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Quality Assurance Project Plan

Edison Large On-site Sewage System Groundwater Assessment

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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. 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/1403121.html

Data for this project will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search Study ID bcar006.

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Author and Contact Information

Barbara M. Carey
P.O. Box 47600
Environmental Assessment Program
Washington State Department of Ecology
Olympia, WA 98504-7710

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

Communications Consultant: phone 360-407-6834.

Washington State Department of Ecology - www.ecy.wa.gov

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

Quality Assurance Project Plan

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November 2014

Approved by:

Signature:	Date: November 2014
Tonya Lane, Client, Water Quality Program, Northwest Regional Office	
Signature:	Date: November 2014
Mark Henley, Client's Unit Supervisor, Water Quality Program, Northwest Regional Office	
Signature:	Date: November 2014
Kevin Fitzpatrick, Client's Section Manager, Water Quality Program, Northwest Regional Office	
Signature:	Date: October 2014
Barbara Carey, Author / Project Manager, EAP	
Signature:	Date: October 2014
Martha Maggi, Author's Unit Supervisor, EAP	
Signature:	Date: October 2014
Will Kendra, Author's Section Manager, EAP	
Signature:	Date: November 2014
Joel Bird, Director, Manchester Environmental Laboratory	
Signature:	Date: November 2014
Bill Kammin, Ecology Quality Assurance Officer	
Signature:	Date: October 2014
Robert F. Cusimano, Western Operations Section Manager, EAP	

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

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2.0 Abstract

The community of Edison, Washington lies at an elevation close to sea level along Edison Slough near the mouth of Samish Bay on the northeastern shore of the Salish Sea. Historically, relatively untreated wastewater from the town of roughly 200 flowed to Samish Bay. A rich shellfish-growing area, Samish Bay has been repeatedly closed for harvesting shellfish in recent years due to bacterial contamination.

Over the past 18 years, Edison has developed a wastewater system to treat and manage sewage from the community's homes, restaurants, and school. The septic tank effluent pumping system includes new septic tanks for homes, a pumping system, and a community treatment facility. Treatment consists of a recirculating gravel filter, UV disinfection, 2 drainfields, and an overflow infiltration trench.

The fact sheet for the Edison Large On-Site Sewage System (LOSS) waste discharge permit (ST0045515) states that a groundwater study will be completed by Ecology to assist in establishing background water quality for nitrate and total coliform bacteria for comparison with downgradient conditions. The study is also intended to confirm that the Ground Water Standards are being met at the property boundary and to reassess performance with regard to antidegradation. This project is intended to meet the requirements for the study, which include:

- Evaluating groundwater flow direction under various flow conditions
- Determining upgradient (background) and downgradient concentrations of nitrate, fecal coliform bacteria, and total coliform bacteria
- Evaluating the effects of the facility on groundwater quality, including nitrate and total coliform bacteria

We will characterize the site hydrogeology that is influenced by several factors including agricultural drains, marine tides, groundwater mounding caused by the facility, and adjacent agricultural inputs of fertilizers and bacteria from manure application.

Statistical comparison of upgradient and downgradient conditions will be used to evaluate the facility's compliance with the Ground Water Quality Standards.

3.0 Background

The small community of Edison is located near the mouth of Samish Bay south of Edison Slough, a tidewater slough, in unincorporated Skagit County (Figures 1 and 2). Before construction of the Edison Large On-Site Sewage System (LOSS), domestic waste in the community received minimal, if any, treatment. On-site sewage systems (OSS) for many homes discharged minimally treated wastewater to street drains that flowed directly into Edison Slough (Ecology, 2013). OSSs in newer homes functioned better, when not inundated by groundwater, but drainage and soil treatment were inadequate on small lots.

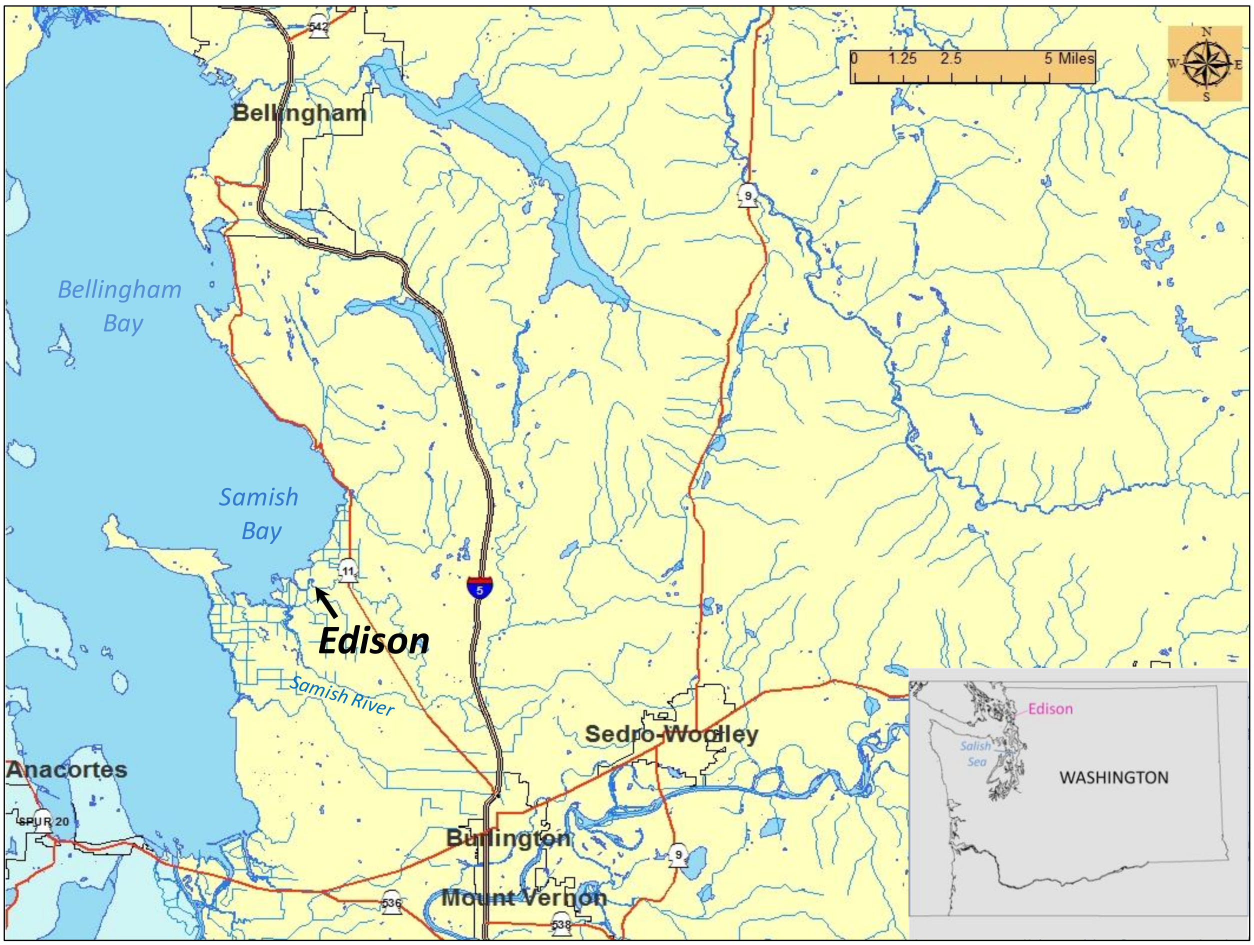

Figure 1. Edison, Washington vicinity map.

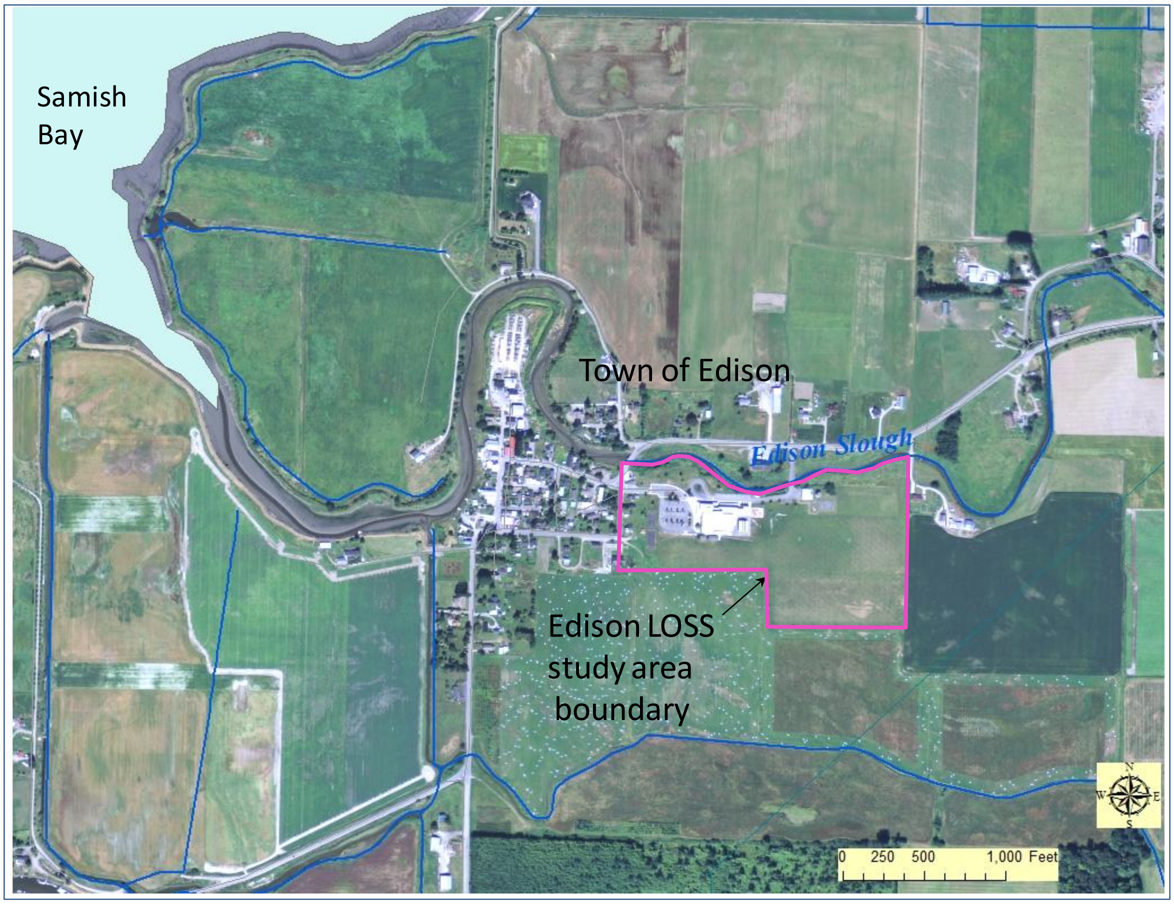

Figure 2. Boundary of the Edison LOSS study area.

The Washington Department of Health (WDOH) has restricted shellfish harvesting in Samish Bay in recent years due to fecal coliform exceedances. Wastewater from the community of Edison has been considered a likely, though relatively modest, source of fecal coliform bacteria to Samish Bay (Swanson, 2008). Shellfish harvest closures have occurred several times in 2014 (Skagit County Public Works, 2014).

The Edison community received financial assistance from the Washington State Department of Ecology (Ecology) and formed the Skagit County Clean Water District-Edison Subarea. The community wanted a wastewater system that would retain the small town atmosphere and not be detrimental to the local shellfish industry. The Burlington-Edison School District joined with the Water District to develop and construct the community wastewater system.

Wastewater from the Edison School septic tank was first discharged to the new wastewater treatment facility in 1996. The treatment facility consisted of a recirculating gravel filter with UV disinfection and 0.6 acre drip disposal field (HWA Geosciences, 2002). As more discharges from the community were added to the treatment system, the disposal field became inadequate to handle flows.

In 1998, the community added the upflow infiltration trench as an additional disposal option. By 2001, geotechnical engineers verified that the original drip system was located above a relatively impervious layer that prevented adequate infiltration of the quantity of water produced by the community. The community then constructed a second drainfield in 2003 (Figure 3).

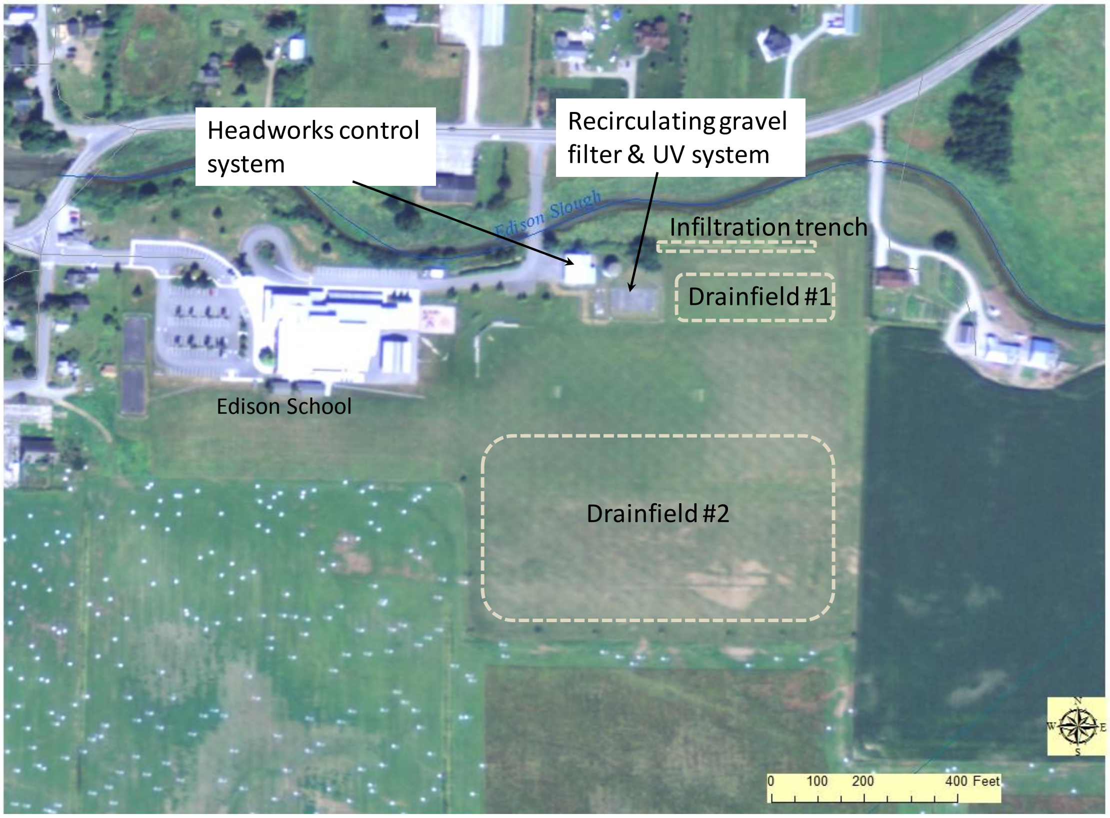

Figure 3. Edison LOSS and drainfield locations.

The present system, consisting of two drainfield areas and an infiltration trench, serves approximately 72 connections including seven food sites and one elementary/middle school without a cooking cafeteria (Ecology, 2013). Nine stubs remain for future connections. Restaurants and the school are required to have grease traps. There are no industrial users.

Waste Discharge Permit

The Skagit County Clean Water District--Edison Subarea (the Edison Subarea) manages the Edison LOSS and is the permittee for the waste discharge permit (Number ST0045515).

The permit allows for a maximum daily combined flow for Drainfields 1 and 2 of 20,000 gpd (2,000 gpd for Drainfield 1 and 18,000 gpd for Drainfield 2) (Ecology, 2013).

3.1 Study area and surroundings

The LOSS study site lies along the south side of Edison Slough, about 1,000 feet from Samish Bay on the delta of the Samish River. The Samish Delta adjoins the larger Skagit River Delta along the northern Salish Sea (Figure 1). The site is in northwestern Skagit County within Water Resource Inventory Area (WRIA) 03. The study area has a temperate marine climate. Winters are mild and wet; summers are cool and dry.

The Samish Bay Watershed encompasses 140 square miles of mostly lowland farms, fields, and timber land (Skagit County Public Works, 2012). The Samish River is the largest tributary to Samish Bay, but several creeks and sloughs, including Edison Slough, also discharge freshwater to the bay (Swanson, 2008). The river begins in Whatcom County and flows south into Skagit County through a narrow valley surrounded by timbered hills, then west through an increasingly broad agricultural valley into Samish Bay.

The average annual discharge for the Samish River is 240 cfs at the USGS Highway 99 gauge (RM 10) (Skagit County Public Works, 2012). The Samish River flow is greatly dependent on recent precipitation. Discharge during rainstorms in the Samish River can be as high as several thousand cfs, whereas summer low flow can be 20 cfs or less. There is generally little snowpack in the headwaters. The river flow and bacterial loading respond quickly to rain events.

Samish Bay has 2,300 acres of commercial shellfish beds and 10 commercial growing operations, as well as recreational shellfishing (Skagit County Public Works, 2012). Closures of shellfish beds occur routinely, due to high fecal coliform levels in Samish Bay and in the Samish River (Skagit County Public Works, 2012).

Land use in the area surrounding the study site is mainly agricultural. Fields surrounding the study site are used to grow crops and typically receive poultry or dairy manure and are drained, by either gravity or tile drains, to prevent flooding (Mohns, 2014). An extensive system of ditches drains the area.

The elevation of the site is roughly 4 to 10 feet above sea level (HWA Geosciences, 2002). In winter months, groundwater is typically 1 to 3 feet below ground surface (Ecology DMR data, 2013-2014). The drainfield area is relatively flat, with the northern section sloping gently northward toward the Edison Slough (Ecology, 2013). The southern section slopes slightly toward the southwest.

Drinking water for the area is supplied by the Blanchard Water Association. There are no drinking water wells within 1 mile of the site (Ecology, 2013).

Drainfield 1 lies 160 to 300 feet south of Edison Slough. Tide gates installed in the slough 1,000 feet west (downstream) of the site are designed to allow some salt water to enter the slough (HWA, Geosciences, 2002). Recently tide gates have been operated to maintain a higher water elevation in Edison Slough (Palmer, 2014), which could cause an increase in the elevation of groundwater at the site.

3.1.1 Logistical problems

The study area is located on the Edison School property. As a safety measure, we will attempt to complete monitoring well installations before the school year begins on September 3, 2014. If we are unable to schedule well installations before school begins, we will install safety barriers to prevent students from entering the construction area. The main safety concern is due to the operation of vehicles and drilling equipment.

We will inform Edison School representatives by email or phone prior to any field activities. We will announce our arrival in person to school office personnel each time we conduct fieldwork. When feasible, we will also attempt to schedule sampling events during school recess days.

Tidal effects will be taken into account due to the proximity to Samish Bay (roughly 1,000 feet downstream). Continuous recording transducers installed in monitoring wells will provide information on tidal influence on water levels and groundwater flow direction. Sampling for water quality parameters will likely not be affected on a short-term basis by tides. However, in the longer term, tides may influence groundwater quality. Semi-monthly water quality sampling will provide adequate information to characterize groundwater quality.

3.1.2 History of study area

The community of Edison was settled 150 years ago. The delta area, where the town and LOSS are located, is intimately connected to Samish Bay, due to the very flat topography. The elevation of the town is very close to sea level. Groundwater and surface water are closely connected due to the proximity of the LOSS to Edison Slough.

The LOSS is constructed beneath an area adjacent a playfield on the Edison School property. The adjacent field is used for soccer and other sports.

The principal hydrogeologic study at the site evaluated the only existing drainfield at the time (Drainfield 1) and disposal trench as described in Section 3.1 (HWA Geosciences, 2002). The 2002 report also provided recommendations regarding the proposed second infiltration area.

3.1.3 Contaminants of concern

The main contaminants of concern for groundwater in this study are nitrate, total coliform bacteria and fecal coliform bacteria. Surface water bodies near the Edison LOSS, including Edison Slough, were included in Ecology's 2008 303(d) Category 5 listing for fecal coliform bacteria, dissolved oxygen, and pH impairments (Ecology, 2013). Bacteria are also implicated in Samish Bay shellfish bed closures. These contaminants have human health effects and maximum contaminant levels under Chapter 246-290 WAC and are associated with sewage.

In addition to nitrate and bacteria, Kimsey (2005) recommends including the following constituents of concern for implementing the Ground Water Quality Standards (Chapter 173-200 WAC) (GWQSs) for OSS facilities:

- Chloride
- Total dissolved solids (TDS)
- Total nitrogen
- Ammonia

TDS and chloride can be an indicator of on-site sewage or seawater intrusion. Ammonia and a portion of the total nitrogen in the effluent can quickly convert to nitrate, which has human health implications. Ammonia can also be toxic for fish at high concentrations. This study, however, is primarily focused on groundwater.

pH is also typically included in groundwater quality characterizations as a field parameter. Because low pH levels were measured in two existing piezometers measured in February 2012, and because the slough has a Category 5 listing for pH, pH is an additional parameter of interest.

3.1.4 Results of previous studies

Findings of the main hydrogeologic study for the site (HWA GeoSciences, 2002), conducted prior to the installation of Drainfield 2, included the following:

- Drainfield 1 could accommodate about 1,650 gallons per day (gpd) due to low permeability soils, high groundwater table, and shallow groundwater gradient. (A later performance-based assessment indicated that 2,000 gpd maximum daily flow was warranted (Ecology, 2013))
- The disposal trench north of -Drainfield 1 could accommodate less than 2,000 gpd for the same reasons listed above. The disposal trench was at one time receiving approximately 10,000 gpd, most of which was surfacing and discharging to Edison Slough.
- Increasing the size of Drainfield 1 would not accommodate design flows (24,000 gpd) in the area near existing Drainfield 1.
- Conditions south of Drainfield 1 appear more favorable for infiltration, due to the larger available area, sandier soils, and slightly lower groundwater table.
- Approximately 1,100 linear feet of trench extending below all low permeability layers would be required to accommodate 12,000 gpd.
- Any infiltration at this site would occur mostly below the groundwater table under saturated flow conditions. Infiltration facilities that expose the greatest cross-sectional area to flow (i.e., linear trenches) would maximize infiltration capacity.

A previous report by Land Profile, Inc. (1998) indicated that the original design for Drainfield 1 was not adequate, considering the unfavorable soil and high water table conditions. The report notes that guidelines for OSSs are better suited for individual homes than for LOSSs and may help explain the failure of the original system design.

Surface water studies in the area include Swanson's (2008) fecal coliform TMDL study of Samish Bay. This study included Edison Slough on the northern boundary of the Edison LOSS site. At a site just upstream of the Edison School, Swanson (2008) found that the 90th percentile fecal coliform concentrations were 960 colony-forming units (cfu)/100 ml (vs. the regulatory standard of 200 cfu/100 ml) and geometric mean of 153 cfu/100ml (compared to the standard of 100 cfu/100ml) during April through July 2006 (Chapter 173-201A-200 WAC).

3.1.5 Regulatory criteria or standards

The GWQSs apply to all state waste discharge permits. Statistical comparison of upgradient and downgradient conditions will help evaluate the facility's compliance with the GWQSs. This study will follow guidance for implementing the GWQSs as provided in Kimsey (2005). The role of the study was outlined in the fact sheet accompanying the state waste discharge permit for the Edison LOSS system, and the outcome will inform future permit requirements.

This study will also address provisions for implementing the GWQSs (Kimsey, 2005), including:

- Characterizing the hydrogeology of the site, including depth and direction of groundwater flow, hydraulic conductivity, and groundwater velocity.
- Establishing background groundwater quality.
- Summarizing the location and construction of existing water supply wells, if any, within 1 mile of the LOSS.
- Determining whether the facility's activities increase groundwater nitrate-N concentration by more than 2 mg/L at the property boundary.
- Determining whether the facility is meeting the GWQSs.

4.0 Project Description

The fact sheet for the Edison LOSS discharge permit specifies that a groundwater study will be completed by Ecology to establish upgradient (background) quality of groundwater for nitrate and total coliform bacteria; to evaluate whether groundwater nitrate-N concentrations are increased as a result of the facility by more than 2 mg/L; and to assess performance with regard to antidegradation.

The results of this study will help inform our understanding of groundwater flow and groundwater quality at the project site and may be used to update the facility's state waste discharge permit. Wells constructed for the study may be used for on-going compliance monitoring.

4.1 Project goals

The project goals are to:

- Characterize the hydrogeology of the site in order to estimate the rate and direction of groundwater flow and potential contaminant movement in the shallow aquifer as described in Table 2.1 of Kimsey (2005), including tidal and seasonal variations.
- Determine background concentrations of constituents of interest.
- Characterize the effluent water quality, especially for parameters specified in Kimsey (2005) and shown in Table 4.1 (total nitrogen, chloride, and inorganics) and 303(d) listed parameters for Edison Slough (pH, dissolved oxygen, and fecal coliform bacteria).
- Evaluate the potential water quality impacts of the LOSS operation on groundwater and any seasonal or tidal variation, including nitrate, total and fecal coliform bacteria.
- Evaluate whether 303(d) listed parameters are reaching Edison Slough from the facility (pH, dissolved oxygen, and fecal coliform bacteria).

4.2 Project objectives

The project objectives are to:

- Install monitoring wells, streambank piezometers, transducers, and a weather station (unless one is available on site) at the site that will allow characterization of the groundwater flow direction (~ 8 wells, up to 2 piezometers), precipitation, and temperature.
- Measure water levels and sample for groundwater quality in monitoring wells and piezometers for 20 months in order to characterize groundwater flow patterns (upgradient and downgradient direction) and water quality upgradient and downgradient of the drainfield system.
- If existing water supply or monitoring wells can be found nearby, sample them for water quality parameters and measure water levels.

- Conduct specific capacity and/or slug tests in monitoring wells to determine the hydraulic conductivity of the aquifer and estimate the velocity of groundwater flow. Compare results with estimates of hydraulic conductivity based on results from grain size analysis of drilling samples.
- Characterize effluent quality.

4.3 Information needed and sources

Information on the location and construction of existing wells near the Edison LOSS will be obtained from the Ecology Water Resources Program Well log system, http://ecyapps7/waterresources/Map/wclswebmap/default.aspx.

Most of the needed data will be generated through the study.

4.4 Target population

The target population is the shallow groundwater and, to a lesser extent, the deeper groundwater at the site upgradient and downgradient of the Edison LOSS Drainfields.

4.5 Study boundaries

Study area boundaries area shown in Figure 2. The southern shore of Edison Slough is the northern border of the study area. The Edison School property forms the western, southern, and eastern boundaries. Agricultural fields border the eastern, southern, and part of the western boundaries.

Water Resource Inventory Area (WRIA) and 8-digit Hydrologic Unit Code (HUC) numbers for the study area

- WRIA - 3
- HUC number - 17110002

4.6 Tasks required

- Install 8 shallow (10 feet) groundwater monitoring wells around the drainfield area via a state-contracted well driller. Wells will meet or exceed requirements of Minimum Standards for Construction and Maintenance of Wells (Chapter 173-160 WAC).
- Collect representative soil samples for grain size during well drilling.
- Install up to 2 streambank piezometers along Edison Slough.
- Install a stilling well just below the site on Edison Slough to record water level height.

- Survey elevations of above instruments relative to each other. Use GIS elevation coverage to tie into local elevation datum.
- Calibrate and install pressure transducers in monitoring wells and piezometer(s) for continuous water level measurements.
- Install a weather station on-site to collect continuous temperature and precipitation data unless there is a reliable gage on site that will provide these data.
- Measure water levels and sample monitoring wells and piezometers (streambank) for water quality parameters every other month for 20 months.
- Collect samples of effluent for water quality characterization during each sampling event, if possible.
- Measure water levels and sample existing piezometers on the site, if usable, (P8, P10, and P11 in Figure 4) every other month for 20 months.
- Measure water levels and sample for water quality parameters in 1 existing deep well on the site (30-40 feet deep).
- Perform manual check measurements of groundwater levels and tide stage during each sampling event.
- Download data from data loggers (water level and weather) during each sample event.
- Conduct specific capacity and/or slug tests on monitoring wells to characterize aquifer hydraulic properties.
- Construct water level elevation maps and contours using transducer water level data.
- Analyze water quality data using appropriate statistical methods (Kimsey, 2005) to characterize background (upgradient) and compare to downgradient water quality.
- Prepare data analysis report.

4.7 Practical constraints

Tidal fluctuations and seasonal changes in precipitation may influence groundwater flow direction. High water table conditions in the winter may make it difficult to sample wells and/or prevent transducers from operating effectively.

Well completions need to be at or below ground for safety, because the study area is also sometimes used as a playfield.

4.8 Systematic planning process

This QAPP is the systematic planning process for the project.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1. Organization of project staff and responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
Tonya Lane Water Quality Program NW Regional Office Phone: (425) 649-7050	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Barbara Carey GWFF, SCS Phone: (360) 407-6769	Project Manager/Principal Investigator/Licensed Hydrogeologist	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. Writes the draft report and final report.
Kirk Sinclair GWFF, SCS Phone: (360) 407-6557	Project support/ Licensed Hydrogeologist	Assists with study design, QAPP development, in-water piezometer installation/decommissioning, transducer operation, and data collection.
Chris Martin Water Quality Program NW Regional Office Phone: (425) 649-7110	Project support/ Licensed Hydrogeologist	Assists with study design, QAPP development, and internal review.
Varies per sampling event	Field Assistant	Helps collect samples and records field information.
Martha Maggi GWFF. SCS Phone: (360) 407-6453	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Will Kendra 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.
Robert F. Cusimano Western Operations Section 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.
Joel Bird Manchester Environmental Lab Phone: 360-871-8801	Director	Reviews and approves the final QAPP.
Contract Laboratory	Project Manager	Reviews draft QAPP, coordinates with Manchester Laboratory QA Coordinator, analyzes soil particle size.
William R. Kammin Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

EAP: Environmental Assessment Program
EIM: Environmental Information Management database
GWFF: Groundwater Forests & Fish Unit
QAPP: Quality Assurance Project Plan
SCS: Statewide Coordination Section

5.2 Special training and certifications

A drilling license is needed to install wells deeper than 10 feet below ground surface (Chapter 18.104 RCW; WAC 173-160).

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

Experience in surveying is needed to establish relative elevations of monitoring wells, piezometers, and the stilling well. Transducer calibration, installation, downloading and data interpretation also require experience.

5.3 Organization chart

See Table 1 for project organization.

5.4 Project schedule

Table 2. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	Due date	Lead staff
Install monitoring wells	September 2014	Barbara Carey
Field work completed	August 2016	Barbara Carey
Laboratory analyses completed	October 2016	
Environmental Information System (EIM) database		
EIM Study ID	bcar006	
Product	Due date	Lead staff
EIM data loaded	January 2017	Barbara Carey
EIM data entry review	March 2017	Kirk Sinclair
EIM complete	April 2017	Barbara Carey
Groundwater report		
Activity Tracker code	13-026	
Author lead	Barbara Carey	
Schedule		
Draft due to supervisor	January 2017	
Draft due to client/peer reviewer	February 2017	
Draft due to external reviewer(s)	NA	
Final (all reviews done) due to publications coordinator	April 2017	
Final report due on web	June 2017	

5.5 Limitations on schedule

The Edison LOSS drainfield area is located on Edison-Bow School District property adjacent to the Edison School. We hope to have all contracted well construction completed before the school year begins on September 3, 2014, to avoid potential safety concerns with students and school personnel.

5.6 Budget and funding

Table 3. Budget for monitoring well drilling, laboratory analyses, and equipment (2014-2016).

Year 1 (FY15)--Lab costs

Groundwater/drilling samples for FY 15 (October 14-June 15)

Parameter	Cost/sample	No. of samples for 1st sample event [1]	Cost for 1st sample event	No. of samples for events 2, 4 [2]	No. of sampling events	No. of samples for events 3, 5[1]	No. of sampling events	Total cost
Alkalinity	$ 18	14	$ 252	0	2	12	2	$ 588
TDS	$ 12	14	$ 168	0	2	12	2	$ 504
Ammonium-N	$ 14	14	$ 196	12	2	12	2	$ 868
Nitrite+Nitrate-N	$ 14	14	$ 196	12	2	12	2	$ 868
Total persulfate N	$ 18	14	$ 252	12	2	12	2	$ 924
Ortho Phosphate	$ 16	14	$ 224	0	2	0	0	$ 224
Total Phosphate	$ 20	14	$ 280	0	2	0	0	$ 280
Cations/anions (Na, K, Ca, Mg)	$ 100	14	$ 1,400	0	0	0	0	$ 1,400
Sulfate	$ 14	14	$ 196	0	0	0	0	$ 196
Chloride	$ 14	14	$ 196	12	2	12	2	$ 868
Bromide	$ 14	14	$ 196	0	0	12	2	$ 532
Iron	$ 41	14	$ 574	0	0	8	2	$ 798
DOC	$ 36	14	$ 504	0	0	12	2	$ 840
Fecal coliform	$ 25	14	$ 350	12	2	12	2	$ 1,022
Total coliform	$ 30	14	$ 420	12	2	12	2	$ 1,092
Nicotine, Caffeine, Nonylphenol, Tricolsan	$ 200	0	$ -	10	1	0	0	$ 2,000
Grain size (drilling samples)[3]	$ 200	20	$ 4,000	0	0	0	0	$ 4,000
								$ 17,004

[1] 12 monitoring wells (8 new + 1 deep existing + 3 shallow existing) + 1 duplicate +1 blank= 14 samples

[2] 10 monitoring wells (8 new and 2 exisiting) + 1 duplicate + 1 blank = 12 samples

[3] Cost is an estimate

Piezometers Year 1 (FY15)

Parameter	Cost/sample	No. of samples/ event	No. of events	Total cost
Alkalinity	$ 18	1	1	$ 18
Ammonium-N	$ 14	1	5	$ 70
Nitrite+Nitrate-N	$ 14	1	5	$ 70
Total persulfate N	$ 18	1	5	$ 90
Ortho Phosphate	$ 16	1	1	$ 16
Total Phosphate	$ 20	1	1	$ 20
Chloride	$ 14	1	5	$ 70
Bromide	$ 14	1	5	$ 70
DOC	$ 36	1	1	$ 36
		Piezometers total cost Year 1:		$ 460 Total

Effluent Year 1 (FY15)

Parameter	Cost/sample	No. of samples[3]	Total cost
Alkalinity	$ 18	1	$ 18
TDS	$ 12	5	$ 60
Ammonium-N	$ 14	5	$ 70
Nitrite+Nitrate-N	$ 14	5	$ 70
Total persulfate N	$ 18	5	$ 90
Ortho Phosphate	$ 16	1	$ 16
Total Phosphate	$ 20	1	$ 20
Cations/anions (Na, K, Ca, Mg)	$ 100	1	$ 100
Sulfate	$ 14	1	$ 14
Chloride	$ 14	5	$ 70
Bromide	$ 14	5	$ 70
Iron	$ 41	1	$ 41
DOC	$ 36	1	$ 36
Fecal coliform	$ 25	5	$ 125
Total coliform	$ 30	5	$ 150
Nicotine, Caffiene, Nonylphenol, Triclosan	$ 200	2	$ 400
	Effluent total cost Year 1:		$ 1,350 Total

Year FY15 total lab costs: $ 18,814

Year 2 (FY16)--Lab costs

Groundwater samples for FY 16 (October 15-June 16)

Parameter	Cost/sample	No. of samples/event [1]	No. of sampling events	Total cost
Alkalinity	$ 18	14	2	$ 504
TDS	$ 12	14	2	$ 336
Ammonium-N	$ 14	14	5	$ 980
Nitrite+Nitrate-N	$ 14	14	5	$ 980
Total persulfate N	$ 18	14	5	$ 1,260
Ortho Phosphate	$ 16	14	0	$ -
Total Phosphate	$ 20	14	0	$ -
Cations/anions (Na, K, Ca, Mg)	$ 100	14	0	$ -
Sulfate	$ 14	14	0	$ -
Chloride	$ 14	14	5	$ 980
Bromide	$ 14	14	2	$ 392
Iron	$ 41	14	2	$ 1,148
DOC	$ 36	14	2	$ 1,008
Fecal coliform	$ 25	14	5	$ 1,750
Total coliform	$ 30	14	5	$ 2,100
[1] 12 monitoring wells (8 new + 1 deep existing + 3 shallow existing) + 1 duplicate +1 bla				$ 11,438

Piezometers Year 2 (FY16)

Parameter	Cost/sample	No. of samples/ event	No. of events	Total cost	
Alkalinity	$ 18	0	5	$ -	
Ammonium-N	$ 14	1	5	$ 70	
Nitrite+Nitrate-N	$ 14	1	5	$ 70	
Total persulfate N	$ 18	1	5	$ 90	
Ortho Phosphate	$ 16	0	0	$ -	
Total Phosphate	$ 20	0	0	$ -	
Chloride	$ 14	1	5	$ 70	
Bromide	$ 14	1	5	$ 70	
DOC	$ 36	0	5	$ -	
		Piezometers total cost Year 2:		$ 370	Total

Effluent Year 2 (FY16)

Parameter	Cost/sample	No. of samples[3]	Total cost	
Alkalinity	$ 18	1	$ 18	
TDS	$ 12	5	$ 60	
Ammonium-N	$ 14	5	$ 70	
Nitrite+Nitrate-N	$ 14	5	$ 70	
Total persulfate N	$ 18	5	$ 90	
Ortho Phosphate	$ 16	0	$ -	
Total Phosphate	$ 20	0	$ -	
Cations/anions (Na, K, Ca, Mg)	$ 100	0	$ -	
Sulfate	$ 14	0	$ -	
Chloride	$ 14	5	$ 70	
Bromide	$ 14	2	$ 28	
Iron	$ 41	0	$ -	
DOC	$ 36	2	$ 72	
Fecal coliform	$ 25	5	$ 125	
Total coliform	$ 30	5	$ 150	
	Effluent total cost Year 2:		$ 753	Total

Year FY16 total lab costs: $ 12,561

Total lab costs for study: $31,375

The total project cost for laboratory and well installations is approximately $39,000.

6.0 Quality Objectives

Quality objectives are statements of the precision, bias, and lower reporting limits necessary to meet project objectives. Precision and bias together express data accuracy. Other considerations of quality objectives include representativeness and completeness. Quality objectives apply equally to laboratory and field data collected by Ecology, to data used in this study collected by entities external to Ecology, and to other analysis methods used in this study.

6.1 Decision Quality Objectives (DQOs)

This study will provide background and analysis of groundwater conditions that can be used to determine compliance with the Ground Water Quality Standards (Chapter 173-200 WAC).

6.2 Measurement Quality Objectives

Field sampling procedures and laboratory analyses inherently have associated uncertainty, which results in data variability. Measurement quality objectives (MQOs) state the acceptable data variability for a project. *Precision* and *bias* are data quality criteria used to indicate conformance with MQOs. A*ccuracy* refers to the combined effects of precision and bias (Lombard and Kirchmer, 2004).

Precision is a measure of the variability in the results of replicate measurements due to random error. 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). Precision for field and laboratory duplicate samples will be expressed as relative percent difference (RPD) as shown in Table 4.

Bias is defined as the difference between the sample value and true value of the parameter being measured. Bias affecting measurement procedures can be inferred from the results of quality control (QC) procedures. Bias in field measurements and samples will be minimized by strictly following Ecology’s measurement, sampling, and handling protocols.

Field sampling precision and bias will be addressed by submitting replicate samples. Ecology’s Manchester Environmental Laboratory (MEL) will assess precision and bias in the laboratory by using duplicates and blanks.

Table 4 outlines expected precision of sample duplicates, and method reporting limits. Targets for precision of field replicates are based on historical performance by MEL for environmental samples taken around the state by Ecology’s Environmental Assessment Program (Mathieu, 2006). The reporting limits of the methods listed in the table are appropriate for the expected range of results and the required level of sensitivity to meet project objectives. The laboratory’s MQOs and QC procedures are documented in the MEL *Lab Users Manual* (MEL, 2008).

Table 4. Measurement quality objectives for field and laboratory analyses.

Parameter	Matrix[1]	Duplicate samples	Matrix spikes	Lowest concentration/level of interest
		Relative % difference (RPD)	% Recovery limits	Units
Field measurements				
Temperature	W	NA	NA	2 C°
pH	W, ME	NA	NA	NA
Specific conductivity	W, ME	NA	NA	10 umhos/cm
Dissolved oxygen	W, ME	NA	NA	0.1 mg/L
Water level	W	0.2	NA	0.01 ft
Laboratory analyses				
Alkalinity	FW, ME	10	20	5.0 mg/L
Ammonia-N	FW, ME	10	20	0.010 mg/L
Nitrite+nitrate-N	FW, ME	10	20	0.010 mg/L
Total persulfate N	FW, ME	10	20	0.025 mg/L
Ortho Phosphate	FW, ME	10	20	0.003 mg/L
Total Phosphate	FW, ME	10	20	0.001 mg/L
Cations/anions (Na, K, Ca, Mg, SO_4)	FW, ME	10	20	0.05-0.5 mg/L
Chloride	FW, ME	10	20	0.1 mg/L
Bromide	FW, ME	10	20	0.1 mg/L
Iron	FW, ME	10	20	0.050 mg/L
DOC	FW, ME	10	20	1.0 mg/L
Fecal coliform- MF[2]	W, ME	40	NA	1cfu/100 ml
Total coliform--MF[2]	W, ME	40	NA	1cfu/100 ml
Nicotine, Caffiene, Nonylphenol, Triclosan	W, ME	MEL (in development)	MEL (in development)	MEL (in development)
Grain size (drilling samples)	S	NA	NA	NA

[1] W= Water, FW= Groundwater filtered in the field, S= Soil, ME= Municipal effluent
[2] MF= Membrane filter
[3] Manchester Environmental Laboratory

6.2.1 Targets for precision, bias, and sensitivity

6.2.1.1 Precision

Precision for field and laboratory duplicate samples will be expressed as relative percent difference (RPD) as shown in Table 4.

Duplicate field samples will be collected by filling two bottles for each laboratory analysis, one after the other for each group of constituents in each bottle. For example, we will fill one bottle for alkalinity and then fill the second bottle for alkalinity. We will repeat this pattern for each constituent.

6.2.1.2 Bias

Bias in field measurements and samples will be minimized by strictly following Ecology's measurement, sampling, and handling protocols. Field sampling precision bias will be addressed by submitting replicate samples (Table 7, Section 10.1). MEL will assess bias in the laboratory by using duplicates and blanks.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method 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. Targets for field and lab measurement sensitivity required for the project are listed in Table 4.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

SOPs to be used during the study are listed in Section 8.1. If possible, we will compare data collected in this study with previous studies and with other similar studies at LOSS facilities.

6.2.2.2 Representativeness

Groundwater level and water quality conditions are relatively slow to change compared with surface water. Therefore, semi-monthly (every other month) sampling is relatively intensive. Tidal influence at the site may complicate groundwater flow conditions. Transducers that record measurements continually (i.e., every 15 minutes) will allow us to observe changes that might occur in even shorter timeframes.

Potential impacts on groundwater from activities at the LOSS will most likely occur in the winter season, when the water table is closest to land surface. Samples from the shallow monitoring wells will be representative of groundwater most recently arriving at the water table and are most representative of recent land use activities.

If the site is in a groundwater discharge area (groundwater is moving vertically upward from below), samples from the deeper wells (30-40 feet) will be representative of water entering from off-site. If shallow, unaffected wells can be installed on the site, samples from such wells upgradient of the drainfields will represent recently recharged water unaffected by the facility.

6.2.2.3 Completeness

EPA has defined completeness as a measure of the amount of valid data necessary from a measurement system (Lombard and Kirchmer, 2004). The goal for the Edison LOSS groundwater study is to correctly 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. Example problems are flooding, site access problems, equipment failure, or sample container shortages.

7.0 Sampling Process Design (Experimental Design)

7.1 Study design

The fact sheet for the waste discharge permit for the Edison LOSS states that Ecology will evaluate potential impacts of the existing discharge to groundwater and to already impaired surface waters in Edison Slough. The GWQSs require an assessment of existing groundwater conditions in order to determine any allowable levels of contaminants downgradient of the facility. Existing conditions include (Kimsey, 2005):

- Background groundwater quality
- Groundwater flow direction

As part of the anti-degradation policy in the GWQSs, we need to assess the condition of contaminants−especially nitrate and total coliform bacteria−before they are affected by the facility. We need this assessment in order to decide whether the anti-degradation or non-degradation concepts apply to the Edison discharge (Ecology, 2013).

Additional requirements to comply with the GWQSs include:

- Effluent characteristics
- Geology
- Hydrogeology

Nearly the entire delta region surrounding the Edison LOSS is drained by a system of ditches, which affects the groundwater flow direction and makes it difficult to assess background conditions. In addition, tidal fluctuations and mounding from the effluent discharge probably influences groundwater flow.

The study is designed to address these issues by:

1. Characterizing the effluent for contaminants of concern, particularly nitrogen species and total and fecal coliform bacteria.
2. Characterizing the direction of groundwater flow via newly installed monitoring wells screened close to the top of the water table (5-10 feet below ground), 2 deeper existing on-site wells (30-40 feet below ground), and a streambank piezometer along Edison Slough. Water level measurements will reveal the horizontal and vertical flow directions. (Figures 4-6 show the proposed monitoring network and well construction details.)
3. Collecting samples from monitoring wells located near the property boundary to help distinguish effects due to facility operations from those related to adjacent agricultural practices.
4. Calculating background groundwater quality using results for at least 8 samples from upgradient monitoring wells as recommended by Kimsey (2005).

5. Comparing background water quality with results from downgradient wells and streambank piezometer(s).
6. Determining if groundwater nitrate-N concentrations are 2 mg/L greater than background near the property boundary, which is an exceedance of the GWSs (Kimsey, 2005).

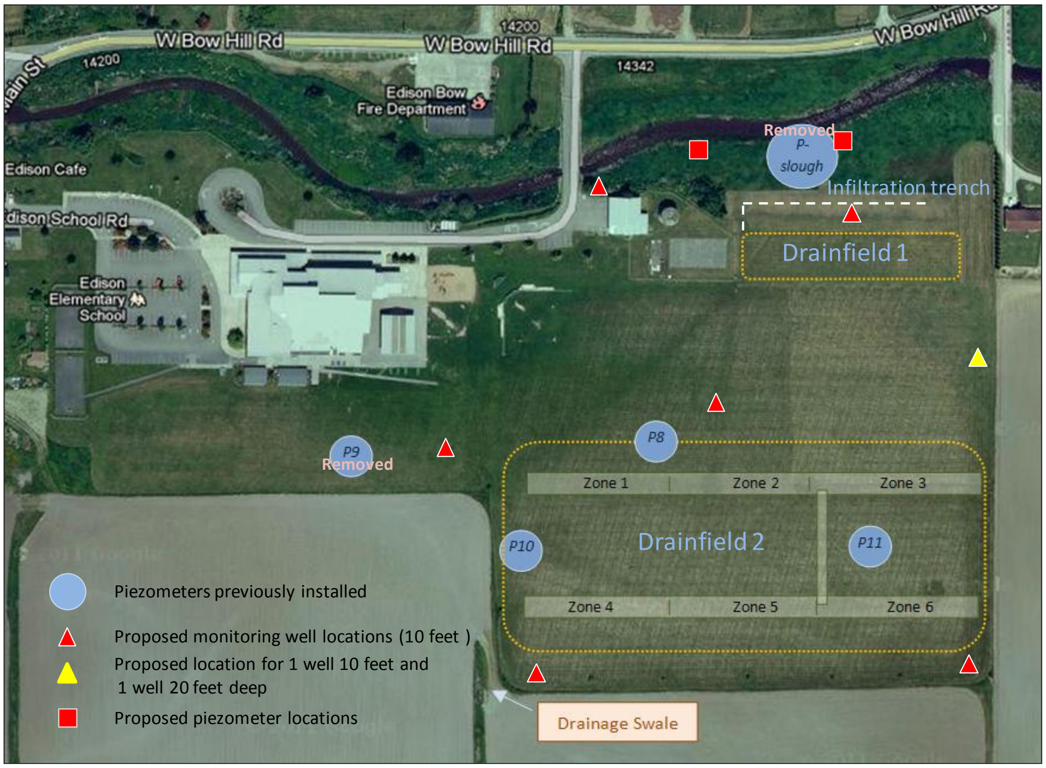

Figure 4. Proposed locations of monitoring wells and piezometers at the study site.

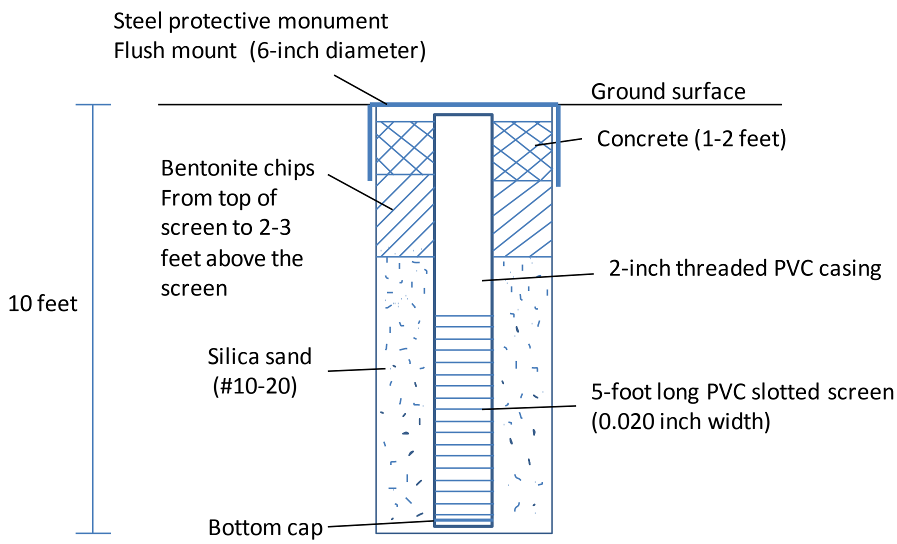

Figure 5. Schematic of the proposed shallow (10 feet) groundwater monitoring wells.

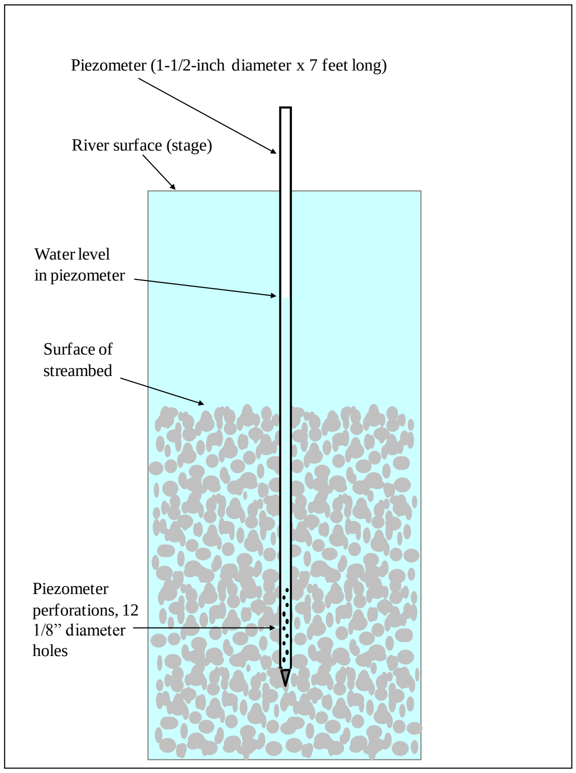

Figure 6. Schematic of proposed in-stream piezometer(s).

We will also use the 3 existing piezometers (P-8, P-10, and P-11) at the site to measure the depth to groundwater and to collect water quality samples, assuming they produce enough water for sample collection (Figure 4).

The groundwater flow direction may be affected by the LOSS drainfields due to the discharge rate and the low permeability of underlying soils (Gray and Osborne, 2003; HWA Geosciences, 2002), especially in the rainy winter season. Continual water level measurements using transducers in shallow monitoring wells will allow us to determine the depth to water and direction of groundwater flow in the shallow aquifer as it varies seasonally and with tidal oscillations.

Water level measurements over time will indicate the direction and variability of the groundwater flow system, which will allow us to identify the upgradient (or background) location(s) for comparison with downgradient conditions.

We will characterize groundwater quality conditions at the site using the same monitoring network during the same time period that water level measurements are occurring. Water quality analytes will include contaminants of concern (Section 3.1.3) as well as chemicals useful in evaluating the source of water: background, on-site sewage, or agriculture (Table 4). Evidence from water quality source-typing will be combined with results of groundwater flow direction to characterize conditions at the site.

7.1.1 Field measurements

Field measurements will be made every 2 months for 20 months beginning about 8 weeks after installation of the monitoring wells. Water level measurements will be made at all monitoring wells, piezometers, and private wells during each sampling event. Transducers will be installed in the monitoring wells and the stream gage for continuous water level measurements.

Other field measurements (temperature, pH, conductivity, dissolved oxygen) will also be collected in monitoring wells and piezometer(s) as listed in Table 4 during each sampling event.

Locations of nearby private wells (2) for sampling have not been identified. We will contact well owners and request permission to sample these wells if they will improve the study design.

7.1.2 Sampling location and frequency

The proposed sampling sites are shown in Figure 4, including 8 new monitoring shallow wells, 2 existing deep wells onsite, up to 2 new instream piezometers, and 3 existing piezometers in the field. The monitoring well and piezometers north of Drainfield 1 will provide information on the flow and quality of water entering or leaving the site via Edison Slough.

Soil samples (split spoon samples) will be collected every 2.5 feet as the monitoring wells are being installed. Samples will be analyzed for grain size, which will provide information to explain rate of groundwater movement and variability across the site.

Field measurements and samples for laboratory analysis will be collected every 2 months, a relatively high frequency for groundwater media in order to observe effects of weather patterns and tides.

Effluent samples will be collected during each sampling event. Samples will be collected at the same location that the plant operator collects compliance samples.

7.1.3 Parameters to be determined

See Table 4 (Section 5.6) for water quality parameters to be determined. In addition, we will estimate aquifer characteristics, including hydraulic conductivity, transmissivity, porosity, storage coefficient, and groundwater flow velocity.

7.2 Maps or diagram

See Figures 1-6.

7.3 Assumptions underlying design

Assumptions underlying the study design include:

- Monitoring wells and piezometers will provide information representative of site conditions.
- Discharge to the drainfields may cause groundwater to be mounded (higher) near the drainfields, with subsurface flow away from those areas.
- At times, groundwater at the study site may be affected by Edison Slough and tidal fluctuations. At other times, Edison Slough may be affected by groundwater from the study site.
- The number and position of groundwater sampling locations will be adequate to provide a statistical basis for establishing background groundwater quality.
- The frequency of groundwater quality sampling exceeds the minimum level recommended in Kimsey (2005) and will provide a statistical basis for establishing background groundwater quality.

7.4 Relation to objectives and site characteristics

The study is designed to take into account potentially complicating factors such as:

- Artificial regional drainage
- Mounding caused by drainfields
- Tidal influences
- Nearby land uses with similar contaminants of concern
- The potential for upward groundwater flow at the site (i.e., from deeper to shallower aquifers)

7.5 Characteristics of existing data

Characteristics of existing data include:

- Effluent data for the Edison treatment facility: Samples are collected quarterly for total Kjeldahl nitrogen, nitrate+nitrite-nitrogen, and total coliform bacteria and monthly for fecal coliform bacteria to meet permit requirements.
- Groundwater study by HWA Geosciences (2002): This study used test pits and piezometers to measure water levels and to perform a general hydrogeologic characterization of the site. Three piezometers from the study are still in place and will be used in this study for water level measurements.
- Groundwater quality and water level data collected in August 2011 and February 2012 from previously installed piezometers at the site: These data were collected by the Skagit County Planning and Development Department and provide historical data for the site.

8.0 Sampling Procedures

8.1 Field measurement and field sampling SOPs

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

- EAP052 for depth to water measurements (Marti, 2009)
- EAP074 for use of pressure transducers as part of groundwater studies (Sinclair and Pitz, 2010)
- EAP078 for purging and sampling monitoring wells (Marti, 2011a)
- EAP061 for installing, monitoring, and decommissioning hand-driven in-water piezometers (Sinclair and Pitz, 2013)
- EAP013 For determining coordinates via hand-held GPS receivers (Janisch, 2006)

Bacteriological samples will be collected according to Chapter A7 of the USGS Field Manual (Wilde et al., 2008).

Drilling core samples collected during monitoring well drilling (split spoon samples) will be photographed and described at the time the sample is collected and then placed in clean 1-gallon Ziploc bags labeled with the well ID and sample depth. Split spoon samples will be stored in a cooler and 20 of the samples will be sent to an analytical laboratory for grain size analysis.

Field measurements will be made at all sampling sites and recorded on waterproof paper in a field notebook. Measurements for pH and dissolved oxygen will be collected using a calibrated Hydrolab MiniSonde® following Ecology's SOP EAP033 (Swanson, 2010) and manufacturer's recommendations.

Water level measurements will be made using calibrated transducers for continuous measurements (SOP EAP074). These measurements will be compared and checked against manual water level measurements during field sampling using a calibrated E-tape (SOP EAP052).

Groundwater samples will be collected using a peristaltic pump fitted with new silastic tubing each time samples are collected with a brief de-ionized water rinse between wells and piezometers. Each monitoring well and streambank piezometer will have a dedicated, ¼-inch diameter polypropylene tube for purging and sample collection that is removed from the well or piezometer between sampling events and stored in clean dedicated plastic bags.

Monitoring wells and piezometers will be purged using standard low-flow techniques (e.g. < 0.5 L/min) until field parameters measured in an airtight flow-through chamber are stable (temperature, pH, specific conductance, and dissolved oxygen). Samples that do not require filtering will be collected first (total and fecal coliform bacteria). The remaining samples will then be collected using disposable in-line filters (0.45 µm). Additional groundwater quality sampling details are specified in SOP EAP078.

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

Effluent grab samples will be collected with the assistance of one of the Skagit County Planning and Development Services or Health Department treatment plant operators. Using protective gloves, we will take samples from the same location that the treatment plant operator takes effluent samples.

Specific capacity tests (or equivalent) will be conducted at all monitoring wells, including the deep well, according to Bradbury and Rothschild (1985) to estimate the hydraulic conductivity of the aquifer.

The latitude/longitude coordinates of all monitoring locations will be recorded with a GPS receiver using protocols detailed by Janisch (2006).

8.2 Containers, preservation methods, holding times

Table 5 shows the sample containers, preservation, and holding times required to meet the goals and objectives of this project.

Table 5. Sample containers, matrix, preservation, and holding times for the study.

Parameter	Matrix[1]	Minimum quantity required	Container	Preservative	Holding time
Alkalinity, chloride, bromide, sulfate	FW, ME	500 mL- NO Headspace	500 mL poly	Cool to 6°C or less	14 days
Ammonia, nitrite + nitrate, total persulfate N	FW, ME	125 mL	125 mL poly, clear	H2SO4 to pH <2; Cool to 6°C or less	28 days
Total phosphorus	FW, ME	50 mL	125 mL poly, clear	1:1 HCl to pH <2; Cool to 6°C or less	28 days
Orthophosphorus	FW, ME	125 mL	125 mL poly, amber	Cool to 6°C or less	48 hours
Cations/anions[2]	FW, ME	350 mL	500 mL HDPE	HNO3 to pH <2; Cool to 6°C or less	6 months
Dissolved organic carbon	FW, ME	50 mL	60 mL poly	1:1 HCl to pH<2; Cool to 6°C or less	28 days
Fecal coliform - MF	W, ME	250 mL	250 mL poly, autoclaved	Cool to 6°C or less	24 hours
Total coliform - MF	W, ME	250 mL	250 mL poly, autoclaved	Cool to 6°C or less	24 hours
Nicotine, Caffeine, Nonylphenol, Triclosan	W, ME	1 liter	1 liter amber glass	Cool to 6°C or less	7 days
Grain size (drilling samples)	Soil	NA	1-gallon Ziploc plastic bag	NA	NA

[1] FW: Filtered water; W: Water; ME: Municipal effluent
[2] Cations/anions: Sodium, potassium, calcium, magnesium, iron

8.3 Invasive species evaluation

Ecology field staff will follow SOP EAP070 on minimizing the spread of invasive species (Parsons et al., 2012). The Edison Slough is not in an area of extreme concern.

8.4 Equipment decontamination

Each monitoring well and new piezometer will be fitted with clean, new, dedicated polypropylene tubing for water quality sampling to minimize cross-contamination between wells and piezometers. For each sampling event, new, clean silastic tubing (~ 1.5 foot length) will be used in the peristaltic pump to collect samples. The silastic tubing will be decontaminated between wells and piezometers with a brief deionized water rinse followed by several minutes of pre-sample purging at each site prior to collecting samples for laboratory analysis. A single field blank will be collected during each sampling event to confirm that purging offers adequate decontamination of the silastic tubing between sampling sites.

The E-tape used to measure water levels in monitoring wells and piezometers will be rinsed with deionized water between wells.

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, if required

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, 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.

Samples with 24- and 48-hour holding times will be shipped by FedEx to the Ecology Manchester Environmental Laboratory. 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 in a plastic bag inside one of the coolers.

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 of sample location
- Field staff
- Environmental conditions
- Date, Time, Sample ID, description of collected samples
- Identity of QC samples (if appropriate)
- Field measurement results
- Pertinent observations and/or any problems with sampling, including deviations from the QAPP
- 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 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

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. 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 field lead will notify MEL of the schedule for sampling events a few weeks before sampling. All samples will be collected Monday through Wednesday so that holding times can be met for all fecal and total coliform bacteria samples. The lab will be notified immediately if there will be any deviations from the scheduled date of sampling. The field 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 samples containers are available.

The Washington Department of Fish and Wildlife (WDFW) has granted Ecology's EAP a programmatic hydraulic project approval (HPA) to install scientific instruments (instream piezometers) for scientific studies under Chapter 77.55.021 RCW (Control Number: 131867-1). As required by the HPA, the project lead will contact the local WDFW Habitat Biologist to confirm a lack of spawning in Edison Slough before piezometers are installed.

9.0 Measurement Methods

9.1 Field procedures table/field analysis table

Table 6. Field and laboratory measurement methods.

Parameter	Matrix[1]	No. of samples	Expected range of results	Method	Method detection limit
Field procedures					
Water level	W	160	0-10 feet	E-tape and transducer	0.01 foot
Temperature	W	170	5-25°C	Hydrolab MS-5 Mini-Sonde	0.2° C
pH	W	170	4-9 S.U.	Hydrolab MS-5 Mini-Sonde	NA
Specific conductivity	W	170	50-1,500 umhos/cm	Hydrolab MS-5 Mini-Sonde	5 umhos/cm
Dissolved oxygen	W	170	0-12 mg/L	Hydrolab MS-5 Mini-Sonde	0.1 mg/L
Laboratory procedures					
Alkalinity	FW, ME	180	5-100 mg/L	EPA 310.2	5.0 mg/L
Ammonia-N	FW, ME	180	0.010-10 mg/L	SM 4500 NH3 H	0.010 mg/L
Nitrite + Nitrate-N	FW, ME	180	0.010-100 mg/L	SM 4500 NO3 I	0.010 mg/L
Total persulfate N	FW, ME	180	0.010-100 mg/L	SM 4500 NO3 B	0.025 mg/L
Total phosphorus	FW, ME	18	0.010-10 mg/L	SM 4500 P F	0.0050 mg/L
Orthophosphorus	FW, ME	18	0.010-10 mg/L	SM 4500 P G	0.0050 mg/L
Cations/anions[2]	FW, ME	16	0.5-250 mg/L	EPA 200.7	0.05- 0.5 mg/L
Chloride	FW, ME	180	1-100 mg/L	EPA300.0	0.1 mg/L
Bromide	FW, ME	180	1-100 mg/L	EPA300.0	0.2 mg/L
Iron	FW, ME	140	.05-5 mg/L	EPA 200.7	.05 mg/L
Sulfate	FW, ME	16	1-100 mg/L	EPA300.0	0.1 mg/L
Dissolved organic carbon	FW, ME	180	1-15 mg/L	SM 5310 B	1.0 mg/L
Fecal coliform - MF[3]	W, ME	106	1-10,000 mg/L	SM 9222 D	1 cfu/100mL
Total coliform- MF[3]	W, ME	106	1-10,000 mg/L	SM 9222 B	1 cfu/100mL
Nicotine, Caffeine, Nonylphenol, Triclosan	W, ME	11	0.01-10 ug/L	SW-846 Method 8270D	0.01-1 ug/L
Grain size (drill samples)	Soil[4]	20	NA	ASTM D422-63	NA

[1] FW= Filtered water, ME= Municipal effluent, W= Water
[2] Cations/anions: Sodium, potassium, calcium, and magnesium
[3] Bacteria samples will be reduced if not detected after 3 sampling events.
[4] ASTM (American Society for Testing and Materials), 2007

9.2 Lab procedures table

See Table 6 in Section 9.1. All water samples to be analyzed in the laboratory will be filtered in the field, except fecal and total coliform bacteria samples.

9.2.1 Analyte

See Table 6 in Section 9.1.

9.2.2 Matrix

See Table 6 in Section 9.1.

9.2.3 Number of samples

See Table 6 in Section 9.1.

9.2.4 Expected range of results

See Table 6 in Section 9.1.

9.2.5 Analytical method

See Table 6 in Section 9.1.

9.2.6 Sensitivity/Method Detection Limit (MDL)

See Table 6 in Section 9.1.

9.3 Sample preparation method(s)

Groundwater and piezometer samples will be field-filtered and placed in pre-acidified bottles supplied by MEL. Effluent samples will be filtered in the laboratory.

9.4 Special method requirements

It will be necessary to specify the size ranges required for grain size analysis for drilling samples for the contract laboratory.

9.5 Lab(s) accredited for method(s)

All chemical analysis for water samples will be performed at MEL, which is accredited for all methods listed in Table 6 except grain size. A contract laboratory accredited for the grain size method specified in Table 6 will be used for grain size analyses.

10.0 Quality Control (QC) Procedures

10.1 Table of field and lab QC required

Table 7 shows the field and laboratory QC requirements for the project.

Table 7. Quality control samples, types, and frequency.

Parameter	Field		Laboratory			
	Blanks	Replicates	Check Standards	Method Blanks	Analytical Duplicates	Matrix Spikes
Temperature	NA	NA	NA	NA	NA	NA
pH	NA	NA	NA	NA	NA	NA
Specific conductivity	NA	NA	NA	NA	NA	NA
Dissolved oxygen	NA	NA	NA	NA	NA	NA
Alkalinity	8-10%	8-10%	1/batch	1/batch	1/batch	1/batch
Ammonia-N	8-10%	8-10%	1/batch	1/batch	1/batch	1/batch
Nitrite+Nitrate-N	8-10%	8-10%	1/batch	1/batch	1/batch	1/batch
Total persulfate N	8-10%	8-10%	1/batch	1/batch	1/batch	1/batch
Orthophosphorus	8-10%	8-10%	1/batch	1/batch	1/batch	1/batch
Cations/anions, chloride, bromide, sulfate	8-10%	8-10%	1/batch	1/batch	1/batch	1/batch
Dissolved organic carbon	8-10%	8-10%	1/batch	1/batch	1/batch	1/batch
Fecal coliform-MF	NA	10%	1/batch	1/batch	1/20 samples	NA
Total coliform-MF	NA	10%	1/batch	1/batch	1/20 samples	NA
Nicotine, Caffeine, Nonylphenol, Triclosan	8-10%	8-10%	1/batch	1/batch	1/20 samples	
Grain size	NA	NA				

The QC samples all will have MQOs (evaluation criteria) associated with them. These are described in Section 6.2. These criteria must be met to obtain fully usable data.

As a QC check on transducer accuracy and operation, semi-monthly manual water-level measurements will be made at each well monitored during the study. The check measurements will be made with a calibrated electrical tape (E-tape) or steel tape using EAP's standard protocols (Marti, 2009).

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 might include:

- Retrieving missing information
- Re-calibrating the measurement system
- Re-analyzing samples within holding time requirements
- Modifying the analytical procedures
- Requesting collection of additional samples or taking additional field measurements
- Qualifying results

11.0 Data Management Procedures

11.1 Data recording/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 (MS) 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.

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 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 Users Manual (MEL, 2008). Variability in lab duplicates will be quantified using the procedures outlined in the MEL 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 Acceptance criteria for existing data

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

11.5 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.

12.0 Audits and Reports

12.1 Number, frequency, type, and schedule of audits

Not applicable. There are no formal audits planned for this study. However, there could be a field consistency review of the project by another experienced EAP hydrogeologist. The aim of such reviews is to improve fieldwork consistency, improve adherence to SOPs, and provide a forum for sharing innovations and strengthening our data quality assurance program.

12.2 Responsible personnel

See Section 12.1.

12.3 Frequency and distribution of report

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

12.4 Responsibility for reports

Barbara Carey will be the lead on the final report.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

Initial field data verification will be performed by the project manager 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 event, the project manager will compare all field data to determine compliance with MQOs. Values that are out of compliance with the MQOs will be noted. 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 Lab 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

All laboratory data that have been verified by MEL staff will be validated by an EAP project staff member. Field measurement data that was verified by a project staff member will be validated by a different staff member.

After data entry and data validation tasks are completed, all field and laboratory data will be entered into the EIM system. EIM data will be independently reviewed by another EAP field person for errors at an initial 10% frequency. If significant entry errors are discovered, a more intensive review will be undertaken.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining whether project objectives have been 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 upon the decision criteria from the QA Project Plan. The project manager will decide how any qualified data will be used in the technical analysis.

14.2 Data analysis and presentation methods

Data will be presented in tabular and graphic form. Groundwater elevations and groundwater contours for each sampling date will be mapped and the direction of groundwater flow labeled. Groundwater quality results will be presented in tabular and graphical form. Transducer data will be graphically displayed. Additional water table maps will be developed for times when transducer data indicates a potential change in groundwater flow direction.

Statistical methods recommended in Appendix E of Kimsey (2005) will be used for establishing background water quality. A minimum of 8 samples is needed to estimate background water quality. The direction of groundwater flow and results of groundwater tracer analytes will influence which data can be used to estimate background water quality.

The main constituents of concern for background are nitrate and total coliform bacteria. This is shown in Table 9 in the fact sheet of the Edison LOSS discharge permit (Ecology, 2013). Background concentrations will be assessed for these and all of the other analytes sampled during the study. If more than one monitoring well is upgradient, then the background groundwater quality for that date will be the mean concentration for each constituent.

Once background conditions are established, we will compare background water quality with results from downgradient monitoring wells and piezometers.

Nitrate-N concentrations from wells constructed close to the property boundary and downgradient of the drainfields will be checked for exceedance of the 2 mg/L increase over background limit.

14.3 Treatment of non-detects

Any non-detects will be included in the study analysis. If there are a small number of non-detects, they will be treated as half the detection limit. If a significant number of non-detects occur, we will use another assessment method (Singh et al., 2006).

14.4 Sampling design evaluation

The sampling design is based on existing information, and the actual conditions at the site may be more complex than indicated. If we identify deficiencies in our sampling design, we will evaluate the potential consequences on the project. We may recommend additional work or activities to resolve such problems.

Based on the information we have about the site, the sampling intensity, of semi-monthly sampling for 20 months, is more than adequate to meet the requirements for characterizing background conditions in groundwater, which is one of the goals of the study and requires a minimum of 8 samples in Kimsey (2005).

14.5 Documentation of assessment

The project manager will include a section in the technical report summarizing the findings of the data quality assessment. This summary is usually included in the data quality section of most reports.

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16.0 Figures

For a list of figures, see the Table of Contents section.

17.0 Tables

For a list of tables, see the Table of Contents section.

18.0 Appendices

Appendix A. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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.

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

Effluent: An outflowing of water from a natural body of water or from a fabricated structure. For example, the treated outflow from a wastewater treatment plant.

Fecal coliform (FC): That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000 fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

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.

303(d) list: Section 303(d) of the federal Clean Water Act, requiring Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

90^{th} percentile: An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90^{th} percentile value is a statistically derived estimate of the division between 90% of samples, which should be less than the value, and 10% of samples, which are expected to exceed the value.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

DOC	Dissolved organic carbon
Ecology	Washington State Department of Ecology
e.g.	For example
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
QA	Quality assurance
SOP	Standard operating procedures
TMDL	Total Maximum Daily Load
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	colony-forming units
ft	feet
gpd	Gallons per day
mg	milligram
mgd	million gallons per day
mg/L	milligrams per liter (parts per million)
s.u.	standard units
ug/L	micrograms per liter (parts per billion)
umhos/cm	micromhos per centimeter
uS/cm	microsiemens per centimeter, a unit of conductivity

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 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)

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)

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): Data Quality Indicators (DQIs) are 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): Data Quality Objectives are 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 is usable for intended purposes.
- J (or a J variant), data is estimated, may be usable, may be biased high or low.
- REJ, data is 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. (USEPA, 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)

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)

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: The term split sample denotes when a discrete sample is further 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

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