

Characterization of the Groundwater Discharge to Moses Lake, Washington

Quality Assurance Project Plan

By
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Environmental Assessment Program
Olympia, WA 98504-7710

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Background/Problem Statement

Due to concerns regarding excess levels of annual nutrient loading to Moses Lake, the Eastern Regional Office (ERO) of the Washington Department of Ecology (Ecology) has asked the Environmental Assessment Program (EAP) to conduct a comprehensive field study of water quality conditions for the lake during the 2001 water year (Figure 1). The ultimate goals of this effort are the development of a water quality model, and an allocation strategy for nutrient loading to the lake (Carroll, et al., 2000). This allocation strategy will be formalized through the development of a Total Maximum Daily Load (TMDL) for nutrients.

Project Description

As an integral part of the EAP Moses Lake TMDL study, this project focuses on improving the understanding of the chemical quality of the direct *groundwater* inflow to the lake, particularly with respect to nutrients (primarily phosphorus and nitrogen). While groundwater has been identified as a significant contributor to the annual nutrient load to the lake (Carroll et al., 2000), few samples of the groundwater discharging directly into the lake have been collected and analyzed. Characterization of the quality of the groundwater entering Moses Lake will assist in the development of an up-to-date, lake-wide nutrient budget.

The primary goal of this study is to document the phosphorus and nitrogen content of the groundwater that is directly discharging into Moses Lake from the study area aquifer system. The data developed from this study may be used in the construction of a water quality model for the lake. To provide sufficient data for this purpose, a total of 10 to 15 samples of groundwater will be collected in the vicinity of the lake shoreline, distributed throughout the study area. It should be noted that this study will not attempt to develop estimates of the annual groundwater-derived discharge volume or nutrient mass loading to the lake. Water budget information developed through other activities of the TMDL study will be integrated with the groundwater quality information collected during this study to develop loading estimates.

The ERO has also expressed an interest in identifying the source of the elevated nutrient concentrations found in the springwater discharging at the head of Rocky Ford Creek, which ultimately drains to Moses Lake. An extensive study of this question is beyond the current available resources of EAP. However, a limited effort to characterize the geochemical profile of the springwater, and compare that profile to the geochemistry of several suspected upgradient source lakes, is described in Appendix A.

Responsibilities

Dave Knight of the ERO Water Quality Program initiated this project through a request to the Environmental Assessment Program. Dave and his staff will help to: 1) arrange permission to access publicly or privately owned lake shoreline property or wells, and 2) review drafts of the project QAPP and final report.

Bob Cusimano is the overall project manager for the Moses Lake TMDL study. Bob will coordinate the various field investigations and sampling efforts that, combined, will provide the

basis for the development of a water quality model and the establishment of a TMDL for the lake. Bob will provide technical input on the groundwater sampling needs for the larger study.

Jim Carroll is the principal investigator for the Moses Lake TMDL study. Jim will manage sampling of surface water for the study and will serve as an additional point of contact for field sampling efforts.

Charles Pitz will be the project lead for the groundwater portion of the Moses Lake TMDL and will have primary responsibility for project planning, data collection and evaluation, and reporting. Charles' phone number is (360) 407-6775.

Cliff Kirchmer will assist in providing technical guidance regarding QA/QC issues or problems that arise during the project. Cliff's phone number is (360) 407-6455.

Bernie Strong will assist in the construction of field sampling equipment. Bernie's phone number is (360) 407-6571.

Manchester Environmental Laboratory (MEL) will conduct the analysis of all field samples collected during this study other than field-measured parameters. The phone number of the MEL is (360) 871-8800. Pam Covey of MEL will be responsible for coordinating requests for analysis and providing access to project data. Pam's number is (360) 871-8827.

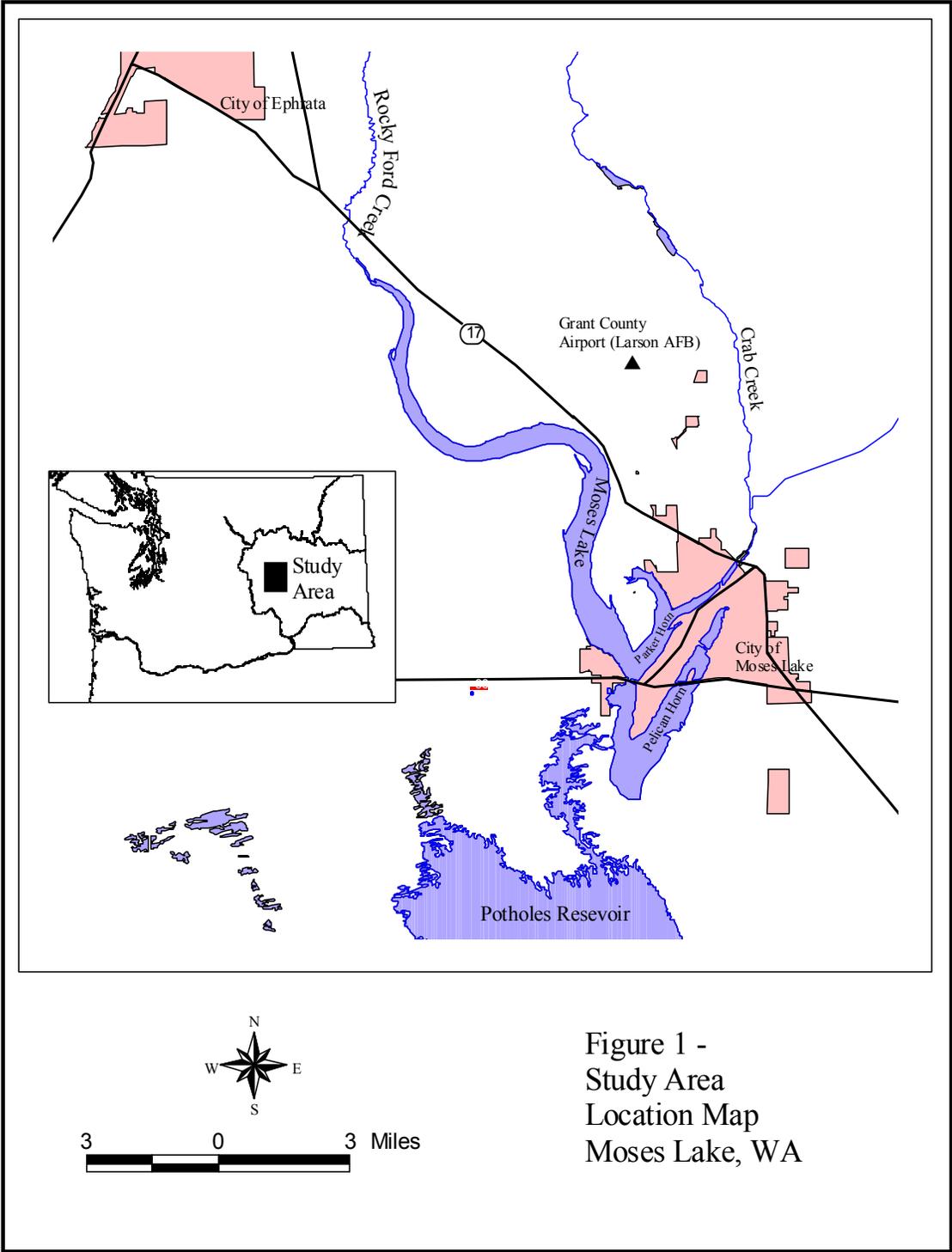


Figure 1 -
Study Area
Location Map
Moses Lake, WA

Schedule

The anticipated project schedule is presented below.

Task	2000	2001	2002
	JASOND	JFMAMJJASOND	JFMAMJ
Project Planning and Background Research	SO		
QAPP Preparation	ND		
Project Preparations <ul style="list-style-type: none"> • Equipment construction and testing • Remote Sensing Image analysis • Sampling point access arrangements • Field surveys to identify discharge zones 		JFMA	
Project setup in EIM		JFM	
Sampling Events		M J O	
LIMS data migration to EIM		J S D	
Compile and evaluate project data		JJASOND	JF
Prepare draft report			D JFMA
Incorporate review comments and finalize report			AMJ

Data Quality Objectives and Decision Criteria

The primary objective of this study is to provide data that are reasonably representative of field conditions for input into a water quality model. Evaluation of the groundwater concentration range that has been reported in the study area, the anticipated variation in the seasonal quality of the groundwater discharge, and the heterogeneity of the sampling media and environment all suggest that the precision and bias routinely obtained by the analytical methods selected are considered adequate for the purposes of this project. A variety of field and laboratory quality control steps will be taken to minimize and assess error in the project data. EAP Watershed Assessment Section (WAS) protocols will be followed when measuring water quality field parameters, and standard methods will be used for sample collection, handling, preservation, and storage (WAS, 1993).

Table 1 describes the data quality objectives for this project (equivalent to the laboratory measurement quality objectives). Routine laboratory quality control procedures will be used to estimate the accuracy, precision, and bias introduced by laboratory procedures and will be reported to the project lead for data analysis (MEL, 2000).

Table 1 – Data Quality Objectives

Parameter	Accuracy (2*precision + bias)	Precision (% RSD)	Bias (%)	Required Reporting Limit
Total Phosphorus (TP)	<35%	<10	<15	10 µg/L
Orthophosphate (<i>Ortho</i> -PO ₄ ⁻³)	<40%	<10	<20	10 µg/L
Ammonia (NH ₃)	<40%	<10	<20	10 µg/L
Nitrate+nitrite as N (NO ₃ ⁻ + NO ₂ ⁻)	<30%	<10	<10	10 µg/L
Total Kjeldahl Nitrogen (TKN)	<40%	<10	<20	1 mg/L
Total Dissolved Solids (TDS)	< 30%	<15	<10	10 mg/L
Chloride	<30 %	<10	<10	100 µg/L

A summary of the laboratory or field methods that will be used for analysis of selected parameters is presented in Table 2. Table 2 also presents the anticipated ranges for the parameters of interest. Field parameters will be used primarily to establish adequate purge of sampling devices prior to collection of samples for lab analysis.

Table 2 – Summary of Field and Laboratory Analytes, Methods, Sample Prep, and Anticipated Concentration Ranges

Analyte	Matrix	Analytical Method	Sample Prep Method	Expected Range of Results*
<i>Field Measurements</i>				
pH	Water	Field meter	NA	5.5 – 8.5 standard units
Specific Conductivity	Water	Field meter	NA	100-900 umhos/cm@25°C
Temperature	Water	Field meter	NA	9-18°C
Dissolved Oxygen	Water	Field meter	NA	<1 – 10 mg/L
<i>Laboratory Analytes</i>				
Total Phosphorus	Water	EPA 365.3	NA	<0.01 – 0.3 mg/L
Orthophosphate	Water	EPA 365.3	Field filter @ 0.45 µm	<0.01 – 0.15 mg/L
Ammonia	Water	EPA 350.1	NA	unknown
Nitrate + nitrite as N	Water	EPA 353.2	NA	<0.01 – 20 mg/L
Total Kjeldahl N	Water	EPA 351.2	NA	unknown
TDS	Water	EPA 160.1	NA	100 – 500 mg/L
Chloride	Water	EPA 300.0	NA	1- 25 mg/L

*Anticipated parameter ranges determined from previous investigations, including values reported for the Rocky Ford Creek headwaters spring (Cusimano and Ward, 1998), which are assumed to be representative of local groundwater conditions.

Study Design

The objectives of this study will be accomplished by sampling groundwater at or near the point of discharge into Moses Lake. Ten to fifteen locations will be sampled depending on access considerations, groundwater flow patterns, and difficulty of sample device installation. The sampling locations will be distributed as equally as possible along those portions of the lake shoreline that are identified as receiving groundwater discharge, but will also be dictated by access considerations.

Groundwater discharge to lakes typically occurs in the near-shore area, decreasing exponentially with distance from shore (Winter, 1978; Winter, 2000). However groundwater inflow is often a highly localized and transient process; identifying a specific area of groundwater inflow in a lake bed can be difficult even under ideal conditions. Additionally, groundwater flow patterns in the area of Moses Lake are highly dynamic throughout the year. Local groundwater flow is significantly influenced by the water management practices implemented as part of the Columbia Basin Irrigation Project (USBR, 2000) and the cyclic nature of area surface irrigation and aquifer

pumping. No water-level monitoring network is available in the lake vicinity that provides a current, detailed picture of the groundwater flow regime.

These factors make it difficult to determine exactly what portions of the lake are receiving groundwater discharge on any given day. All available groundwater data will be examined in order to identify those areas of the lake where groundwater discharge is the *most probable*. Field surveys and remote sensing image analysis may also be used to help identify discharge areas. Sampling locations will be focused in the areas thought most likely to be receiving discharge, as access allows.

A two-tiered sampling approach will be used for this study. The preferred sampling method will be the installation of mini-piezometers installed 1 to 2 meters below the sediment/water interface in the lake's littoral zone. Samplers installed near the groundwater/surface water interface are considered one of the most representative methods of characterizing direct groundwater discharge to a surface water body (Harvey et al., 2000; EPA, 1991; Lee, 1976; Lee 2000, Belanger and Mikutel, 1985).

If the installation of a mini-piezometer is not possible for any reason along a select section of the lake shoreline, groundwater will alternatively be sampled from near-shore domestic drinking water wells screened or open within the uppermost aquifer (depending on availability of wells). This second approach is a more indirect method of sampling groundwater discharge and will only be used if mini-piezometer installation is not practical.

The mini-piezometer (or piezometer/well) network will be sampled during early May, late July, and early October of 2001 in order to characterize changes in groundwater discharge quality with season. Lake freeze-over, and the manipulation of the Moses Lake water level between late October and mid-April by the USBR, prohibit the installation and sampling of mini-piezometers during that time period. Samples will be analyzed for target nutrients (total phosphorus, orthophosphate, ammonia, nitrate/nitrite, total Kjeldahl nitrogen) as well as select water quality indicator parameters (chloride, TDS).

Field Procedures

If possible, mini-piezometers will be driven 1 to 2 meters below the water/sediment interface in the littoral zone of the lake. Water depth will dictate the distance from the shoreline that field personnel can deploy the piezometers. To deploy a mini-piezometer, one-quarter (1/4) inch polyethylene sample tubing will be attached to a drive point. The bottom foot of the tubing is perforated and screened to serve as an intake point for pore water samples. A narrow diameter hollow drive pipe is slipped over the tubing and is used to drive the drive point/tubing assembly into the lakebed sediments to the desired depth. The drive pipe is then carefully removed, allowing the formation to collapse around the tubing. The tubing extends to the lake surface for sampling access.

Prior to sampling, a measurement of the hydraulic head in the mini-piezometer will be collected and compared to the lake surface level to determine the direction and magnitude of the vertical hydraulic gradient. Hydraulic head will be measured directly from the tube if the water level is higher than the lake level, or using a manometer or electric water level probe if the tubing water

level is below the lake level. Samples will not be collected for chemical analysis if the head measurements indicate that there is a measurable downward vertical gradient between the lake and the underlying pore water. Alternative piezometer locations may be chosen in the field if the head relationship indicates that a newly installed piezometer is located in a groundwater recharge area or if lake-bed sediment type prohibits installation to the desired depth. Successfully installed piezometers will be located for mapping purposes using a Global Positioning System (GPS) unit and topographic map.

To sample a mini-piezometer, a peristaltic pump will be attached to the tubing. Pumping rates less than 1 liter/minute will be used for both purging and sampling to minimize downward annular leakage of lake water into the tubing openings, and prevent sediment clogging and suspension. While pumping, pore-water temperature, electrical conductivity, pH, and dissolved oxygen concentration will be measured periodically in a flow-cell isolated from the exterior atmosphere. Field parameters are measured primarily to provide an indication of adequate purging of the sampling device. Samples of the pore water for the target analytes will be collected only after these indicator parameters have stabilized within 10% of consecutive measurements. All samples will be collected in pre-cleaned bottles supplied by MEL and stored on ice pending their arrival at the laboratory. Table 3 summarizes the container requirements, sample volume, method of preservation, and maximum permissible holding time for the various target analytes.

Table 3 – Container, Sample Volume, Preservation and Holding Time Requirements

Analyte	Container Type	Sample Volume (mL)	Preservation	Holding Time
Total Phosphorus	polyethylene	250 ^A	Adjust pH <2 w/H ₂ SO ₄ and cool to <4°C	28 days
Orthophosphate	Amber W/M polyethylene	125	Filter in field and cool to <4°C	48 hrs
Ammonia	polyethylene	250 ^A	Adjust pH <2 w/H ₂ SO ₄ and cool to <4°C	28 days
Nitrate+nitrite as N	polyethylene	250 ^A	Adjust pH <2 w/H ₂ SO ₄ and cool to <4°C	28 days
TKN	polyethylene	250 ^A	Adjust pH <2 w/H ₂ SO ₄ and cool to <4°C	28 days
TDS	polyethylene	1000 ^B	Cool to <4°C	7 days
Chloride	polyethylene	1000 ^B	Cool to <4°C	28 days

^A - Total phosphorus, ammonia, nitrate-nitrite and TKN sample collected in a common 250 ml bottle.

^B - TDS and chloride sample collected in common 1000 ml bottle.

Samples that require field filtration (i.e. orthophosphate) will be filtered at the time of collection using a 60 cc, 0.45 µm disposable syringe filter supplied by the laboratory. Prior to filtering, the syringe and plunger will be rinsed with sample water. The first 20 cc of filtrate will be discarded prior to filling the sample container.

If possible, one of the sampling stations will be chosen for vertical profiling of pore-water quality during each sampling round. This will be accomplished by driving two to three separate mini-piezometers to various depths below the sediment/water interface.

If mini-piezometer sampling is not possible for this project along some or all of the lake shoreline, groundwater samples will alternatively be collected from near-shore domestic wells, depending on availability. Wells will be selected according to the following criteria:

- A well driller's report (well log) must be available for the well describing the depth of completion and formation materials encountered during drilling.
- The well must have a state well tag ID number to confirm the construction details of the well.
- The well must be easily accessed for water quality sampling.
- The well must be completed in the uppermost aquifer as described by previous investigators (Golder, 1991; Grolier and Bingham, 1971, 1978; Grolier and Foxworthy, 1961; Walters and Grolier, 1960; Whiteman, et al., 1994). Wells completed in the uppermost aquifer are preferred for this study since they are the most likely wells to reflect the water quality of the groundwater discharging to the lake.
- The current well owner must grant access to the well for sampling.
- The well must have a dedicated pump.
- The well cannot have a water treatment device, such as a water softener or iron treatment system, or a large storage tank that cannot be bypassed during well purging and sampling.
- The well must be located within one-half (0.5) mile of the lake shoreline.

Prior to sampling, the well will be purged through a flow-cell until temperature, conductivity, pH, and dissolved oxygen have stabilized within 10% of a consecutive measurement. Sample collection, filtration, and handling will then proceed as described above.

Laboratory Procedures

Standard MEL laboratory analytical methods are appropriate for meeting the data quality objectives of this study. Low detection limit methods are not necessary for the goals of the study. Table 4 summarizes the anticipated analytical costs for the project.

Table 4 – Estimated Laboratory Cost by Parameter

Parameter	Number of Samples	Cost Per Sample⁽¹⁾	Cost per Parameter
Total P	58	\$16	\$928
Ortho-P	61	\$12	\$732
Nitrate+Nitrite	58	\$12	\$696
Ammonia	58	\$12	\$696
TKN	58	\$31	\$1798
TDS	57	\$10	\$570
Chloride	57	\$12	\$684
Total Lab Cost			\$6104

⁽¹⁾ Assumes MEL “planned” price.

Quality Control Procedures

Field Quality Control

All field meters will be calibrated in accordance with the manufacturer’s instructions at the start of each sampling day. Blind field replicate samples, comprising at least 10% of total samples, will be submitted to the laboratory during each sampling event to assess random error. Replicate locations will be selected on the basis of existing information for the first sampling round and on the initial analytical results for later rounds. An equipment rinsate blank will be submitted to the laboratory for analysis of target nutrients during the first sampling round to determine if cross contamination by the sampling apparatus is occurring. A filtration blank will be collected and analyzed for orthophosphate once per sampling round.

Representativeness

An important concern regarding the use of mini-piezometers for sampling the pore water beneath a lakebed is downward annular leakage of lake water into the openings at the base of the sampler tubing. To minimize this problem, all mini-piezometers will be driven a minimum of 1 meter into the lake-bed sediments in order to improve the annular seal around the tubing. Additionally, pumping from mini-piezometers will be maintained at very low flow rates to minimize reversal of the hydraulic gradient and resultant drawdown within the piezometer tubing. If appropriate, a clean, fine-grained silica sand may be backfilled into the void space around the piezometer tubing at the sediment/water interface to minimize drawdown of lake water into the annular space created during piezometer installation and withdrawal.

Sampling only piezometers that exhibit an upward vertical hydraulic potential will also minimize the chances for downward leakage, due to the fact that annular leakage under these conditions will be upward from the sediments to the lake. The hydraulic potential at the end of sampling

will be rechecked and recorded to determine if drawdown of the piezometer potential occurred during pumping.

To assist in evaluating the likelihood of the annular leakage of surface water into the screened portion of the piezometer, the pH, temperature, conductivity, and dissolved oxygen levels of the lake water will be collected and recorded immediately prior to the initiation of purging. These values will be compared to the values collected during purging.

Finally, a visual test for leakage will be conducted for at least two of the mini-piezometers each sampling round. To conduct this test, a food-grade coloring dye will be released immediately adjacent to the tubing at the sediment/water interface and observations of discoloration of the purge water will be recorded.

All attempts will be made to identify areas of probable groundwater inflow for sampling. Because the emphasis of this study is primarily on characterizing the quality of the groundwater inflow, rather than the quantity, sampling of the groundwater in the areas of highest discharge rate, while preferable, is not considered critical to the goals of the study.

Completeness

To maximize the amount of usable data collected during this study, we will follow accepted WAS protocols for water-quality data acquisition (WAS, 1993). Only appropriately calibrated and maintained field equipment will be used. All attempts will be made to ensure that samples are packaged in a manner to prevent loss in transit and arrive at the MEL within the appropriate holding time.

Comparability

An important concern for this project is the comparability of the groundwater data collected for this study to the surface water data collected by other EAP investigators as part of the Water Year 2001 lake characterization. To ensure data comparability, the sampling, handling, and analysis techniques for the target analytes (total phosphorus, orthophosphate, ammonia, nitrate/nitrite, and total Kjeldahl nitrogen) will follow standardized procedures to match those being employed by the other investigators.

Lab Quality Control

Routine laboratory quality control procedures will be adequate to estimate laboratory precision and accuracy for this study. Manchester Laboratory's quality control samples and procedures are discussed in detail in the Quality Assurance Manual, Manchester Environmental Laboratory (MEL, 1988). Results will be provided to the project lead.

Data Management Procedures

Field data will be recorded at the time of sampling in a field notebook; and if appropriate, input in the Environmental Information Management (EIM) data repository.

Data generated by MEL will be managed by the Laboratory Information Management System (LIMS) and sent to the project lead in both electronic and hard copy format. After evaluation of the analytical data against the project data quality objectives, the reported results will be input into the EIM system.

Data Review and Validation

Prior to distribution to the project lead, analytical data generated by MEL will be reviewed and verified against acceptance criteria according to the data review procedures outlined in the laboratory's user manual (MEL, 2000).

Upon receipt of the verified data from MEL, the project lead will compare the quality assurance and analysis performance information against the project data quality objectives. Data will be assessed for completeness and for indications of bias introduced by field procedures. If appropriate, sampling approach, quality control steps, or analytical procedures will be modified for future sampling rounds to address identified problems.

Precision

The relative percent difference (RPD) will be calculated for duplicate sample results in order to provide an indication of the degree of random variability introduced by sampling and analytical procedures. These values will be statistically compared to the project data quality objectives.

Bias

The analysis performance for spike recoveries, blanks, instrument calibration, and control samples provided by MEL to the project lead will be evaluated to determine the analytical bias in the sampling results. These evaluations will be compared to the project data quality objectives.

Completeness

The precision and bias assessments will be used to identify those analytical results that fail to meet the data quality objectives of the project. In addition, the required versus actual holding times prior to analysis for each sample will be evaluated to confirm the reported values are valid.

Data Quality Assessment

Upon receipt of the last round of analytical results from the laboratory, the overall data set will be evaluated for representativeness and completeness. Data error will be assessed against the project goals and the project manager will determine the applicability of the data to future water quality modeling efforts.

Reporting

A final report will be prepared that summarizes the study methods, quality assurance evaluation results, and study findings. The report will be submitted in draft form to internal reviewers in EAP, and to the ERO prior to final publication.

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Appendix A

The springwater discharging at the head of Rocky Ford Creek is known to be a significant source of nutrients entering Moses Lake (Cusimano and Ward, 1998). Various source areas for the water discharging at the springs have been proposed over the years, including Soap Lake to the north, groundwater flow from the Ephrata area in the west, and the irrigation return-flow impoundments located towards the northeast (Figure A-1) (Brook Lake, Round Lake)(Bain, 1985; Mundorff et al., 1952). The strongest evidence published to date supports the interpretation that surface outflow from Brook Lake is hydraulically connected to the springs via a high transmissivity, subsurface paleochannel.

The ERO has expressed interest in identifying the source of the elevated phosphorus concentrations in the springwater. An extensive study of this question is beyond the current available resources of EAP. However, a limited effort will be made during the lake characterization study to determine if there are basic geochemical similarities between the spring water and the water of several of the upgradient lakes or springs that have been suggested as source areas for the springs.

For this study, we propose to collect water samples of the springwater, as well as water samples from Soap Lake, Brook Lake, Round Lake, and Gloyd Seeps for analysis for general chemistry parameters. Sample results will be plotted on both trilinear and Stiff diagrams for analysis and comparison of the geochemical signature of the different water sources.

Table A-1 below summarizes the selected general chemistry parameters, laboratory methods, reporting limit, and estimated costs for this portion of the study.

Table A-1

Parameter	Method	Reporting Limit	Cost per sample	Number of samples	Total Cost
Magnesium, total	ICP	25 ug/L	\$14	5	\$70
Potassium, total	ICP	500 ug/L	\$14	5	\$70
Sodium, total	ICP	25 ug/L	\$14	5	\$70
Calcium, total	ICP	25 ug/L	\$14	5	\$70
Alkalinity as CaCO ₃ , total	SM 2320B	10 mg/L	\$14	5	\$70
Chloride	SM 4110C	0.1 mg/L	\$12	5	\$60
Sulfate, total	SM 4110C	0.5 mg/L	\$12	5	\$60
Total Dissolved Solids	SM 2540C	1 mg/L	\$10	5	\$50
				Total Cost	\$520

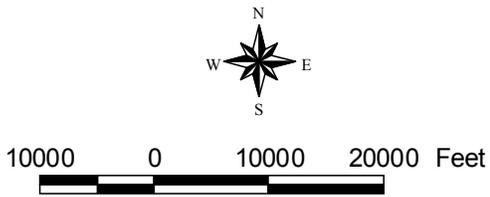
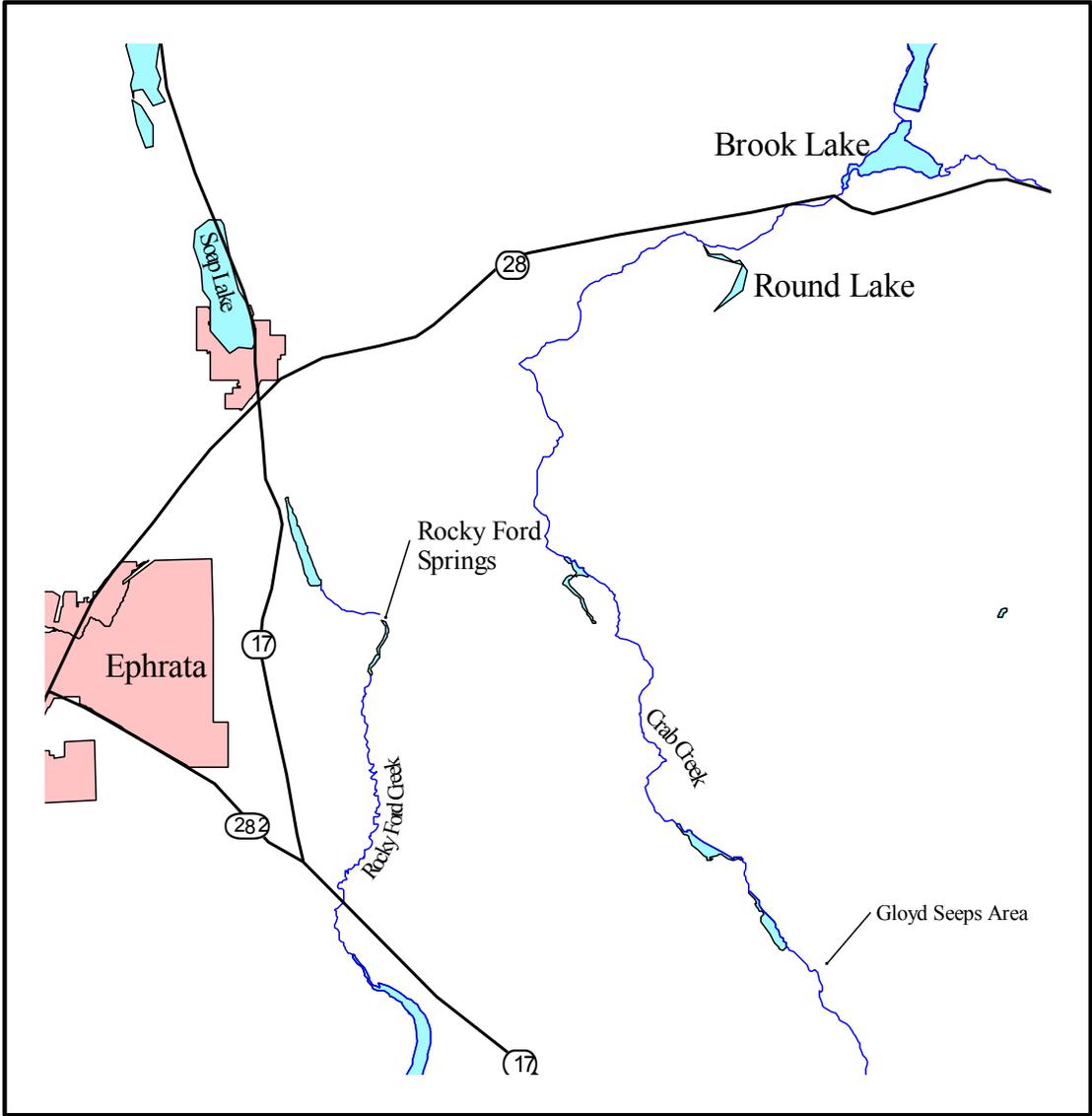


Figure A-1
 Geochemistry
 Sampling Locations
 Rocky Ford Springs and
 Surrounding Lakes/Springs

Table A-2 summarizes the sample container, preservation, and holding time requirements for the proposed sampling.

Table A-2

Parameter	Holding Time	Bottle Type	Preservation
Magnesium	6 months	1 L HDPE	HNO ₃ to pH <2, Temp <4°C
Potassium	6 months	1 L HDPE	HNO ₃ to pH <2, Temp <4°C
Sodium	6 months	1 L HDPE	HNO ₃ to pH <2, Temp <4°C
Calcium	6 months	1 L HDPE	HNO ₃ to pH <2, Temp <4°C
Alkalinity	14 days	500 ml wide mouth polyethylene	Temp <4°C
Chloride	28 days	500 ml wide mouth polyethylene	Temp <4°C
Sulfate	28 days	500 ml wide mouth polyethylene	Temp <4°C
TDS	7 days	1 L wide mouth polyethylene	Temp <4°C