg/L |
| Chloride | 20 | NA | 20 | +/-25 | NA | 0.1 mg/L |

Table 6. Measurement quality objectives for field parameters expressed as acceptance criteria for field instrument pre-calibration and post-calibration.

**Pre- and Post- Use Calibration Acceptance Criteria by Parameter**

| Pre-calibration | Post-calibration |
|---|---|
| **pH pre-calibration acceptance criteria** | **pH post-calibration acceptance criteria** |
| less than or equal to ±0.05 = pass | less than or equal to ±0.15 = pass |
| greater than ±0.05, re-calibrate | greater than ±0.15 and less than or equal to ±0.5 = "J" qualify |
| | greater than ±0.5 = reject |
| **Conductivity pre-calibration acceptance criteria** | **Conductivity post-calibration acceptance criteria** |
| less than or equal to ±2% = pass | less than or equal to ±5% = pass |
| greater than ±2%, re-calibrate | greater than ±5% and less than or equal to ±10% = "J" qualify |
| | greater than ±10% = reject |
| **ORP pre-calibration acceptance criteria** | |
| less than or equal to ±2% = pass | **DO% Saturation post-calibration acceptance criteria** |
| greater than ±2%, re-calibrate | less than or equal to ±5% = pass |
| | greater than ±5% and less than or equal to ±10% = "J" qualify |
| | greater than ±10% = reject |
| | **ORP pre-calibration acceptance criteria** |
| | less than or equal to ±5% = pass |
| | greater than ±5% and less than or equal to ±10% = "J" qualify |
| | greater than ±10% = reject |

### 6.2.1.3 Sensitivity

Sensitivity is the measure of a method's ability to detect a substance. It is commonly described as *detection limit*. In a regulatory sense, the method detection limit (MDL) is usually used to describe sensitivity. This study's required targets for field and lab measurement sensitivity are listed in Table 5.

### 6.2.2 Targets for comparability, representativeness, and completeness

#### 6.2.2.1 Comparability

Standard Operating Procedures (SOPs) to be used during the study are listed in Section 8.2. We will compare data collected in this study with data from previous studies conducted in this area, especially Erickson, (2000, 1998), Redding (2008), and Carey (2017). Laboratory and field methods used in 1997 are consistent with those to be used in 2018; however, samples collected in 1997 were not filtered. EAP's standard practice for samples collected from 2003 to 2016 has been to filter samples in the field.

In order to assess the effect of filtering on sample results, 5% of samples will be duplicated with one sample being filtered and the other being unfiltered. The difference between filtered and unfiltered samples will be compared with the difference between duplicates that were both filtered. The mean difference between the two groups of duplicates (duplicates consisting of one filtered and one non-filtered, and duplicates consisting of filtered only) will be compared statistically (95% confidence) to determine if there is a difference. If there is no statistical difference between the filtered and unfiltered duplicates, then we will assume that the samples from 1997 are comparable with those from 2018. If there is a statistical difference at the 95% confidence level, this will be reported in the analysis of differences between results for 1997 and 2018.

#### 6.2.2.2 Representativeness

In order to obtain samples representative of the aquifer, we will (1) follow SOPs for groundwater sampling as listed in Section 8.2, (2) ensure that field meters are properly calibrated, and (3) ensure consistency among sampling teams by pre-training team leads.

Samples will be collected during March-April to represent the same season and conditions as those for samples collected in a comparable study in 1997 (Erickson, 1998). The same effects from weather and groundwater, both physical and chemical, should occur as they did in 1997.

#### 6.2.2.3 Completeness

The goal for the 2018 Sumas-Blaine Aquifer nitrate characterization study is to correctly collect and analyze 100% of the planned measurements and samples. However, problems occasionally arise during sample collection that cannot be controlled. Therefore, a completeness of 95% is acceptable. Example problems are equipment failure and site access problems.

## 6.3 Acceptance criteria for quality of existing data

Nitrate results collected in this study will be compared with data previously collected by Ecology and the USGS. 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 quality assurance (Level 5).

Nitrate data collected by the USGS are stored in the National Water Information System (NWIS), and the data quality is high.

## 6.4 Model quality objectives

NA

# 7.0 Study Design

## 7.1 Study boundaries

The SBA study area includes the portion of the Abbotsford-Sumas aquifer that is located in the U.S. (see Figure 1).

## 7.2 Field data collection

The proposed sampling locations are largely the same as those sampled by Ecology in 1997 (Erickson, 1998) (Figure 1).

### 7.2.1 Sampling locations and frequency

This project involves one-time re-sampling of approximately 200 of the 248 private SBA water supply wells that Ecology sampled in 1997 (Erickson 1998) (Figure 1). We will probably not be able to resample all of the original 248 wells sampled in 1997 due to changes in property ownership and the long period of time since most of these wells were last sampled.

New wells will be added if 200 of the formerly sampled wells are not available. New wells will be chosen to provide even spatial coverage across the aquifer as well as documentation of well construction and depth similar to wells not available.

### 7.2.2 Field parameters and laboratory analytes to be measured

The parameters to be measured/sampled for each well include:

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

## 7.3 Modeling and analysis design

NA

### 7.3.1 Analytical framework

NA

### 7.3.2 Model setup and data needs

NA

## 7.4 Assumptions in relation to objectives and study area

The study design is based on the following assumptions:

- Sampling at the same time of year as the previous 1997 sampling minimizes the influence of seasonal variation when comparing results. This assumes that seasonal climate factors that affect sample results are consistent each year (e.g., precipitation, temperature). Therefore, we evaluate the 1997 and 2018 results in the context of differences in temperature and precipitation patterns observed during these years.
- Distribution of wells sampled in 1997 is still representative of the land uses present in the SBA; therefore, the 2018 results will be representative of recent and current land uses.
- Changes in nitrogen loading to groundwater from various land uses (e.g., agriculture and residential) will be reflected in samples from the wells.

## 7.5 Possible challenges and contingencies

The main possible challenge for the study relates to accessing private property.

### 7.5.1 Logistical problems

Miscommunication with property owners is the main potential logistical problem. We will ensure that property owners (1) have given verbal or written permission for us to sample their wells, (2) have agreed to the date and time that we will be there to sample, and (3) will be notified if our schedule changes during the sampling event.

### 7.5.2 Practical constraints

Sampling 200 wells within a 2-3 week period will require a large number of people. We plan to have 5 teams of 2 people working for at least 2 weeks.

### 7.5.3 Schedule limitations

If there are not sufficient personnel available to accomplish the entire sampling plan in 2-3 weeks, the sampling period may be extended by another week. This will not negatively affect the usability of the data.

# 8.0 Field Procedures

## 8.1 Invasive species evaluation

NA

## 8.2 Measurement and sampling procedures

Groundwater samples and procedures for the study will follow Ecology SOPs:

- EAP052 for depth to water measurements (Marti, 2009)

- EAP096 for sampling water supply wells for general chemistry (Carey, 2016a)
- EAP033 for measurements using a Hydrolab (Swanson, 2010)
- EAP099 for sampling monitoring wells for general chemistry (Carey, 2016b)

Field measurements will be made at all sampling sites and recorded on waterproof paper in a field notebook. Measurements for temperature, pH, specific conductivity, ORP, and DO will be collected using a calibrated Hydrolab MiniSonde® following Ecology's SOP EAP033 (Swanson, 2010) and manufacturer's recommendations. Field measurement methods are listed in Table 7.

Table 7. Field measurement methods.

| Analyte | Sample Matrix | Samples (Number) | Expected Range of Results | Detection or Reporting Limit | Instrumental Method |
|---|---|---|---|---|---|
| Water level | Water | 100 | 0-20 feet | 0.1 | Electrical tape |
| Temperature | Water | 200 | 8-12°C | 0.2°C | Hydrolab MS-5 |
| pH | Water | 200 | 4-8 S.U. | NA | Hydrolab MS-5 |
| Specific conductivity | Water | 200 | 50-1,000 umhos/cm | 5 umhos/cm | Hydrolab MS-5 |
| Dissolved oxygen | Water | 200 | 0.0-10 mg/L | 0.1 mg/L | Hydrolab MS-5 |
| Oxidation/ reduction potential | Water | 200 | (-300)-(+350) mV | NA | Hydrolab MS-5 |

Water supply wells will be purged using a Y-fitting on an outdoor faucet as close to the well head as possible. One discharge from the Y-fitting will be connected to a garden hose and set at a high discharge rate. The other outlet from the Y-fitting will be connected to an airtight flow-through chamber set at a low flow rate (~ 300 ml/minute).

Purging will continue until the volume of water in the well's storage tank has been discharged and field parameters are stable (temperature, pH, specific conductance, and dissolved oxygen). This typically requires about 30 minutes. All laboratory bound samples will be field filtered into the appropriate container (Table 6) using disposable in-line filters (0.45 µm) and then stored on ice. Additional groundwater quality sampling details are specified in SOP EAP096.

Groundwater samples will be analyzed in the laboratory for the parameters shown in Table 3.

## 8.3 Containers, preservation methods, holding times

Table 8 lists the sample containers, preservation, and holding times required to meet the goals and objectives of this project.

Table 8. Sample containers, preservation, and holding times.

| Parameter | Matrix | Container | Preservative | Holding Time |
|---|---|---|---|---|
| Ammonia-N and Nitrite+nitrate-N | Water | 125 mL poly, clear | $H_2SO_4$ 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 tubing will be decontaminated between sites by pre-sample purging of the sample tubing after the well and storage tank have been purged using the Y-fitting shown in Figure 2.

Sample teams will start each day with 5 pre-cleaned Y-fittings (shown in Figure 2) and sample tubes—one for each well to be sampled that day. At the end of the day, the Y-fittings and connectors will all be cleaned with detergent and rinsed with tap water and deionized water. Cleaned sampling assemblies will then be stored in clean zip-lock plastic bags to be used the next sample day. At least 5 liters of water will be rinsed through the sample tubing before a sample is collected.

A new prepackaged, in-line filter will be used for each sample. At least 5 liters of water will be rinsed through the sample tubing before a sample is collected.

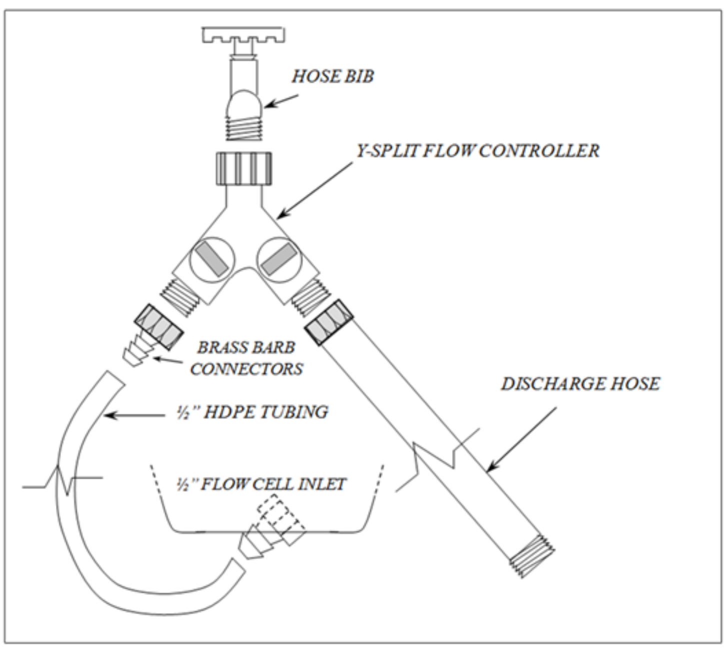


Figure 2. Y-fitting for purging and sampling water supply wells.

*Purge water from the well and storage tank discharge from the right side of the Y. The sample tubing is attached to the left side of the Y.*

## 8.5 Sample ID

Sample IDs will consist of the EIM sample ID used for the 1997 data.

Wells that have not previously been sampled will be given a new unique ID using the USGS numbering system described in Appendix B.

## 8.6 Chain-of-custody

Once collected, samples will be stored on ice in coolers inside the sampling vehicle. When field crew members are not in the sampling vehicle, it will be locked to maintain chain-of-custody. Upon return to the Operations Center (OC), the chain-of-custody portion of the *Laboratory Analysis Required* sheet will be filled out and the coolers will be placed in the walk-in cooler.

Iced coolers will be sealed or secured with metal clips. Identification numbers for the metal clips or seals will be recorded on the *Laboratory Analysis Required* form that will be placed in a plastic bag inside one of the coolers.

If sample teams return to the OC on Friday, samples will placed in new coolers with blue ice to maintain freezing temperatures in the coolers stored in the OC walk-in cooler for transport to Ecology's Manchester Environmental Laboratory (MEL) on Monday morning. Samples brought to the OC on Thursday do not require transfer to new coolers and will be transported to MEL on Friday morning.

## 8.7 Field log requirements

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

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

Field logs will consist of waterproof 8.5 x 11-inch field sheets, pre-printed for ease of recording, and will be 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, then 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 include the following:

- Any field staff new to the type of sampling conducted for this study will be trained by senior field staff or the project manager, following relevant Ecology SOPs.
- The Hydrolab MS-5 mini-sondes 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 6).
- 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

Lab procedures are listed in Table 9.

Table 9. 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 [2,3] |
|---|---|---|---|---|---|---|
| Ammonia-N | FW | 100—3/23/18<br>100—3/30/18 | 0.001-2.00 | 0.010 | NA | SM 4500 NH3 H[2] |
| Nitrite+nitrate-N | FW | 100—3/23/18<br>100—3/30/18 | 0.01-60.0 | 0.010 | NA | SM 4500 NO3 I[2] |
| Chloride | FW | 100—3/23/18<br>100—3/30/18 | 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)

Well water 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 SOPs EAP096 and EAP099 (Carey, 2016a and 2016b).

## 9.3 Special method requirements

NA

## 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 8.

# 10.0 Quality Control Procedures

Four to five teams of 2 samplers each will collect samples over 2-3 weeks. One member of each team will be an EAP employee with experience sampling groundwater. Team leads will meet before sampling begins to review sampling procedures. Teams will be in phone contact with each other as needed and conduct updates at the end of each day to review progress.

## 10.1 Table of field and laboratory quality control

Table 10 lists the field and laboratory QC requirements for the project.

Table 10. Quality control samples, types, and frequency.

| Parameter | Field | | Laboratory | | | |
|---|---|---|---|---|---|---|
| | Blanks[1] | Replicates[2] | Check Standards | Method Blanks | Analytical Duplicates | Matrix Spikes |
| Ammonia-N | 20 | 15% | 1/20 samples | 1/20 samples | 1/20 samples | 1/20 samples |
| Nitrite+nitrate-N | 20 | 15% | 1/20 samples | 1/20 samples | 1/20 samples | 1/20 samples |
| Chloride | 20 | 15% | 1/20 samples | 1/20 samples | 1/20 samples | 1/10 samples |

[1] Field blanks include: 1 trip blank and 1 filter blank per team per week. (4-5 teams per week).
[2]10% of field replicates samples will be field-filtered and 5% of replicates will not be field-filtered for comparison with 1997 results.

Each type of QC sample listed above has an MQO 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 that need to be taken to improve sampling or laboratory performance

# 11.0 Management Procedures

## 11.1 Data recording and reporting requirements

All field data will be recorded in a field notebook. Field notebooks will be checked for missing or improbable measurements before leaving each site. Field-generated data will be entered into Microsoft Excel® spreadsheets as soon as practical after returning from the field. Data entry will be checked by the field assistant against the field notebook data for errors and omissions. Missing or unusual data will be brought to the attention of the field lead or project manager for consultation. The final QA'd field data will then be entered into EIM.

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

## 11.2 Laboratory data package requirements

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

## 11.3 Electronic transfer requirements

MEL will electronically transfer all laboratory-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 laboratory data will be entered into EIM, following existing Ecology business rules and the EIM User's Manual.

## 11.5 Model information management

NA

# 12.0 Audits and Reports

## 12.1 Field, laboratory, and other audits

No formal audits are planned. However, field teams will be shifted at the beginning of each sample week in order to review consistency among teams. All team leaders will be experienced hydrogeologists (most, if not all, from EAP). Teams will change partners to ensure fieldwork consistency and adherence to SOPs, while also sharing innovation and strengthening the data quality assurance program. The project lead, who will also be a team leader will check in daily with team leads to discuss QA issues.

## 12.2 Responsible personnel

See Section 12.1.

## 12.3 Frequency and distribution of reports

A final report will be published according to the project schedule shown in Section 5.4.

## 12.4 Responsibility for reports

Eric Daiber will be the main author with support from Pam Marti and Eugene Freeman.

# 13.0 Data Verification

## 13.1 Field data verification, requirements, and responsibilities

Initial field data verification will be performed by the team lead (an EAP hydrogeologist) immediately after completing field measurements/sample collection prior to departing the site. This process involves checking the data sheet for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be repeated.

After each sampling day, the project manager will evaluate all field data to determine compliance with MQOs (Table 6). Values that are out of compliance with the MQOs will be noted and, if necessary, wells will be re-sampled and/or equipment re-calibrated. At the conclusion of the study, any values that are not in compliance will be compiled and assessed for usability by the project lead.

## 13.2 Laboratory data verification

MEL staff will perform the laboratory verification following standard laboratory practices. After the laboratory 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 laboratory data package, with special attention being paid to laboratory QC results. If any issues are discovered, they will be resolved by the project manager.

## 13.3 Validation requirements, if necessary

NA

## 13.4 Model quality assessment

NA

### 13.4.1 Calibration and validation

NA

#### 13.4.1.1 Precision

NA

#### 13.4.1.2 Bias

NA

#### 13.4.1.3 Representativeness

NA

#### 13.4.1.4 Qualitative assessment

NA

### 13.4.2 Analysis of sensitivity and uncertainty

NA

# 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 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 (Tables 5 and 6). 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 half the detection limit. Only ammonia-N and nitrite+nitrate-N results are likely to be non-detects.

## 14.3 Data analysis and presentation methods

Data will be presented in tabular and graphic form. If sufficient groundwater elevation data can be collected, groundwater elevation contours will be mapped and the direction of groundwater flow determined and labeled. Groundwater quality results will be presented in tabular, graphical, and geographical form.

Summary statistics for the 2018 nitrate-N and chloride data will be compared with those from 1997 (mean, median, maximum, minimum). Both the mean and median nitrate-N and chloride concentrations in 1997 and 2018 will be compared to determine if they are statistically different. Parametric or non-parametric methods may be used.

The nitrite+nitrate-N results for individual wells that were sampled in 1997 and 2018 will be compared individually using methods such as actual mg/L difference and relative percent difference. Results for particular areas may be compared for statistical differences (e.g., north of the Nooksack River vs. south of the river).

For wells with a total of 6 samples collected throughout the spring season (February-April) during previous data collection efforts, statistical trend analysis will be done to observe changes over time. Mann-Kendall trend analysis or equivalent method will be used to evaluate trends in nitrate and chloride concentrations.

## 14.4 Sampling design evaluation

The sampling design is intended to evaluate the change in nitrate and chloride concentrations at the wells sampled in 1997 (Erickson, 1998). If we cannot access 200 of the wells sampled in 1997, we will try to find equivalent (e.g. depth and design) wells nearby to replace unavailable wells in order to get the same aerial distribution as in 1997.

## 14.5 Documentation of assessment

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

# 15.0 References


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# 16.0 Appendix A. Glossaries, Acronyms, and Abbreviations

## Glossary of General Terms

**Aquifer:** A subsurface formation that contains saturated, permeable material and yields significant quantities of water to wells and springs.

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

**Groundwater:** Subsurface water in the saturated zone that is under pressure that is equal to or greater than atmospheric pressure.

**Hydraulic Conductivity:** Rate of water movement through a material at a unit gradient and depends on the size and arrangement of the pores between the particles.

**Parameter:** Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

**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) |
| EAP | Ecology's Environmental Assessment Program |
| Ecology | Washington State Department of Ecology |
| e.g. | For example |
| EIM | Environmental Information Management database |
| EPA | U.S. Environmental Protection Agency |
| GIS | Geographic Information System software |
| MEL | Manchester Environmental Laboratory |
| MQO | Measurement quality objective |
| 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 procedure |
| 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) |
| mL | milliliter |
| mV | millivolt |
| s.u. | standard units |
| umhos/cm | micromhos per centimeter |

## Quality Assurance Glossary

**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 population 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)

**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 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 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 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 the 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 40CFR 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)

**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 (%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)

## References for QA Glossary

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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

# 17.0 Appendix B. USGS Well Numbering System

The following is from: Jones, Vaccaro, and Watkins, 2006. Hydrogeologic Framework of Sedimentary Deposits in Six Structural Basins, Yakima River Basin, Washington. U.S. Geological Survey Scientific Investigations Report 2006–5116.

> "The USGS assigns numbers to wells and springs in Washington that identify their location in a township, range, and section. Well number 20N/15E-26N01 indicates successively, the township (T. 20 N.) and the range (R. 15 E.) north and east of the Willamette baseline and meridian (Figure B.1). The first number following the hyphen indicates the section (26) within the township, and the letter following the section number (N) gives the 40-acre subdivision of the section, as shown above. The number (01) following the letter is the sequence number of the well within the 40-acre subdivision."

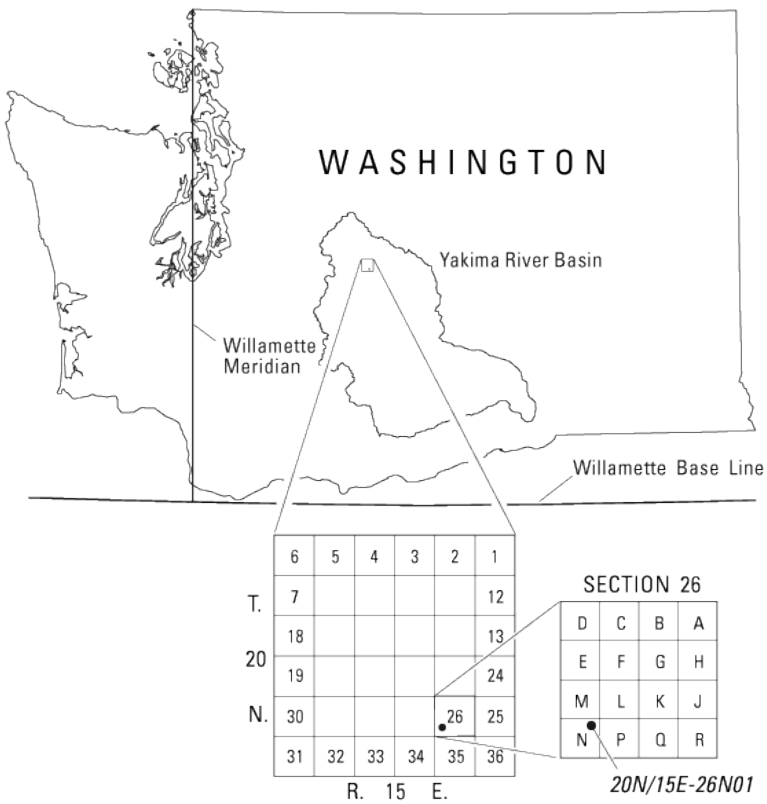


Figure B.1. Example of USGS well numbering system.