Final Report

Great Salt Lake Water Quality Studies

Quality Assurance Project Plan

Prepared for

North Davis Sewer District

in cooperation with the

Utah Department of Environmental Quality, Division of Water Quality

August 2006

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Acronyms

%R	Percent Recovery
°C	Degrees Celsius
µg	Microgram
AA	Atomic Absorption
AF	Atomic Fluorescence
CCB	Continuing Calibration Blank
CCV	Continuing Calibration Verification
CDA	Comma-Delimited ASCII
CFR	Code of Federal Regulations
COC	Chain of Custody
CRM	Certified Reference Material
CV	Calibration Verification
DL	Detection Limit
DMS	Data Management System
DQO	Data Quality Objective
DRC	Dynamic Reaction Cell
EDD	Electronic Data Deliverables
EPA	United States Environmental Protection Agency
GSL	Great Salt Lake
HDPE	High-density polyethylene
HNO_3	Nitric Acid
ICB	Initial Calibration Blank
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
ICV	Independent Calibration Verification
IS	Internal Standard
Kg	Kilogram
L	Liter
LCS	Laboratory Control Sample
LET	Laboratory & Environmental Testing, Incorporated
LFB	Laboratory Fortified Blank
LT	Lower Tolerance

MB	Method Blanks
MD	Matrix Duplicate
MDL	Method Detection Limit
mg	Milligram
mL	Milliliter
MQO	Method Quality Objective
MS	Matrix Spike
MS	Matrix Spike
MSA	Method of Standard Addition
MSD	Matrix Spike Duplicate
MSD	Matrix Spike Duplicate
PDD	Post-Digestion Duplicate
PE	Performance Evaluation
PQL	Practical Quantitation Limit
PS	Post-Digestion Spike
PSD	Post-Digestion Spike Duplicate
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
R	Recovery
RL	Reporting Limit
RPD	Relative Percent Difference
RS	Reference Sample
RSD	Relative Standard Deviation
SOP	Standard Operating Procedure
SOW	Scopes of Work
TOC	Total Organic Carbon
UDWQ	Utah Division of Water Quality
UT	Upper Tolerance
VDMS	Validated Data Management System

1.0 Introduction

This Quality Assurance Project Plan (QAPP) presents the quality assurance (QA) and quality control (QC) requirements designed to ensure that environmental data collected for the Great Salt Lake (GSL) Selenium Water Quality Studies will be of the appropriate quality to achieve the Data Quality Objectives (DQOs) defined in Section 3.0 of this QAPP. Specific protocols for sampling, sample handling and storage, chain of custody, laboratory analyses, data handling, data management, and data evaluation and assessment are discussed. Requirements for performance evaluations, corrective actions, and preventive maintenance of equipment are specified. The elements included in the QAPP are consistent with those specified in the United States Environmental Protection Agency (EPA) *Requirements for Quality Assurance Project Plans, EPA QA/R-5* (EPA, 2001). The objectives of the GSL QAPP are as follows:

- Ensure that data collection and measurement procedures are standardized among all participants.
- Define staff roles and responsibilities.
- Monitor the performance of the various measurement systems being used in the individual projects to maintain statistical control and provide rapid feedback, so that corrective measures, if needed, can be taken before data quality is compromised.
- Periodically assess the performance of these measurement systems and their components.
- Verify that reported data are sufficiently precise, accurate, representative, complete, and comparable, so that they are suitable for their intended use.

2.0 Project Description

The Utah Division of Water Quality (UDWQ), in partnership with the GSL Water Quality Steering Committee and Science Panel, has identified four projects (two of which are divided into parts A and B) to provide critical information for the development of a site-specific water quality standard for selenium for the open waters of GSL (also referred to as Gilbert Bay). Each of the projects has its own objectives, but due to the complexities inherent in the ecosystem of the GSL, they are closely interconnected, as described in the DQOs (Section 4) and the *Conceptual Model for Selenium Cycling in the Great Salt Lake* (Johnson et al., undated). Below are summaries of the individual projects being performed as part of the GSL Water Quality Studies. Detailed scopes of work (SOW) outlining the project backgrounds, frequency of sample collection and matrices/species collected, schedules, and budgets are included within the SOWs. Additionally the DQOs referenced in Section 4.0 and included as Appendix A describe the individual project objectives as well as the overarching goals of the GSL Water Quality Studies.

2.1 GSL Project 1A

This project will focus primarily on determining what kinds of foods shorebirds (specifically, American avocets and black-necked stilts) eat during the breeding season, the concentrations of selenium in those food items and in the tissues (blood, liver, and eggs) of the shorebirds, and the effects of selenium on reproductive success of the shorebirds.

2.2 GSL Project 1B

During the spring season, this project will determine what kinds of foods California gulls eat during the breeding season, the concentrations of selenium in those food items and in the tissues (blood, liver, and eggs) of the gulls, and the effects of selenium on their reproductive success. During the fall season, the project will assess selenium concentrations in the tissues (blood and liver) of eared grebes soon after the birds arrive at the GSL and shortly before their departure; it also will determine whether there is a relation between selenium concentrations and body condition of the birds. Similarly, the project will assess selenium concentrations in the tissues (blood and liver) of common goldeneyes soon after the birds arrive at the GSL in early winter and shortly before their departure in late winter. The project will also determine whether there is a relation between selenium concentrations and body condition of the birds.

2.3 GSL Project 2A

Project 2A will determine the importance of the benthic food web for bioaccumulation of selenium in birds. Larval and pupal brine flies are likely important dietary components of birds utilizing the GSL and thus provide an important mechanism for selenium uptake. Larval brine flies feed on periphyton and likely on phytoplankton and detrital food resources that settle onto

the lake's littoral zone. Very little is known about this benthic food web, and nothing is known in relation to the bioaccumulation of selenium in the food web leading to birds.

2.4 GSL Project 2B

This project specifically addresses trophic transfer of selenium within food webs from water to particulate matter (seston) to the dominant zooplankton species (brine shrimp, *Artemia franciscana*). Brine shrimp represent a large portion of the biomass in GSL, and are important food items for a wide range of avian species.

2.5 GSL Project 3

Project 3 will determine the amount of selenium entering the open water of the GSL through surface water. Selenium loadings to the open water of the GSL also may occur via groundwater discharge and atmospheric deposition, but they are assumed to be small and will not be measured as part of this project. With respect to surface water, most rivers that flow into the GSL are monitored for discharge and concentration of chemical constituents by the United States Geological Survey. Unfortunately, all of the established gauging sites are located significant distances upstream of where the outflow actually enters the open water of the GSL. Significant changes in the selenium concentration, as well as other chemical constituents, can occur between the established gauging stations and where the inflow enters the open water of the GSL. New stream gauging station locations will be installed to facilitate the measurement of selenium loads entering the open water of the GSL. Data gathered from the new gauging infrastructure will allow for the modeling of mean daily selenium loads from all input sources to the GSL.

2.6 GSL Project 4

This project will provide a budget for selenium in the open water of the GSL. The selenium inputs determined in Project 3 must be balanced against selenium outputs, which are expected to occur mainly via two mechanisms: (1) release of selenium vapor to the atmosphere; (2) permanent burial of selenium in the sediment. These output fluxes cannot be estimated from published literature because these two release processes in the GSL have not been heavily investigated. Furthermore, the existing literature for other systems does not address a system of the size, salinity, vertical and spatial heterogeneity, and temporal variability as represented in the GSL. The execution of Project 4 requires well-conceived field measurements.

3.0 Project Organization

A team of researchers, including local and national experts from local universities, state and federal agencies, and industry (CH2M HILL), have united to deliver all four projects (two of which are divided into parts A and B) and facilitate effective coordination among projects (see Table 3-1). This team will collaborate with the UDWQ, the Steering Committee, and the Science Panel to achieve the project DQOs in a highly credible manner while balancing the perspectives of regulators, scientists, and stakeholders.

TABLE 3-1
Project Team—CH2M HILL

Name	Project Responsibilities	Contact Information
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TABLE 3-2
Project Team—Principal Investigators

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4.0 Data Quality Objectives

Data Quality Objectives specify the data types, quality, quantity, and uses as needed to make decisions and are the basis for designing data and sample collection activities. This QAPP provides the minimum specifications for data quality and validation required for GSL activities. These minimum standards are designed to provide a common baseline for creating comparable data.

The guidance for establishing DQOs as outlined in the EPA (2000) document should be followed when planning for data collection. Each project must incorporate the seven-step DQO process, as appropriate, using site-specific information as inputs to the DQO process. The seven-step DQO process as outlined in the guidance document is as follows:

- Step 1: State the Problem
- Step 2: Identify the Decision
- Step 3: Identify the Inputs to the Decision
- Step 4: Define the Boundaries of the Study
- Step 5: Develop a Decision Rule
- Step 6: Specify Tolerable Limits on Decision Errors
- Step 7: Optimize the Design for Obtaining Data

The DQOs established for each of the four GSL projects are listed in Appendix A.

5.0 Laboratory Services

Laboratory & Environmental Testing, Incorporated (LET) of Columbia, Missouri will analyze biota (dietary components, bird tissues, and eggs) and sediment samples for selenium for this project. LET will also perform or oversee the Total Organic Carbon (TOC) analysis. Some TOC samples will be analyzed by the Principal Investigators, such as the TOC studies of the stromatolites. Frontier GeoSciences, Inc. (Frontier) of Seattle, Washington will analyze the water samples for total and dissolved selenium. The selenium speciation analyses for the water samples will be performed by Frontier either by calculation or by using Modified EPA 200.8. In the event that Frontier cannot perform the selenium species analyses as required, the analyses may be subcontracted to another qualified laboratory. The University of Utah will develop analytical procedures utilizing Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)/Field Flow Fractionation for selenium determinations as well. After method development has been completed, Method Quality Objectives (MQOs) will be established. Additional analyses may be performed that are not included within this QAPP. In those cases, the principal investigator will define the requirements to meet the project needs and a laboratory will be identified and contract established to meet those needs. If the analysis becomes routinely required, a brief amendment to this QAPP will be created. Laboratory Standard Operating Procedures (SOPs) are included as Appendix B.

5.1 Precision, Accuracy, Representativeness, Completeness, and Comparability

Data collection and analyses for each project will be consistent with the DQOs, which are designed to ensure consistency in data reporting and comparability among sampling site locations, so that spatial and temporal variability in selenium can be adequately evaluated. Reporting limits (RLs) have been established that are low enough to evaluate effects for various environmental media as summarized in Table 5-1. MQOs are included in Table 5-2.

TABLE 5-1
Constituents of Concern, Analytical Methods, and Target Reporting Limits

Analyte	Method	Target Reporting Limits		
		Sediment (mg/Kg)	Water (µg/L)	Biota (mg/Kg)
Total Recoverable Selenium	Hydride Generation AF	--	0.1	
Dissolved Selenium	Hydride Generation AF	--	0.1	--
Inorganic Selenium	Hydride Generation AF		0.1	
Selenate	Calculation or Mod EPA 200.8 w/DRC	--	0.05	--
Selenite	Hydride Generation AF or Mod EPA 200.8 w/DRC	--	0.1(HGAF)/0.05	--
Selenocyanate	Mod EPA 200.8 w/DRC		0.05	
Total Selenium	Hydride Generation AA	0.2	--	0.2
Total Organic Carbon	LECO Carbon Analyzer (LET SOP)	0.2%		

µg = Microgram
AF = Atomic Fluorescence
DRC = Dynamic Reaction Cell
Kg = Kilogram
L = Liter
LET = Laboratory and Environmental Testing
mg = Milligram
SOP = Standard Operating Procedures

5.2 Elements of Quality Control

Laboratory QC checks indicate the state of control that prevailed at the time of sample analysis. Quality control checks that involve field samples, such as matrix spikes (MS) and matrix spike duplicates (MSD), matrix duplicates (MD), and field duplicates, also indicate the presence of matrix effects. Field-originated blanks provide a way to monitor for potential contamination to which field samples are subjected. This QAPP specifies requirements for method blanks, Laboratory Control Samples (LCSs) or reference samples (RSs), and MS/MSDs and MDs that laboratories participating in the data collection effort must follow.

A laboratory QC batch is defined as a method blank (MB), LCS or RS, MS/MSD, or an MD, depending on the method. Each preparation or analytical batch will be identified in such a way as to be able to associate environmental samples with the appropriate laboratory QC samples.

5.2.1 Quality Control Analyses/Parameters Originated by the Laboratory

Method Blank

Blanks are used to monitor each preparation or analytical batch for interference and/or contamination from glassware, reagents, and other potential sources within the laboratory. A method blank is an analyte-free matrix to which all reagents are added in the same amount or proportions as are added to the samples. It is processed through the entire sample preparation and analytical procedures along with the samples in the batch. There will be at least one MB per preparation or analytical batch. If a target analyte is found at a concentration that exceeds the RL, corrective action must be performed to identify and eliminate the contamination source. All

associated samples must be re-prepared and re-analyzed after the contamination source has been eliminated. No analytical data may be corrected for the concentration found in the blank.

Laboratory Control Sample/Reference Sample

The LCS or RS will consist of an analyte-free matrix spiked with a known quantity of the target analyte from a traceable source. Target analytes specified in the QAPP will be spiked into the LCS/RS. Ideally, the spike levels will be less than or equal to the midpoint of the calibration range. If LCS/RS results are outside the specified control limits, corrective action must be taken, including sample re-preparation and re-analysis, if appropriate. If more than one LCS is analyzed in a preparation or analytical batch, the results of all LCS/RSs must be reported. Any LCS/RS recovery outside QC limits affects the accuracy for the entire batch and requires corrective action.

Matrix Spike/Matrix Spike Duplicate

A sample matrix fortified with known quantities of specific compounds is called a matrix spike. It is subjected to the same preparation and analytical procedures as the native sample. Target analytes specified in the QAPP are spiked into the sample. Matrix spike recoveries are used to evaluate the effect of the sample matrix on the recovery of the analytes of interest. An MSD is a second fortified sample matrix. The relative percent difference (RPD) between the results of the duplicate matrix spikes measures the precision of sample results. Ideally, the spike levels will be less than or equal to the mid-point of the calibration range.

Internal Standards

Some methods require the use of internal standards to compensate for losses during analysis. Internal standards are compounds that have similar properties as the analytes of interest, but are not expected to occur naturally in the samples. A measured amount of the internal standard is added to the standards, samples, and QC samples following preparation. When the internal standard results are outside the control limits, corrective action must be taken, including sample re-analysis, if appropriate.

Matrix/Laboratory Sample Duplicate

A sample duplicate selected by the laboratory is called a laboratory sample duplicate or matrix duplicate. It is subjected to the same preparation and analytical procedures as the native sample. The RPD between the results of the native sample and laboratory sample duplicate measures the precision of sample results. The data collected may also yield information regarding whether the sample matrix is heterogeneous.

This QAPP has been designed to maximize the probability that environmental data collected during this program will meet or exceed the DQOs. It provides a systematic approach to data acquisition and management to accomplish the following purposes:

- Ensure that data collection and measurement procedures are standardized among all team participants.
- Monitor the performance of the various measurement systems being used in the program to maintain statistical control and provide rapid feedback, so that corrective measures, if needed, can be taken before data quality is compromised.

- Periodically assess the performance of these measurement systems and their components.
- Verify that reported data are sufficiently precise, accurate, representative, complete, and comparable, so that they are suitable for the intended use.

The data quality criteria for this project consist of qualitative and quantitative indicators, including precision, accuracy, representativeness, completeness, and comparability. Accuracy, precision, and completeness requirements for various indicators are shown in Table 5-2.

5.2.2 Precision

Precision is a measure of reproducibility of analyses under similar conditions. Precision can be defined as the degree of mutual agreement among individual measurements and represents an estimate of random error. Precision values will be calculated by comparing actual sample results with results of replicate analyses (field duplicate and MD QC samples) and Matrix Spikes/Matrix Spike Duplicates (MS/MSDs). Precision values will be expressed in terms of RPD or percent recoveries. MS/MSDs will compromise approximately 5 percent of the sampling effort for each matrix.

5.2.3 Accuracy

Accuracy is the degree of agreement between a measured value and the "true" or expected value. As such, it represents an estimate of total error from a single measurement, including both systematic error ("bias") and random error that may reflect variability due to imprecision. Accuracy is expressed in terms of percent recoveries determined from results of MS/MSDs and LCSs, and evaluation of continuing calibration verification information.

5.2.4 Representativeness

Representativeness is the degree to which sample data accurately expresses the characteristics of a population of samples, parameter variations at a sampling point, or an environmental condition. It is a qualitative parameter that is achieved through proper sampling program design and use of appropriate sampling strategies and techniques. For example, holding time requirements for different types of samples affect the representativeness of conditions at the site at the time the samples were collected. The use of QC samples that are similar in composition to samples being measured provides a means of estimating precision and accuracy that are representative of sample measurements. Factors that impact representativeness include site homogeneity, sample homogeneity at a single point, and available information around which the sampling program was designed. This sampling program has been designed to maximize representativeness through the process of selecting sample locations and inclusion of field duplicate samples at a frequency goal of 5 percent of the samples.

TABLE 5-2
Method Quality Objectives for Analytical Methods

Hydride Generation AA - Selenium by LET SOP		Frequency	Criteria	Corrective Action
Calibration	Minimum four points (instrument blank should be included)	Daily prior to analyses	r > 0.995	1) Evaluate system and take corrective action. 2) Recalibrate, if appropriate.
	Initial Calibration Verification (ICV)	After calibration	Response for any analyte within ± 20% of predicted response	1) Evaluate system and take corrective action. 2) Repeat calibration.
	Initial Calibration Blank (ICB)	Immediately after each initial calibration curve	< RL	1) Appropriate corrective actions taken including investigating source of contamination. 2) Repeat blank analysis and re-analyze all samples associated with this blank. 3) Indicate sample results associated with blank contamination in the case narrative.
	Continuing Calibration Verification (CCV)	Immediately following initial calibration curve, every 10 analyses, and at the end of the analytical sequence	Response for any analyte within ± 10% of predicted response	1) Evaluate system and take corrective action. 2) Re-analyze CCV once. 3) If source problem cannot be determined, a new calibration curve must be generated and all samples re-analyzed back to the last successful CCV.
	Continuing Calibration Blank (CCB)	Every 10 analyses and at the end of the analytical run (to be done immediately after each CCV)	< RL	1) Appropriate corrective action taken including investigating source of contamination. 2) Repeat blank analysis and re-analyze all samples back to the last passing CCB. 3) Indicate sample results associated with blank contamination.
Quality Control	Method Blank (MB)	One per sample batch	< RL for all target analytes	1) Appropriate corrective action taken including investigating source of contamination. 2) Re-prepare and re-analyze MB. 3) If MB fails again, then re-prepare and re-analyze samples associated with MB.
	Matrix Spike (MS) and Matrix Duplicate (MD)	One of each per sample batch, or at least 5 percent of samples	%R in MS = 80-120; At >10x MDL, RPD for MD = ≤ 20% At <10x MDL, [MD result-sample result] = < 2x MDL	1) Check calculations. 2) Check LCS, if recoveries are within limits, flag all associated data as attributable to matrix effects.
	Reference Sample (RS)	One per sample batch	One of the following must be met if the result is greater than 10 times the MDL: 1) Be within two standard deviation of the mean 2) Be within ±20 % of the mean 3) Be within two times the MDL of the mean	1) Review recent RS data for trend. 2) If trend is observed, locate and correct problem. 3) Re-analyze RS. 4) If RS fails again, re-digest and re-analyze all samples within the batch.
Hydride Generation AF - Selenium by SOP FGS-055.3.1		**Frequency**	**Criteria**	**Corrective Action**
Calibration	Initial calibration A minimum 5-points calibration curve	Before initial sample analysis, every 24 hours, whenever analytical system modifications are made, or when continuing calibration verification fails.	Correlation coefficient of linear regression is ≥ 0.995.	Correct problem and repeat initial calibration.
	Initial calibration blank (ICB) and continuing calibration blanks (CCBs)	The ICB, immediately following the initial calibration verification. CCBs must be performed every 10 analytical runs (a run being one bubbler) and at the end of the analysis sequence.	Mean < 0.050 µg/L	Correct problem and repeat initial calibration.
	Continuing calibration verification (CCV)	One CCV must be performed every 10 analytical runs and at the end of the analysis sequence.	%R = 80%-120%	If a CCV fails, we investigate, correct the problem, prove the instrument performance and continue with analysis. If problem cannot be corrected, analysis is halted and all samples from last good CCV are re-analyzed.
	Initial calibration verification (ICV); must be from second source (Selenomethionine or NIST 1640)	The ICV, immediately following each initial calibration.	%R = 80%-120%	Correct problem and repeat initial calibration.

TABLE 5-2 (CONTINUED)
Method Quality Objectives for Analytical Methods

Trace Metals by ICP-MS w/DRC		Frequency	Criteria	Corrective Action
Calibration	Calibration Standards	Daily, prior to sample analysis	r ≥ 0.995; 1st standard ≤ PQL	1) Re-analyze suspect calibration standard. 2) If criteria are still not met, then re-prepare standards and recalibrate the instrument.
	Internal Standards (IS)	Each standard, blank, and sample is spiked with IS	%R = 50-150 compared to calibration blank	1) If the responses of the internal standards in the following CCB are within the limit, re-run the sample at an additional 2x dilution. 2) If not, then samples must be re-analyzed on a new calibration.
	Check Calibration Verification (CV)	At beginning and end and 1 per 10 sample preparations	%R = 80-120	1) Halt analysis, correct problem, recalibrate, and re-analyze affected samples.
	Independent Calibration Verification (ICV)	1 following instrument calibration	%R = 90-110	1) Correct problem prior to continuing analysis; recalibrate if necessary.
Quality Control	Method Blank (MB)	Minimum of 3 per batch	Mean ≤ RL Standard Deviation ≤ MDL	1) All samples associated with contaminated MBs must be re-analyzed.
	Matrix Duplicate (MD)	A laboratory MD must be performed for every 20 samples	RPD ≤ 20% or results within 2x PQL if < 5x PQL	1) If RPD criteria not met, then sample may be re-prepared and re-analyzed, but this is not required (sample matrix may be heterogeneous). 2) A post-digestion duplicate (PDD) can be analyzed to evaluate instrument precision.
	Matrix Spike/Matrix Spike Duplicate (MS/MSD)	One MS/MSD pair must be analyzed for every 20 samples in the laboratory analytical batch	%R = 80-120 RPD ≤20%	1) If RPD > 20%, results may be qualified. 2) If RPD criteria not met, then sample may be re-prepared and re-analyzed, but this is not required (sample matrix may be heterogeneous). 3) A post-digestion spike (PS) and post-digestion spike duplicate (PSD) can be analyzed to evaluate instrument accuracy and precision, and also to determine if matrix interference is occurring at the prep stage or at the analytical stage. 4) A method of standard additions curve may be prepared and analyzed along with the samples to quantify and correct for interference.
	Laboratory Control Sample (or Laboratory Fortified Blank (LFB)/ Blank Spike)	Minimum of 1 per batch	%R = 80-120	1) If LFB recovery is outside of the control limit, then batch must be re-prepared and re-analyzed.
	Certified Reference Material (CRM)	Must be matrix matched to samples; minimum of 1 per batch	%R = 70-130, unless limits set by CRM manufacturer are greater	1) If CRM true value is ≥5 x the RL and if the recovery is outside of the control limit, then batch must be re-prepared and re-analyzed.
Total Organic Carbon (LET SOP)		**Frequency**	**Criteria**	**Corrective Action**
Calibration	Check Calibration Verification (CV)	At beginning and end and 1 per 10 sample preparations	%R = 80-120	1) Halt analysis, correct problem, recalibrate, and re-analyze affected samples.
Quality Control	Method Blank (MB)	Minimum of 3 per batch	≤RL	1) All samples associated with contaminated MBs must be re-analyzed.
	Laboratory Control Sample (or Laboratory Fortified Blank/ Blank Spike)	Minimum of 1 per batch	%R = 70-130	1) If LFB recovery is outside of the control limit, then batch must be re-prepared and re-analyzed.
	Matrix Duplicate (MD)	A laboratory MD must be performed for every 20 samples.	RPD ≤ 20% or results within 2x PQL if < 5x PQL	1) If RPD criteria not met, then sample may be re-prepared and re-analyzed, but this is not required (sample matrix may be heterogeneous).

Notes

µg = Microgram
AA = Atomic Absorption
AF = Atomic Fluorescence
CCB = Continuing Calibration Blank
CCV = Continuing Calibration Verification
CRM = Certified Reference Material
CV = Calibration Verification
DRC = Dynamic Reaction Cell
ICB = Initial Calibration Blank
ICP-MS = Inductively Coupled Plasma - Mass Spectrometry
ICV = Independent Calibration Verification
IS = Internal Standard
L = Liter
LET = Laboratory & Environmental Testing, Incorporated
LFB = Laboratory Fortified Blank
MB = Method Blank
MD = Matrix Duplicate
MDL = Method Detection Limit
MS = Matrix Spike
MSD = Matrix Spike Duplicate
PDD = Post-Digestion Duplicate
PQL = Practical Quantitation Limit
PS = Post-Digestion Spike
PSD = Post-Digestion Spike Duplicate
R = Recovery
RL = Reporting Limit
RPD = Relative Percent Difference
RS = Reference Sample
RSD = Relative Standard Deviation
SOP = Standard Operating Procedure

5.2.5 Completeness

Completeness can be defined both qualitatively and quantitatively. Qualitative completeness is determined as a function of all factors that contribute to sampling. Quantitative completeness is calculated as the percentage of measurements that are judged to be valid compared to the total number of measurements planned. Effectively, it measures the amount of data available for valid measurement compared to the amount that was lost or destroyed. For this investigation, a completeness factor of 90 percent for all matrices is established, and is strictly defined as the ratio of the number of usable data points (not flagged "R" indicating the result has been rejected) over the possible number of data points, by method/matrix.

5.2.6 Comparability

Comparability is a qualitative indicator of the confidence with which one data set can be compared to another. Confidence is achieved by maintaining standard techniques and procedures for collecting and analyzing representative samples and reporting the analytical results in standard units. Standard EPA methods are used for the analytical chemistry throughout this program unless laboratory-specific methods can be shown to provide equivalent or better results.

5.3 Method Detection Limits, Reporting Limits, and Instrument Calibration Requirements

5.3.1 Method Detection Limits

The Code of Federal Regulations (40 CFR 136) defines method detection limit (MDL) as the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte.

The appropriate analytical laboratory will calculate and report an MDL for each analyte of interest in each matrix (i.e., water, sediment, tissue) before analyzing field samples. The laboratory will calculate the MDLs statistically, based on instrument performance, at least once annually for each analytical method employed as required under 40 CFR 136. Ideally, the RLs will be at least two times the calculated MDL to assure that the quantification of detected compounds is valid.

The laboratories may select to establish sensitivity using a standard other than 40 CFR 136. Exceptions to the MDL requirement will be evaluated by the project team and will approve any changes.

5.3.2 Reporting Limits

Only those data that result in quantification within the demonstrated working calibration range may be reported by the laboratory. Quantification based on extrapolation is not acceptable to report. If samples are outside the calibration range, they must be diluted or concentrated, as necessary, and analyzed again. Reporting limits are driven by the DQOs and ideally are at least two times the calculated MDL. The laboratory may report data

between the MDL established in accordance with Section 5.3.1 and the reporting limits provided in Table 5-1.

5.3.3 Instrument Calibration

The laboratory instruments will be appropriately calibrated by qualified personnel before the analysis of each sample batch. The frequency and quality criteria for calibration under EPA guidance depend on the analytical methods being performed. All calibrations also must meet method time requirements. Requirements for initial and continuing instrument calibration are specified in Table 5-2.

5.4 Elements of Quality Control

Internal QC checks are used to determine if analysis is "in control" (batch QC), as well as the effect of the sample matrix, if any, on data generated (matrix QC). The QC parameters include MBs, LCS, and MS/MSDs. Table 5-2 presents QC limits for MBs, LCSs, MDs, and MS/MSDs.

5.4.1 Method Blank

Laboratory pure water serves as an MB (also called laboratory reagent blank) to monitor each analytical batch for interference and for contamination from glassware, reagents, and other potential contaminants generated within the laboratory. The MB is processed through the entire analytical procedure along with each sample batch during the sample preparation period. One MB per sample batch is analyzed, and if the concentration is greater than the RL or is equal to or greater than three times the MDL for one or more analytes, a corrective action is triggered to identify and eliminate contamination sources.

5.4.2 Laboratory Control Sample

Internal control samples are used as a reference to assess accuracy of an analysis. The LCS for this project will consist of reagent water or cleaned sand spiked with a known amount of analyte that comes from a separate source than that used to establish calibration standards. If LCS results exceed the specified control limits, corrective procedures must be implemented.

5.4.3 Matrix Spike/Matrix Spike Duplicate

A sample matrix fortified with known quantities of specific compounds is called a matrix spike. It is subjected to the same analytical procedures as the samples of interest to evaluate the effect of the sample matrix on the recovery of the compound of interest. In other words, the MS is used to estimate the analytical precision of the method. An MSD is a second laboratory fortified sample matrix that also is used to determine analytical precision.

Recovery data for these fortified compounds will be used to determine the existence of matrix effects samples analyzed during the project. Low recovery rates might result from matrix interferences or might relate to instrument response, which could be checked using a calibration standard. Spiked sample results that exceed the control limits will be subject to evaluation of both calculations and instruments, followed by corrective action.

5.4.4 Matrix Duplicate

A matrix duplicate is a laboratory duplicate sample that is a separate aliquot of the original sample, which is taken through the same digestion and analysis procedures as the original sample. It is similar to a field duplicate except that the duplicate is not 'blind' to the laboratory. These samples can be used to determine analytical precision by determining the absolute difference between the matrix duplicate result and the sample result or the RPD.

5.4.5 Equipment Blank

Equipment blanks are processed by rinsing decontaminated sampling equipment with American Society for Testing and Materials Type II/deionized water. The rinse water is collected in sample bottles, preserved, and handled the same as the samples. Frequency of sample collection is once for each sampling apparatus during each event.

5.4.6 Field Duplicates/Replicates

Field duplicates provide yet another means of maintaining quality control by measuring the precision of the sampling process. The laboratory will not be given the identity of the duplicates, but the QA reviewer will receive source information to aid in data review and validation. At a minimum, abiotic and biotic media samples will be collected at 5 percent frequency.

6.0 Quality Control Procedures

6.1 Holding Time Compliance

All sample preparation and analysis shall be completed within the method-required holding times. The holding time for a sample begins at the time of sample collection. The preparation holding time is calculated from the time of sample collection to the time of completion of the sample preparation process as described in the applicable method, before any volume reduction procedures. If no preparation is required, the analysis holding time is calculated from the time of sample collection to the time of completion of all analytical runs, including dilutions and any required re-analysis. In methods requiring sample preparation before analysis, the analysis holding time is calculated from the time of preparation completion to the time of completion of all analytical runs, including dilutions and any required re-analysis. Holding times are determined on the basis of days, hours, and minutes. If the time of the sample collection is not provided, the laboratory must assume the most conservative (i.e., earliest) time of day.

If holding times are exceeded and the analyses are performed, the results shall be flagged accordingly and identified in the data package case narrative. Table 6-1 provides holding time and preservation requirements for the methods covered by this QAPP.

TABLE 6-1
Holding Time and Preservation Requirements

Analyte	Method	Matrix	Holding Time	Container	Minimum Sample Volume	Preservation
Total Selenium	Hydride Generation AA	Sediment	180 days	250 mL wide-mouth glass jar	250 mL	Cool 4°C in field ideally no longer than a week; long term store frozen or freeze dry
Total Selenium	Hydride Generation AA	Biota	180 days	250 mL wide-mouth glass/nalgene jar	500 mg (dry)	Cool 4°C in field; store frozen
Total Recoverable Selenium	Hydride Generation AF	Water	180 days	1 liter glass or HDPE bottle	250 mL	HNO_3 to pH < 2
Dissolved Selenium	Hydride Generation AF	Water	180 days Field Filtered/24 hours lab filter-180 days	1 liter glass or HDPE bottle	250 mL	HNO_3 to pH < 2 after filtration
Selenite	Hydride Generation AF	Water	180 days Field Filtered/24 hours lab filter-180 days	1 liter glass or HDPE bottle	250 mL	HNO_3 to pH < 2 after filtration
Total Organic Carbon	Loss on Ignition	Sediment	28 days	250 mL wide-mouth glass/nalgene jar	25 grams	Cool 4°C

AA=Atomic Absorption AF=Atomic Fluorescence °C=degrees Celsius HDPE=High-density Polyethylene
HNO_3=Nitric Acid mL=Milliliter mg = Milligram

6.2 Chain-of-Custody

Collecting data of known quality begins at the point of sample collection. These procedures are outlined in the following sections and must be followed to preserve and ensure the integrity of all samples from the time of collection through analysis. Sample custody records must be maintained both in the field and in the subcontractor laboratory. A sample is considered to be in someone's custody if it is either in his or her physical possession or view, locked up, or kept in a secured and restricted area. Until shipment, sample custody will be the responsibility of the sampling team leader.

Chain-of-custody records document sample collection and shipment to the laboratory. A chain-of-custody form will be completed for each sampling event. The original copy will be provided to the laboratory with the sample shipping cooler, and a copy will be retained in the field documentation files. The chain-of-custody form will identify the contents of each shipment and maintain the custodial integrity of the samples. All chain-of-custody forms will be signed and dated by the responsible sampling team personnel. The "relinquished by" box will be signed by the responsible sampling team personnel, and the date, time, and air bill number will be noted on the chain-of-custody (COC) form. The laboratory will return the executed copy of the COC with the hardcopy report.

At a minimum, the COC form must contain:

- Site name
- Project Manager's name, telephone number, and fax number
- Unique sample identification
- Date and time of sample collection
- Source of sample (including name, location, sample type, and matrix)
- Number of containers
- Designation of MS/MSD
- Preservative used
- Analyses required
- Name of sampler
- Custody transfer signatures and dates and times of sample transfer from the field to transporters and to the laboratories
- Bill of lading or transporter tracking number (if applicable)
- Lab name, address, and contact information
- Any special instructions

Erroneous entries on COC records will be corrected by drawing a line through the error and entering the corrected information. The person performing the correction will date and initial each change made on the COC form.

6.3 Sample Packaging and Transport

The following sections contain guidelines for sample packaging and transport.

6.3.1 Sample Container Preparation

- The labels will be secured to each container with clear tape, if not previously done.
- Container lids will be checked for tightness, and if the container is not full, the outside of the container will be marked with indelible ink at the sample volume level.
- Sample bottles will be double-bagged in heavy-duty plastic. Glass containers will be covered with bubble wrap to prevent breakage.

6.3.2 Shipping Cooler Preparation

- All previous labels used on the sample-shipping cooler will be removed.
- The drain plugs will be sealed to prevent melting ice from leaking.
- A cushioning layer of packing material such as bubble wrap will be placed at the bottom of the cooler (approximately 1-inch thick) to prevent breakage during shipment.
- All ice will be double-bagged in a zip-locked plastic bag. If samples are shipped frozen with dry ice, the proper paperwork from the shipping carrier will be followed.

6.3.3 Placing Samples in the Cooler

- The COC form will be placed in a zip-locked bag.
- Samples will be placed in an upright position in the cooler.
- Ice will be placed on top of samples and between samples. Ideally, ice will be placed in resealable plastic bags in duplicate to minimize leakage of ice melt into the cooler.
- Void space between samples will be filled with packing material.

6.3.4 Closing the Cooler

- The cooler lid will be taped with strapping tape, encircling the cooler several times.
- Custody seals may also be affixed to the cooler lid to further ensure the integrity of the samples.

6.3.5 Transport

- Sample coolers will be transported to the laboratory (an overnight courier may be used) as soon after sample collection as possible.
- The laboratory will be notified that samples are being shipped.

6.3.6 Sample Receipt

The laboratory will designate a sample custodian who will log in samples using a standardized Sample Receipt Form. The custody seal will be inspected to verify that it is intact, and the sample custodian will then check the condition of samples and verify custody records. If present within the container, ice will be noted, and temperature recorded. Any breakage, leakage, or other damage will be noted and recorded. The sample custodian will record all tracking information and pass it to the data librarian and the laboratory project manager. All of this information will appear on the Sample Receipt Form. If discrepancies are noted between the COC report and the actual contents of the container, these will immediately be reported to the contractor, who will in turn report to the CH2M HILL project manager. Along with sample receipt documentation, the following information will be documented on the Sample Receipt Form by the sample custodian:

- Date Samples received
- Contractor sample identification number
- Laboratory sample identification number
- Analytical tests requested for each sample batch
- Sample matrix
- Number of samples in the batch
- Container description and location in the laboratory

After being logged in, the samples will be refrigerated or frozen as appropriate. The laboratory must have formally documented procedures for sample holding and storage, and laboratory personnel will know the required sample holding times and preservation conditions. If samples are not extracted or analyzed within the required holding time for the appropriate method, the contractor project manager will be advised of the problem, and the contractor will immediately notify the CH2M HILL project manager for guidance on corrective action. All corrective actions must be fully documented. After confirmation by the CH2M HILL project manager, samples with expired holding times will be discarded.

6.3.7 Sample Dilutions

Dilution of the samples results in elevated reporting limits and ultimately affects the usability of the data as it pertains to decision making processes related to potential actions at the sampling site. It is important to minimize dilutions and maintain the lowest possible reporting limits. When dilutions are necessary due to high concentrations of target analytes, lesser dilutions should also be reported to fully characterize the sample for each analyte. The level of the lesser dilution that provides the lowest possible reporting limits without having a lasting deleterious effect on the analytical instrument is preferred.

7.0 Deliverables

The laboratory that will perform analyses must have established procedures to conduct data reduction, review, and reporting. Laboratory-specific procedures are evaluated during technical systems audits to ensure that the process steps discussed in this section are properly performed.

The primary analyst(s) will be responsible for review of their work as their work is being performed and for applying the measurement qualifiers (i.e., laboratory qualifier flags) based on the DQOs. During this process, a case narrative or QC exception report will be generated documenting nonconformance issues and resolutions. A designated peer reviewer, defined as a qualified staff member who is not the primary analyst, will perform an independent review to determine that project specifications have been met. The Laboratory Manager or designee will be responsible for final approval of the laboratory analytical report prior to sending the report to project staff. All raw data will be archived in confidential laboratory files.

Most laboratories use a Laboratory Information Management System to store, transfer, and report analytical data. These files must also undergo a QC check to verify that results are complete and correct. The laboratory is responsible for generating hard copies (i.e., final analytical report) and electronic files of the analytical results in standard formats needed by the project staff. The specific information and electronic file formats are established and tested before analysis of any samples to ensure that the formats will be compatible with the project database, and that all required information is reported.

The hard copy and electronic laboratory reports for all samples and analyses will contain the information necessary to perform data evaluation. The following information is typically included for each preparation batch (when applicable) and each analytical batch:

- Field ID number
- Date received
- Date prepared
- Date analyzed
- Method
- Results for each analyte
- Sample-specific reporting limit
- Units
- Laboratory qualifier flags, also called measurement qualifiers, for all data that do not meet project QC specifications
- Narrative

- Matrix spike and laboratory control spike concentrations
- Matrix spike and laboratory control spike results
- Matrix spike and laboratory control spike recoveries and RPDs
- Method blank results
- Initial and continuing calibration verification results (hard copy only)
- Initial and continuing calibration verification recoveries (hard copy only)
- Analytical batch number
- Preparation batch number
- Analytical sequence or laboratory run log that contains sufficient information to correlate samples reported in the summary results to the associated method QC information, such as initial and continuing calibration analyses.
- Confirmation results
- Calibration blank results for inorganic analyses (required in hardcopy format only)
- ICP interference check sample true and measured concentrations and percent recoveries (required in hardcopy format only)
- Method of standard addition results (if applicable; required in hardcopy format only)
- Post-digestion spike recoveries (if applicable; required in hardcopy format only)
- Internal standard recovery and retention time information, as applicable
- Instrument Tuning and mass calibration information for gas chromatography/mass spectrometry and ICP-MS analyses
- Any other method-specific QC sample results

Complete documentation of sample preparation and analysis and associated QC information will be maintained by the laboratory for all project samples in a manner that allows easy retrieval in the event that additional validation or more information is required.

Data flow from the laboratory and field to the project staff and data users follows established procedures to ensure that data are properly tracked, reviewed, and validated for use. The field data are generally entered into a computer master log and COC forms are generated for submittal to the laboratory with the samples. The field data are verified by the data management task leader after entry by comparison with field data sheets and notebooks. Field data are transferred to the project database by downloading the electronic master log files daily.

The electronic analytical data from the laboratory are submitted with hard-copy reports and uploaded to the project database by using a set of programs to read, check, and match the analytical results to the field data in the database. The electronic results are reviewed by project staff to ensure accurate reporting and adherence to project specifications. Ten

percent of all electronic results will be reviewed for correct sample identification, dates, sample-specific detection limits, flags, and agreement between the hard copy and electronic data. If systematic errors or frequent occurrence of random errors are observed, a successively higher percentage of reports will be reviewed. After the analytical reports are used to verify the electronic transfer process, they are permanently stored in project files.

8.0 Sampling Procedures

8.1 Field Sampling

Environmental samples will be collected directly into pre-cleaned containers provided by the laboratory when appropriate. Sampling procedures will adhere to EPA-recommended preservation requirements for each parameter of interest. Use of proper containers and preservation methods will retain sample integrity. Containers and preservatives will generally be provided by the laboratory that will be completing the analytical testing, but will also be purchased in some cases by the project team.

Holding time compliance and proper sampling preservation begin during field sampling. Temperature control and pH adjustment are the most common preservation techniques. Field personnel who will conduct sampling for this project will be thoroughly trained in proper use of sample collection gear and acceptable sampling procedures.

The following sample procedures have been included in Appendix C:

- Avian egg harvest, embryo examination, and shell thickness determination with intent to save contents for chemical analysis
- Sampling protocol for total and dissolved water samples from GSL (includes equipment decontamination procedures)
- Sediment sample procedure
- Brine fly and brine shrimp sampling procedures
- Selenium vapor sampling procedures

8.2 Sample Handling and Custody

Field sampling personnel will maintain a daily, waterproof field notebook. The field notebook will contain the following information:

- Date and time sampling began
- Name of sampling personnel
- Location of sampling station (i.e., name/number and Global Positioning System coordinates)
- Station description
- Type of sampling and equipment used
- Field observations (e.g., weather, depth of water, condition of water, other relevant conditions)

- Number of grabs made and amount of sample taken
- Types of analyses to be performed
- Physical properties of water (conductivity, temperature, dissolved oxygen, and pH)

As required by the project manager, additional information will be recorded in the field notebook.

Samples will be transported to the laboratory, as appropriate based on media, with proper COC records for each sample. For example, water samples will be shipped within 24 hours of collection while sediment and biota may be shipped after each sampling event provided the samples are properly preserved and stored. Each person who releases a set of samples will sign and date the COC form and require the receiver to sign and date the form. Each will keep a copy of the signed form. Each form will consist of a record of all samples taken from each station. Each form will include the sample ID number, location, and date collected.

Field sampling personnel will attach labels to the outside and/or inside of the sample containers. Labels will include the following information:

- Sample ID number
- Collection station number/Station name
- Date samples collected (added in field)
- Matrix (coded as to sediment, water, or biota type)
- Time samples collected (added in field)
- Initials of sampling team (added in field)

The label should then be covered with a layer of clear packing tape to protect it.

9.0 Data Validation

Data validation will be performed on **all** of the analytical data using level 2, 3, or 4 procedures as defined below. The initial data packages for each laboratory/matrix/method combination will be reviewed following level 4 protocols. A tiered approach for data validation on the remaining data will be performed based upon the findings of the initial data validation.

Level 2 data validation consists of reviewing the following items:

- A review of the data set narrative to identify any issues that the lab reported in the data deliverable
- A check of sample integrity (sample collection, preservation, and holding times)
- An evaluation of basic QC measurements used to assess the accuracy, precision, and representativeness of data, including QC blanks, LCSs, MS/MSD, and field or laboratory duplicate results
- A review of sample results and detection limits to verify that project analytical requirements are met
- Initiation of corrective actions, as necessary, based on the data review findings
- Qualification of the data using appropriate qualifier flags, as necessary, to reflect data usability limitations

Level 3 validation procedures also will include reviewing the evaluation of calibration and QC summary results against the project requirements and other method-specific QC requirements.

Level 4 validation procedures will include reviewing sample raw data and verification of analyte identification and calculations for at least 10 percent of the data:

- Data validation qualifiers can be electronically applied to the data, either directly or through upload to the DMS from a spreadsheet or equivalent
- The laboratory selected can produce a data package that contains the necessary information to perform data validation in a logical, well-organized manner
- An initial data quality assessment report after the level 4 data validation is completed will be provided outlining the recommendations for the review of the remaining data
- A final data quality assessment report will be prepared after 2006 data collection activities are completed

TABLE 9-1
Flagging Conventions - Minimum Data Evaluation Criteria for Inorganic Metals Methods

Quality Control Check	Evaluation	Flag	Results Qualified	Samples Affected
Holding Time	Holding time exceeded for analysis	J	detects	Sample only
		UJ	non detects	
	Holding time exceeded by a factor of two	R	non detects	
Sample Preservation	Sample preservation requirements not met (sample preservation may be adjusted at the laboratory with no flagging required)	J	detects	Sample
		UJ	non detects	
Temperature Blank	> 6 degrees C	J	detects	Samples in same cooler
		UJ	non detects	
Calibration Verification: ICV, CCV	%R > UT	J	detects	All associated samples in analysis batch
	%R < LT	J	detects	
		UJ	non detects	
Interference Check Sample	%R > UT	J	detects	All associated samples in analytical batch
	%R < LT	J	detects	
		UJ	non detects	
Laboratory Control Sample	%R > UT	J	detects	All samples in digestion batch
	%R < LT	J	detects	
		UJ	non detects	
Blanks: MB, ICB, CCB	Multiply highest blank concentration by 5	U	flag detected results < calculated values	All samples in digestion batch (MB); all samples in analysis batch (ICB, CCB)
Equipment Blank	Multiply highest blank concentration by 5	U	flag detected results < calculated values	All samples, same field team, matrix, and date

TABLE 9-1
Flagging Conventions - Minimum Data Evaluation Criteria for Inorganic Metals Methods

Quality Control Check	Evaluation	Flag	Results Qualified	Samples Affected
Matrix Spikes	%R > UT	J	detects	All samples from same site as parent sample
	%R < LT	J	detects	
		UJ	non detects	
	RPD > UT	J	detects	
Laboratory Duplicates (including MDs)	One or both sample results < 5 times the RL and a difference of ± RL for water not met	J	detects	All samples in digestion batch
	Concentration of reported analyte > 10 times MDL in either sample and RPD > UT	J	detects	
	Concentration of reported analyte < 10 times MDL in either sample and absolute difference > 2 x RL	J	detects	
Serial Dilution	If concentration is > 25 time MDL and % difference > UT	J	detects	All samples from same site as parent sample if analytical spike not performed
		UJ	non detects	
Field Duplicates	Concentration of reported analytes are > 5 times the RL in either sample and RPD > UT (35% for sediment)	J	detects	Field duplicate pair
	One or both sample results < 5 times the RL and a difference of a ± 2 times RL for water (± 4 times for soil)	J	detects	
		UJ	non detects	

Notes
Spike recovery limits do not apply when sample concentration exceeds the spike concentration by a factor of 4 or more.

%R = Percent Recovery
CCB = Continuing Calibration Blank
CCV = Continuing Calibration Verification
ICB = Initial Calibration Blank
ICV = Initial Calibration Verification
LT = Lower Tolerance
MB = Method Blank
MD = Matrix Duplicate
MDL = Method Detection Limit
MSA = Method of Standard Addition
RL = Reporting Limit
RPD = Relative Percent Difference
UT = Upper Tolerance

TABLE 9-2
Qualifier Flag Definitions

Flag	Definition
J	Analyte was present but reported value may not be accurate or precise, value is estimated
R	This result has been rejected
U	This analyte was analyzed for but not detected at the specified DL
UJ	This analyte was not detected above the reported PQL but the reported PQL is approximate and may not represent actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

Notes
DL = Detection Limit
PQL = Practical Quantitation Limit

The QA/QC staff conducting data evaluation is responsible for ensuring data qualifier flags are assigned as needed based on the established QC criteria, and any limitations are communicated to the data users. These data qualifier flags are not related to any flags that may be assigned by the laboratory. Data qualifier flags explain the type and extent of limitation placed on a result, while laboratory flags identify QC results that are outside laboratory tolerances and may or may not lead to subsequent data qualifiers assigned during data evaluation. The QA/QC staff is also responsible for initiating corrective actions for analytical or other problems identified during the data evaluation process. Corrective actions range from verifying that the method was in statistical control during the analytical runs, to re-analysis of the sample or resampling or reissuing the laboratory report for clerical errors.

9.1 Chemical Blank Data Evaluation

Blank results indicate whether any reported analytes may be attributed to laboratory sources (instrument, reagents, glassware, etc.) or field sources or conditions (equipment, shipping, etc.) rather than the sampled media. Laboratory blanks include method and/or system blanks in each analytical batch. Equipment blanks are field blanks that are collected at specified frequencies or under selected conditions to monitor contamination from non-laboratory sources.

Equipment or field blank results are evaluated individually, related to the field samples. The probable contamination source is identified and associated sample results are qualified as necessary based on the relative concentrations between the blank and sample. For example, if equipment blank results show contamination and the sample collected from the sampling equipment rinseate shows the same analyte at concentrations attributable to blank concentrations, the sample results are “U” flagged to indicate they should be considered nondetect. Samples collected before and after the blank are also evaluated to determine the potential sources and impacts of carryover.

9.2 Chemical Accuracy

Accuracy is associated with correctness and is a comparison between a measured value and a known or expected value. Accuracy is assessed by comparing LCS, MS, and performance evaluation (PE) sample recoveries with the project objectives as well as manufacturer's tolerances on commercially purchased PE samples.

9.3 Laboratory Control Samples

Laboratory control samples are spikes of method analytes in reagent-grade water (or may be commercially purchased solid LCSs). The LCSs are taken through sample preparation and analysis to assess statistical control of method. If recovery is outside the established tolerances, samples from the same preparation and/or analytical batch may exhibit similar analyte recoveries and should be qualified. Any non-detected sample results associated with low LCS recoveries (after the duplicate has been analyzed with the same result) indicate a potential false negative and may be flagged as estimated. The system must be assessed to determine the reason for out-of-tolerance occurrence, and corrective action may be indicated, up to and including re-extraction and re-analysis (if still within holding time) or resampling of affected samples.

9.4 Matrix Spikes

Matrix spike results are assessed by comparison with the recovery ranges presented in this QAPP. If MS recoveries are outside this range, two conditions must be evaluated:

- The spike concentration relative to the parent sample concentration; and
- The associated LCS recovery.

If the parent sample concentration is greater than four times the spike concentration, the spike concentration is considered insignificant, relative to sample dilution and /or analytical variability. Since the recovery does not represent the ability to recover the analyte from the matrix, it is generally not calculated, or at least should not be used to qualify data.

If MS and/or MSD recovery is outside the range cited and the associated LCS is within specification, matrix interference is demonstrated and sample results are qualified as estimates or rejected if recoveries are extremely high or low. If systematic matrix interference is exhibited, similar sample results such as those from the same site or lithology must be evaluated. The reviewer's judgment is used to determine if the results should be qualified.

The qualified data are discussed in the sampling task QC report, and specific limitations such as poor or enhanced recovery for specific analytes is discussed. Further investigation or corrective action may be taken to find methods to reduce interferences.

9.5 Precision

Precision is a measure of variability between duplicate analyses and is calculated for field and laboratory duplicates. Precision is evaluated by comparing the RPD of MS/MSDs, matrix duplicates, and field duplicate samples with RPD objectives stated in Table 5-2.

If field duplicate RPDs exceed the objective, the analytical results for the samples collected by the sampling team, from the same equipment, from the same site, from similar matrices, or on the same day may be affected. Close evaluation of the results should indicate the most likely source variability, and the corresponding samples are qualified as warranted.

If all analytical specification are satisfied and sampling error is not suspected, the field duplicate results indicate the variability of the matrix. The field duplicate objectives should be used to initiate further evaluation, but are not expected to control the analysis or field conditions. Estimated qualifier flags may be assigned for samples or matrices with high field duplicate RPDs to indicate sample heterogeneity or high matrix variability rather than a data quality problem.

An average RPD may be calculated and reported as a measure of overall analytical precision or matrix variability for methods and analytes with many duplicate samples or analyses.

9.6 Completeness

Completeness is calculated for each method and matrix after the QC data have been evaluated and data qualifiers assigned.

10.0 Data Management

Data management entails storing, handling, accessing, and securing data collected during the project. Data gathered during this project will be consolidated and compiled into a project database that can be used to support project data reporting. The following sections describe the project's data management process and associated project staff responsibilities.

10.1 Team Organization and Responsibilities

The following are the team members and overview of their responsibilities for the data management process:

- **Principal Investigators/Project Manager—**ensure that the project team properly collects, documents, and implements the plan to ensure that all data collected are properly managed.
- **Project Chemist/Project Advisors —** oversee sample tracking, data management process that includes upload into the project database, data validation, and provide guidance on the preparation and review of required data tables.

10.2 Sample Tracking

The project chemist is responsible for tracking samples and deliverables to ensure that the analytical results for all samples sent for analysis are received. The Principal Investigators will assign someone from their respective sampling teams to send the project chemist COCs of samples to initiate the sample tracking process.

10.3 Data Tracking and Management

CH2M HILL will maintain a project tracking system for each COC/laboratory sample delivery group collected. The data will be tracked from collection through completion and review of the data verification/validation process.

10.4 Data Collected in the Field

Sample location coordinates, depths, procedures used to collect the sample, field measurements (as applicable for each project), and any other data collected will be provided by the Principal Investigators for incorporation into the database. Ideally these data will be transferred in an electronic format, but may also be in hardcopy format. All field data submitted for inclusion into the database will undergo a technical review prior to submission by the Principal Investigators and loaded into the project database.

10.5 Electronic Data Deliverables

Electronic Data Deliverables (EDDs) will be submitted from the laboratory in the specified format in Appendix D or a format mutually agreeable between the laboratory and the project team.

10.6 Laboratory Data Hard Copy Storage

All raw analytical laboratory data are stored as the original hard copy. Hard copy information includes COC forms, analytical bench sheets, instrument printouts, certificates of analyses, and QA/QC report summaries.

10.7 Electronic Data Deliverables Verification

Once the EDD is received at CH2M HILL, the EDD must be checked using CH-Analyzer to verify correct format and content. If errors are found, the file will be returned to the laboratory for correction and re-submittal. Even if the formatting of the EDD is completely correct, the project chemist may reject the EDD if the contents of the file do not comply with the data library standardization requirements. These checks must be conducted to ensure the consistency and the validity of the EDD's content before the data are electronically transferred to the Validated Data Management System (VDMS) for data validation. The objective of applying the CH-Analyzer is to ensure that the validation process is carried out on consistently high-quality data and minimize the chance of finding data errors later in the validation process, forcing the lab to re-send corrected data and then start the validation process over again.

10.8 Validated Data Management System

Once the EDD verification is complete, the EDD must be electronically transferred into CH2M HILL's VDMS for data quality verification and validation according to project specifications. At import, the data are checked against a list of valid values. Once all error messages are resolved, validation can begin.

VDMS can be operated to perform semi-automated and automated validation of environmental analytical data. VDMS will be operated in the semi-automated fashion and will allow the chemist to apply validation flags data for:

- Dilutions
- Re-extractions
- Confirmation samples
- Lab blanks
- Field blanks
- Blank spikes
- Blank spike duplicates
- Field duplicates
- Holding times
- Matrix spikes

- Matrix spike duplicates
- Surrogates

At the first level of semi-automation, VDMS performs QC checks against acceptable valid values and runs a completeness check on the electronic data.

VDMS presents the findings for the chemist's acceptance and/or changes to data validation flags and final approval. VDMS presents reports that summarize all of the analytical data, determine whether analytical results meet accuracy and precision criteria as specified by the project QAPP, and isolate data that indicate contaminant concentrations that exceed project action levels if needed. The chemist can utilize VDMS to create project tables for data quality evaluation reports and other customized project deliverables.

10.9 Project File

The final project file will be the central repository for all documents relevant to sampling and analysis activities. The CH2M HILL project manager is the custodian of the project file and maintains the contents of the evidence files for the project, including relevant records, reports, logs, field notebooks, pictures, contractor reports, and data reviews in a secured area with limited access.

Principal Investigators will keep all records for their respective, individual project files until completion with copies of notable documents and data sent to CH2M HILL. Project files will be turned over to CH2M HILL upon completion of each individual project. CH2M HILL will keep all records until program completion and closeout whereupon they will be turned over to UDWQ. As necessary, records may be transferred to an offsite records storage facility or database records transferred to other database platforms as requested by the UDWQ. The records storage facility must provide secure, controlled-access records storage. Records of raw analytical laboratory data, QA data, and reports will be kept by the subcontract laboratory for at least 7 years.

11.0 Corrective Action

Corrective action may be required as a result of deviations from field or analytical procedures. Deficiencies identified in audits and data quality evaluations may also call for corrective action. All project personnel have the responsibility, as part of the normal work duties, to identify, report, and solicit approval of corrective actions for conditions adverse to data quality.

The QAPP has specified the corrective action to be taken when deviations from calibration and QC acceptance criteria occur. Field and laboratory staff may encounter conditions that require immediate corrective action that are not addressed in the QAPP. These personnel will document conditions and the results of corrective actions in a field logbook or laboratory non-conformance report and communicate their actions as soon as feasible to the field team leader, laboratory supervisor, and if necessary, the project chemist, for immediate input. A mechanism must be in place to allow for supervisory review and/or client input for all deviations or deficiencies. A corrective action reporting system that requires immediate documentation of deviations or deficiencies and for supervisory review of the actions taken to correct them will be established. At a minimum, the corrective action report should include:

- The type of deviation or deficiency
- The date of occurrence
- The impact of the deviation or deficiency, such as samples affected
- The corrective action taken
- Documentation that the process has been returned to control

The only time that a corrective action report may be waived is when a deviation or deficiency is immediately corrected and its impact is precluded. An example would be an unacceptable initial calibration that is repeated before samples are analyzed.

Each corrective action report must be reviewed and approved by a person of authority, such as the field team leader or laboratory supervisor. The ultimate responsibility for the laboratory corrective action process is the QC Manager, who must ensure that proper documentation, approval, and close out of all out-of-control or non-conformance events is performed. A non-conformance report will summarize each non-conformance condition. Corrective action reports that could potentially affect data quality must be brought to the attention of the project manager. Report disposition will be the responsibility of the project manager. Copies of corrective action reports must be maintained in the laboratory or field project files.

12.0 Preventive Maintenance

The primary objective of an instrument/equipment maintenance program is to promote the timely and effective completion of a measurement effort. The maintenance program is designed to minimize the downtime of crucial sampling and/or analytical equipment due to expected or unexpected component failure. In implementing this program, efforts are focused in three primary areas:

- Establishment of maintenance responsibilities
- Establishment of maintenance schedules for major and/or critical instrumentation and apparatus
- Establishment of an adequate inventory of critical spare parts and equipment

These are discussed in the following subsections.

12.1 Maintenance Responsibilities

Equipment and instruments used in this project fall into two general categories:

- Laboratory instruments (e.g., Inductively Coupled Plasma, Atomic Absorption, Spectrophotometers, etc.)
- Field sampling equipment (e.g., field meters, etc.)

Maintenance of laboratory instruments is the responsibility of the laboratory contracted to perform the analytical portion of this program. Generally, the laboratory manager or supervisor of a laboratory is responsible for the instruments and equipment in his or her work area. The laboratory manager will establish maintenance procedures and schedules for each major equipment item. Although this responsibility may be delegated to laboratory personnel, the manager retains responsibility for ensuring adherence to prescribed protocol. All laboratories are bound by analytical contractual agreements to maintain the ability to produce data that meet the project objectives and to follow method specifications. This ensures that adequate spare parts, maintenance schedules, and emergency repair services are available.

Maintenance responsibilities for field equipment are assigned to the Principal Investigators for specific sampling tasks. However, the field team using the equipment is responsible for checking the status of the equipment prior to use and reporting any problems encountered. The field team is also responsible for ensuring that critical spare parts are included as part of the field equipment checklist. Non-operational field equipment is removed from service and a replacement obtained.

All field instruments will be properly protected against inclement weather conditions during the field investigation. Each instrument is specially designed to maintain its operating integrity during variable temperature ranges that are representative of ranges that

will be encountered during hot or cold weather working conditions. It is recommended, but not required, that at the end of each working day, all field equipment be taken out of the field and placed in a cool, dry room for overnight storage.

12.2 Maintenance Schedules

The effectiveness of any maintenance program depends to a large extent on adherence to specific maintenance schedules for each piece of equipment. Other maintenance activities are conducted as needed. Manufacturers' recommendations provide the primary basis for established maintenance schedules, and manufacturers' service contracts provide primary maintenance for many major instruments (e.g., LC instruments, atomic absorption spectrometers, analytical balances, etc.).

Each analytical instrument is assigned an instrument logbook. All maintenance activities are recorded in the instrument log. The information to be entered includes:

- Date of service
- Person performing service
- Type of service performed and reason for service
- Replacement parts installed (if appropriate)
- Date of next scheduled service
- Equipment calibration records
- Miscellaneous information

12.3 Spare Parts

In addition to a schedule for maintenance activities, an adequate inventory of spare parts is required to minimize equipment down time. The inventory includes those parts and supplies that:

- Are subject to frequent failure;
- Have limited useful lifetimes; or
- Cannot be obtained in a timely manner should failure occur.

Field managers and the respective laboratory managers are responsible for maintaining an adequate inventory of spare parts. In addition to spare parts and supply inventories, an in-house source of backup equipment and instrumentation should be available.

13.0 Audits

13.1 External Audits

Announced and unannounced audits of the field operations and of the laboratories may be conducted during any stage of the project.

13.2 Internal Audits

Annual audits of the laboratory shall be conducted by the laboratory's QA Officer. The audits shall verify, at a minimum, that written standard operating procedures are being followed; standards are traceable to certified sources; documentation is complete; data review is being done effectively and is properly documented; and data reporting, including electronic and manual data transfer, is accurate and complete. All audit findings shall be documented in QA reports to management. Necessary corrective actions shall be taken within a reasonable time frame. The QA Officer shall verify that such actions are effective and complete and shall document their implementation in an audit closeout report to management.

To assess sample and data collection procedures, the Principal Investigators will oversee their staff and ensure that sampling is performed in accordance with applicable procedures.

14.0 References

EPA, 2000. *Guidance for the Data Quality Objectives Process.* EPA QA/G-4. EPA/600/R-96/055. Office of Environmental Information, Washington, DC. August.

EPA, 2001. *Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual.* EPA-823-B-01-002. Office of Water. October.

Johnson, W.P., M. Conover, W. Wurtsbaugh, and J. Adams. Undated. *Conceptual Model for Selenium Cycling in the Great Salt Lake*. Prepared for the Division of Water Quality of the Utah Department of Environmental Quality by Center for Water, Ecosystem, and Climate Science.

APPENDIX A

Data Quality Objectives

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
1. Problem Statement	**Purpose:** Clearly define the problem that requires new environmental data so that the focus of the study will be clear and unambiguous. **Outputs From This Step** • A concise description of the problem. • A list of the planning team members and identification of the decision maker. • A summary of available resources and relevant deadlines for the study.	**Problem:** The open waters of the GSL are protected for their current beneficial uses (identified as "Aquatic Wildlife") through the application of a narrative criteria clause, rather than a numerical value. Due to the highly individual nature of the Great Salt Lake's water, the Utah Department of Environmental Quality (DEQ) has not yet identified a numeric water quality standard (i.e., selenium concentration) specific to the GSL. The goal of this project is to complete a group of interrelated studies that will contribute to the establishment of an interim standard for selenium by the third quarter of 2007. Essential components of the GSL ecosystem, as related to the establishment of the site-specific standard, have been identified in a detailed conceptual model for selenium cycling in the GSL (Bill Johnson et al., CWECS, University of Utah). These DQOs (including those for each of the individual projects) and the accompanying scopes of work describe the approach for obtaining information that is needed for establishment of the site-specific standard. The main focus of the work is to determine loading of selenium to GSL, its distribution within the lake, and transfer factors from one medium to another (e.g., from diet to bird eggs). **Planning team members:** Dr. Mike Conover, Clay Perschon, Dr. Wayne Wurtsbaugh, Brad Marden, Dr. David Naftz, and Dr. William Johnson (Principal Investigators); Dr. Harry Ohlendorf, Dr. Earl Byron, Gary Santolo, and Daniel Moore (Project Advisors); Jeff DenBleyker (Project Manager); with ultimate decision authority by Utah DEQ, considering input by the GSL Steering Committee and GSL Science Panel. **Resources:** Current estimated budget for this work is about $1,342,000 (plus $124,000 in USGS cost-sharing). Technical expertise for conducting the field studies is available from the CWECS team members, who also will provide needed equipment. Analytical laboratory services are available from a limited number of commercial laboratories for completing the selenium and other analyses. Selenium-related expertise and project management support will be provided by CH2M HILL project advisors and the project manager. **Deadlines:** Although deadlines vary among the individual projects, the initial focus is to provide sufficient information by late 2006 or early 2007 for Utah DEQ to establish an interim standard for selenium by the third quarter of 2007. It is expected that initial results will be available for selenium concentrations (and their significance) in bird eggs (California gulls, American avocets, black-necked stilts), common invertebrates (brine flies and brine shrimp), inflowing waters from various sources, ambient waters (as waterborne selenium concentration and also as dissolved gas) of Gilbert Bay (i.e., the "open waters" of GSL), and sediment (including bed sediment and material being deposited to the sediment).

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
2. Decision Statements	**Purpose**: Define the decision(s) that will be resolved using data to address the problem. **Approach**: Identify the key question that the study attempts to address and alternative actions that may be taken, depending on the answer to the key study question. **Outputs From This Step** • A statement of the decision that must be resolved using data in order to address or solve the problem. • A list of possible actions or outcomes that would result from each resolution of the decision statement. *Note from EPA guidance on DQO: If the principal study question is not obvious and specific alternative actions cannot be identified, then the study may fall in the category of exploratory research, in which case this particular step of the DQO Process may not be needed.*	**Decisions:** The overall question to be resolved can be stated as "What is the acceptable waterborne concentration of selenium that will be appropriately protective of beneficial uses of Great Salt Lake waters?" More specific questions that support this overall decision are presented in the individual project-specific DQOs. In general, they include the following: • What are the transfer factors that describe relationships between selenium concentrations in bird diets and the concentrations found in bird eggs? • What is the relative importance (based on selenium concentrations and their availability) of various food-chain exposure pathways for aquatic wildlife? • Are significant ecological effects occurring in aquatic wildlife? If so, to which ones and at which locations? What are the associated selenium concentrations in tissues (including bird blood, liver, and eggs)? • What are the sources of waterborne selenium entering GSL, and what is the relative significance of each of the various sources? • What are the most important processes that affect the partitioning, cycling, and release of selenium in the GSL open waters? **Possible outcomes:** • Information is adequate to quantify relationships among trophic levels and to conclude that current selenium loadings to GSL have a measurable adverse effect on aquatic wildlife in the open-water GSL ecosystem. Steps should be taken to reduce present and future selenium loadings by establishing a more protective site-specific standard for selenium. • Information is adequate to quantify relationships among trophic levels and to conclude that current selenium loadings to GSL have no measurable adverse effect on aquatic wildlife in the open-water GSL ecosystem. Future selenium loadings to GSL can be maintained at this level or increased concurrent with low-intensity water-quality and biological monitoring. • Information is not adequate to quantify relationships among trophic levels or to determine whether current selenium loadings to GSL have a measurable adverse effect on aquatic wildlife in the open-water GSL ecosystem. Further studies are needed to make a defensible conclusion about the significance of effects.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
3. Inputs to the Decision	**Purpose**: The purpose of this step is to identify the informational inputs that will be required to resolve the decision, and to determine which inputs require environmental measurements. **Activities** • Identify the information that will be required to resolve the decision. • Determine the sources for each item of information identified. • Identify the information that is needed to establish the action level for the study. • Confirm that appropriate field sampling techniques and analytical methods exist to provide the necessary data. **Outputs From This Step** • A list of informational inputs (including sources and potential action levels) needed to resolve the decision. • The list of environmental variables or characteristics that will be measured.	**Informational inputs:** • Trophic transfer factors from diet to birds and ecological significance of selenium to avian aquatic wildlife at representative locations; Project 1 • Selenium bioaccumulation in brine flies (including larvae, pupae, and adults) and brine shrimp (including cysts as well as whole-body tissue) and the seasonal and spatial availability of these food-chain organisms for aquatic wildlife; Project 2 • Selenium concentrations and flow volume from sources entering GSL; Project 3 • Selenium flux from the water column to the atmosphere and to the lake bottom as well as remobilization from sediment to the water column; Project 4 **Variables/characteristics to be measured:** • Selenium in the following media (see project-specific DQOs for more details): – Gull, avocet, and stilt blood, liver, and eggs – Eared grebe tissues (blood and liver) – Duck tissues (blood and liver) – Periphyton and brine flies (larvae, pupae, and adults) – Seston and brine shrimp (whole-body tissues and cysts) – Inflow water – Ambient waters of Gilbert Bay (as waterborne total, dissolved volatile, and vapor selenium concentrations) – Particulate phase in water column – Sediment (submerged sediment cores and exposed sediment) • Other variables (see project-specific DQOs for more details): – Incidence of embryo mortality and abnormalities in nesting birds – Body condition of grebes and ducks – Periphyton/detrital biomass – Brine fly larval and pupal density – Brine shrimp population characteristics (e.g., biomass, abundance, age structure) – ^{13}C and ^{15}N to correlate with selenium concentrations in seston and brine shrimp – Flow of water from various sources – Sediment flux (via sediment traps) – Mixing of Deep Brine Layer with Shallow Layer between and during storm and wind events (using turbidimeter and thermistor strings)

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
4. Study Boundaries	**Purpose**: Specify the spatial and temporal circumstances that are covered by the decision. **Activities** • Define the domain or geographic area within which all decisions must apply. • Specify the characteristics that define the population of interest. • When appropriate, divide the population into strata that have relatively homogeneous characteristics. • Define the scale of decision making. • Determine when to collect data. • Determine the time frame to which the study data apply. • Identify any practical constraints on data collection. **Outputs From This Step** • Characteristics that define the domain of the study. • A detailed description of the spatial and temporal boundaries of the decision. • A list of any practical constraints that may interfere with the study.	**Spatial:** The project area is defined as the open waters of the Great Salt Lake (also referred to as Gilbert Bay) located north and west of Farmington Bay, west of the Weber River input, and south of Promontory Point, Bear River Bay, and the North Arm (bounded by the railroad causeway). **Temporal:** The maximum period of data collection will be from mid-April 2006 through March 2007 for Project 1 and through February 2008 for Project 3. However, it is expected that other projects will provide initial results by late 2006 and will be completed in 2007. **Practical constraints on data collection:** Weather is the major constraint for all of the projects, because storms can limit our ability to conduct any of the sampling and measurement activities on the lake. Availability of boats and other field equipment, as well as equipment functionality, also may limit some activities. Methodology for quantitative sampling of brine fly larvae and pupae has not yet been tested on the lake.
5. Decision Rules	**Purpose**: The purpose of this step is to integrate the outputs from previous steps into a single statement that describes the logical basis for choosing among alternative actions. **Activities** • Specify the parameter that characterizes the population of interest. • Specify the action level for the study. • Combine the outputs of the previous DQO steps into an "if...then..." decision rule that defines the conditions that would cause the decision maker to choose among alternative actions. **Outputs From This Step** • An "if...then..." statement that defines the conditions that would cause the decision maker to choose among alternative courses of action.	• If information is adequate to quantify relationships among trophic levels and to conclude that current selenium loadings to GSL have a measurable adverse effect on aquatic wildlife in the open-water GSL ecosystem, then the Science Panel will assist the Utah DEQ and the Steering Committee in establishing a site-specific selenium standard to reduce selenium loading. • If information is adequate to quantify relationships among trophic levels and to conclude that current selenium loadings to GSL have no measurable adverse effect on aquatic wildlife in the open-water GSL ecosystem, then the Science Panel will assist the Utah DEQ and the Steering Committee in establishing a site-specific selenium standard, presumably maintaining the current level or increasing it, concurrent with low-intensity water-quality and biological monitoring. • If information is not adequate for the Science Panel to quantify relationships among trophic levels or to determine whether current selenium loadings to GSL have a measurable adverse effect on aquatic wildlife in the open-water GSL ecosystem, then further studies will be recommended to provide the needed information for the Science Panel.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
6. Tolerable Limits on Decision Rules	**Purpose**: Specify the decision maker's acceptable limits on decision errors, which are used to establish appropriate performance goals for limiting uncertainty in the data. **Activities** • Determine the possible range of the parameter of interest. • Define both types of decision errors and identify the potential consequences of each. • Specify a range of possible parameter values where the consequences of decision errors are relatively minor (gray region). • Assign probability values to points above and below the action level that reflect the acceptable possibility for the occurrence of decision errors. • Check the limits on decision errors to ensure that they accurately reflect the decision maker's concern about the relative consequences for each type of decision error. **Outputs From This Step** • The decision maker's acceptable decision error rates based on a consideration of the consequences of making an incorrect decision.	These outputs are more applicable to specific studies than to the overall DQOs, and are presented as the study-specific limits applicable to the precision, accuracy, representativeness, completeness, and comparability of the data, including an appropriate quality assurance/quality control plan, for Projects 1, 2, 3, and 4.
7. Optimization of the Sampling Design	**Purpose**: Identify the most resource-effective sampling and analysis design for generating data that are expected to satisfy the DQOs. **Activities** • Review the DQO outputs and existing environmental data. • Translate the information from the DQOs into a statistical hypothesis. • Develop general sampling and analysis design alternatives. • For each design alternative, formulate the mathematical expressions needed to solve the design problems. • For each design alternative, select the optimal sample size that satisfies the DQOs. • Select the most resource-effective design that satisfies all of the DQOs. • Document the operational details and theoretical assumptions of the selected design in the Sampling and Analysis Plan. **Outputs From This Step** • The most resource-effective design for the study that is expected to achieve the DQOs, selected from a group of alternative designs generated during this step.	These outputs are more applicable to specific studies than to the overall DQOs, and are presented as the study-specific limits applicable to the precision, accuracy, representativeness, completeness, and comparability of the data, including an appropriate quality assurance/quality control plan, for Projects 1, 2, 3, and 4.

Data Quality Objectives for Project 1A: Concentration and Effects of Selenium in Shorebirds

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
1. Problem Statement	**Purpose:** Clearly define the problem that requires new environmental data so that the focus of the study will be clear and unambiguous. **Outputs From This Step** • A concise description of the problem. • A list of the planning team members and identification of the decision maker. • A summary of available resources and relevant deadlines for the study.	**Problem:** The Great Salt Lake (GSL) provides a critical resource for breeding shorebirds and consequently has been identified as a site of Hemispheric Importance. Shorebirds (American avocet, black-necked stilt) can be negatively affected by increased selenium contamination. High ambient levels of selenium may reduce reproductive success (Conceptual Model Component [CMC] 1). These species consume large quantities of macro-invertebrates and will likely assimilate selenium rapidly (CMC 11). In order to understand the potential effects of selenium on shorebirds at GSL the following questions need to be addressed: • What is the diet of American avocets and black-necked stilts at GSL? • What is the ambient concentration of selenium in the water and macro-invertebrates consumed by shorebirds? • What is the concentration of selenium within the liver and blood of American avocets and black-necked stilts? • What is the concentration of selenium within the eggs of American avocets and black-necked stilts? • What is the hatching success of American avocet and black-necked stilt eggs? **Planning team members:** Dr. John Cavitt (Principal Investigator), Gary Santolo (Project Advisor), with ultimate decision authority by Utah Department of Environmental Quality, considering input by the GSL Steering Committee and GSL Science Panel. **Resources:** Estimated budget for sampling year 2006 is $104,500, including lab costs. Field and laboratory equipment is available from Weber State University or through charter (e.g., airplanes and boats). Analytical laboratories will be used for chemical analysis of samples. Selenium-related expertise will be provided by CH2M Hill staff scientists. **Deadlines:** Technical memorandum addressing above questions will be completed by November 1, 2006.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
2. Decision Statements	**Purpose**: Define the decision(s) that will be resolved using data to address the problem. **Approach**: Identify the key question that the study attempts to address and alternative actions that may be taken, depending on the answer to the key study question. **Outputs From This Step** • A statement of the decision that must be resolved using data in order to address or solve the problem. • A list of possible actions or outcomes that would result from each resolution of the decision statement. *Note from EPA guidance on DQO: If the principal study question is not obvious and specific alternative actions cannot be identified, then the study may fall in the category of exploratory research, in which case this particular step of the DQO Process may not be needed.*	**Decisions:** The guiding questions for project 1a include the following • What do the shorebirds eat at GSL, and what are the transfer factors for selenium from the diet to bird eggs? • Are significant ecological effects occurring in American avocets and black-necked stilts? If so, to which ones and at which locations? • What are the associated selenium concentrations in tissues (including bird eggs)? **Possible outcomes:** • Information is adequate to quantify transfer factors for selenium from the diet to bird eggs and to conclude that current selenium loadings to GSL have a measurable adverse effect on American avocets and black-necked stilts. Steps should be taken to reduce present and future selenium loadings by establishing a more protective site-specific standard for selenium. • Information is adequate to quantify transfer factors for selenium from the diet to bird eggs and to conclude that current selenium loadings to GSL have no measurable adverse effect on American avocets and black-necked stilts in the open-water GSL ecosystem. Future selenium loadings to GSL can be maintained at this level or increased concurrent with low-intensity water-quality and biological monitoring. • Information is not adequate to quantify transfer factors for selenium from the diet to bird eggs or to determine whether current selenium loadings to GSL have a measurable adverse effect on American avocets and black-necked stilts in the open-water GSL ecosystem. Further studies are needed to make a defensible conclusion about the significance of effects.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project

3. Inputs to the Decision	**Purpose**: The purpose of this step is to identify the informational inputs that will be required to resolve the decision, and to determine which inputs require environmental measurements.
	
	Activities
	
	• Identify the information that will be required to resolve the decision.
	• Determine the sources for each item of information identified.
	• Identify the information that is needed to establish the action level for the study.
	• Confirm that appropriate field sampling techniques and analytical methods exist to provide the necessary data.
	
	Outputs From This Step
	
	• A list of informational inputs (including sources and potential action levels) needed to resolve the decision.
	• The list of environmental variables or characteristics that will be measured.
		Informational inputs:
		
		The following inputs will be collected at four sites within the GSL:
		
		• Diet of American avocets and black-necked stilts at GSL
		• Ambient concentration of selenium in the water and macro-invertebrates consumed by shorebirds
		• Concentration of selenium within the liver and blood of American avocets and black-necked stilts
		• Concentration of selenium within the eggs of American avocets and black-necked stilts
		• Hatching success of American avocet and black-necked stilt eggs
		
		Variables/characteristics to be measured:
		
		• Aggregate percentage and aggregate volume (cc) of food items recovered from the upper digestive tract (pharynx, esophagus, proventriculus, and ventriculus) of American avocets and black-necked stilts
		
		• Selenium concentration in the following:
		  – Water near foraging sites
		  – Macro-invertebrates samples at foraging sites
		  – Liver and blood of avocets and stilts
		  – Avocet and stilt eggs
		
		• Hatching success at each site monitored
		
		• Other variables:
		  – Incidence of embryo mortality and abnormalities in nesting birds
		  – Body condition of American avocet and black-necked stilts

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
4. Study Boundaries	**Purpose**: Specify the spatial and temporal circumstances that are covered by the decision. **Activities** • Define the domain or geographic area within which all decisions must apply. • Specify the characteristics that define the population of interest. • When appropriate, divide the population into strata that have relatively homogeneous characteristics. • Define the scale of decision making. • Determine when to collect data. • Determine the time frame to which the study data apply. • Identify any practical constraints on data collection. **Outputs From This Step** • Characteristics that define the domain of the study. • A detailed description of the spatial and temporal boundaries of the decision. • A list of any practical constraints that may interfere with the study.	**Spatial:** The project area is defined as the open waters of the Great Salt Lake (also referred to as Gilbert Bay) located north and west of Farmington Bay, west of the Weber River input, and south of Promontory Point, Bear River Bay, and the North Arm (bounded by the railroad causeway). The following four study areas will be surveyed for nesting aggregations: • West Carrington Bay – This area has almost no freshwater input and may be influenced by the deep brine layer that forms and depletes at different times than the main body of the lake. • The South Shore and Eardley Spit – These areas have very little fresh water inflow. • The Southeast Corner of the GSL – This area experiences inflows from the Goggin Drain and Lee Creek, both of which are primarily freshwater. The C-6 ditch flows in from Kennecott and a pipeline of Kennecott wastewater is also discharged into the main body of the lake near this area. • Pintail flats at Ogden Bay – This area is influenced by freshwater from all of the main inflows to the lake. **Temporal:** The period of data collection will be from April to August 2006 (possibly extending to April to August 2007). Initial results will be obtained by November 2006. Annual variation may be determined by repeating data collection during the 2007 breeding season. It is assumed that the need for extending this task will be evaluated at the end of 2006. **Practical constraints on data collection:** Occurrence of breeding birds is a major constraint for this project. Study sites were chosen due to unique attributes of hydrology and may not contain breeding aggregations. Weather is also a constraint for this project, because storms can limit our ability to conduct the sampling and measurement activities on the lake. Availability of boats and other field equipment, as well as equipment functionality, also may limit some activities.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
5. Decision Rules	**Purpose**: The purpose of this step is to integrate the outputs from previous steps into a single statement that describes the logical basis for choosing among alternative actions. **Activities** • Specify the parameter that characterizes the population of interest. • Specify the action level for the study. • Combine the outputs of the previous DQO steps into an "if...then..." decision rule that defines the conditions that would cause the decision maker to choose among alternative actions. **Outputs From This Step** • An "if...then..." statement that defines the conditions that would cause the decision maker to choose among alternative courses of action.	• If information is adequate to quantify transfer factors for selenium from the diet to bird eggs and to conclude that current selenium loadings to GSL have a measurable adverse effect on American avocets or black-necked stilts in the open-water GSL ecosystem, then the Science Panel will assist the Utah DEQ and the Steering Committee in establishing a site-specific selenium standard to reduce selenium loading. • If information is adequate to quantify transfer factors for selenium from the diet to bird eggs and to conclude that current selenium loadings to GSL have no measurable adverse effect on avocets or stilts in the open-water GSL ecosystem, then the Science Panel will assist the Utah DEQ and the Steering Committee in establishing a site-specific selenium standard, presumably maintaining the current level or increasing it, concurrent with low-intensity water-quality and biological monitoring. • If information is not adequate for the Science Panel to quantify transfer factors for selenium from the diet to bird eggs or to determine whether current selenium loadings to GSL have a measurable adverse effect on avocets and stilts in the open-water GSL ecosystem, then further studies will be recommended to provide the needed information for the Science Panel.
6. Tolerable Limits on Decision Rules	**Purpose**: Specify the decision maker's acceptable limits on decision errors, which are used to establish appropriate performance goals for limiting uncertainty in the data. **Activities** • Determine the possible range of the parameter of interest. • Define both types of decision errors and identify the potential consequences of each. • Specify a range of possible parameter values where the consequences of decision errors are relatively minor (gray region). • Assign probability values to points above and below the action level that reflect the acceptable possibility for the occurrence of decision errors. • Check the limits on decision errors to ensure that they accurately reflect the decision maker's concern about the relative consequences for each type of decision error. **Outputs From This Step** • The decision maker's acceptable decision error rates based on a consideration of the consequences of making an incorrect decision.	Because of the judgmental nature of the sampling approach used in this study, no acceptable limits for decision error rates were determined for the sampling design. Specifications of tolerable limits on decision errors through the use of standard statistical methods are not applicable for these parameters. Data quality may also be specified under Measurement Quality Objectives. This quality assessment typically involves specifying performance criteria in terms of the precision, accuracy, representativeness, completeness, and comparability of the data. These performance criteria provide a measure of how well the established Measurement Quality Objectives were met. For this investigation, Measurement Quality Objectives for chemical measurements will be specified in the Quality Assurance Project Plan (QAPP); in general, the Measurement Quality Objectives for selenium are about ±20% and for non-selenium measurements they are ±10%. The QAPP will specify all QA/QC objectives for sample measurement based on each matrix and may be more restrictive or less restrictive than ±20%.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
7. Optimization of the Sampling Design	**Purpose**: Identify the most resource-effective sampling and analysis design for generating data that are expected to satisfy the DQOs. **Activities** • Review the DQO outputs and existing environmental data. • Translate the information from the DQOs into a statistical hypothesis. • Develop general sampling and analysis design alternatives. • For each design alternative, formulate the mathematical expressions needed to solve the design problems. • For each design alternative, select the optimal sample size that satisfies the DQOs. • Select the most resource-effective design that satisfies all of the DQOs. • Document the operational details and theoretical assumptions of the selected design in the Sampling and Analysis Plan. **Outputs From This Step** • The most resource-effective design for the study that is expected to achieve the DQOs, selected from a group of alternative designs generated during this step.	The sampling plan is summarized as follows: • Nesting areas will be surveyed by aerial transect beginning in late April and coordinates of nesting aggregations will be recorded to facilitate the remaining tasks. • Once nesting aggregations have been identified, they will be visited to determine the stage of breeding and to identify foraging locations. • Five adults of each species will be collected at each site at the beginning of the nesting season, after observing them feed for >15 minutes. Dietary information will be obtained by direct examination of gut contents (pharynx, esophagus, proventriculus and ventriculus). Blood (if possible) and liver samples will be taken from each bird for selenium analysis. • From each of the foraging areas, the following samples will be collected for selenium analysis: invertebrates (brine fly adults and/or larvae or pupae and brine shrimp, depending on what the birds are eating), surficial sediment, and water. If available, three samples of each species and life stage (i.e., larvae, pupae or adult of brine flies) will be collected at each area, with sufficient biomass for analysis (target 5 grams) and additional biomass when that is feasible. • A single egg will be collected from each of 10 nests for each species at each location upon discovery of the nest. After the clutches are completed, an additional 10 eggs containing late-stage embryos (based on egg flotation) per species will be collected from each site. Each embryo will be checked for stage of development and developmental abnormalities, including a determination of the embryo's position in the egg. Egg contents will then be placed in a marked chemically-cleaned container and preserved frozen for later analysis. Up to 10 eggs of each species from each site will be analyzed for total selenium; eggs with late-stage embryos will be selected preferentially, if available. The remaining samples will be stored for possible later analysis. • Nests of both species will be located within each site and monitored to provide data on breeding productivity such as hatching success and nesting success using established methods (such as Mayfield methods). Near the time of hatching, nests will be checked to collect any fail-to-hatch eggs.

Data Quality Objectives for Project 1B: Concentrations and Effects of Selenium in Gulls, Grebes, and Ducks

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
1. Problem Statement	**Purpose:** Clearly define the problem that requires new environmental data so that the focus of the study will be clear and unambiguous. **Outputs From This Step** • A concise description of the problem. • A list of the planning team members and identification of the decision maker. • A summary of available resources and relevant deadlines for the study.	**Problem:** The objective of this project is to determine if selenium concentrations in the Great Salt Lake (GSL) are causing significant ecological effects in avian aquatic wildlife, and if so, to which ones and at which locations. We will concentrate our work on nesting California gulls at three gull colonies, grebes staging on the GSL in the fall, and overwintering ducks. These birds and their food-web relationships are generally described in the conceptual model for selenium cycling in the GSL as components 3, 5, 12, and 13, although the model identifies only northern shovelers and eared grebes as the species. High-priority questions to be answered in Project 1: • Where do California gulls nest and forage within the GSL? • What is the diet of nesting California gulls? • What are the ambient selenium concentrations in the water, sediment, and diet items at the foraging sites of nesting California gulls in the GSL? • What are the associated selenium concentrations in nesting California gulls (blood and liver), a random sample of gull eggs, gull eggs with dead or abnormal embryos, and deformed gull chicks? • What are selenium concentrations in adult eared grebes staging on the GSL when they first arrive and right before they leave, and how does body condition of grebes relate to selenium concentrations in their tissues? • What are selenium concentrations in overwintering ducks (adult male common goldeneye), and how does body condition of ducks relate to selenium concentrations in their tissues? • At which locations in GSL are high selenium concentrations in tissues associated with high ambient selenium concentrations? **Planning team members:** Dr. Mike Conover, Dr. Heather Keough, and Clay Perschon (Principal Investigators), and Gary Santolo (Project Advisor), with ultimate decision authority by Utah Department of Environmental Quality, considering input by the GSL Steering Committee and GSL Science Panel. **Resources:** Estimated budget for sampling year 2006-7 is $208,400, including lab costs. Technical expertise for conducting the field and laboratory studies is available from the Utah Division of Wildlife Resources and Utah State University, who also will provide needed equipment. Commercial analytical laboratories will be used to analyze ambient selenium concentrations and associated selenium concentrations in tissues. **Deadlines:** 30 days after completion of contract with Utah Division of Wildlife Resources • White paper that briefly summarizes each of the study efforts completed as part of the GSL Ecosystem Project • Map that summarizes DWR's and USU's knowledge of where birds have been most likely to nest on islands and along the shores of Gilbert Bay, and where fall-staging eared grebes and over-wintering ducks are most likely to be located on GSL. October 1, 2006 will serve as the deadline for the following deliverables: • Determine diet and foraging areas for California gulls • Determine selenium concentration in the diet of nesting gulls (i.e., exposure of gulls to selenium during egg-laying) • Assess selenium concentrations in adult California gulls sampled from the nesting population, a random sample of gull eggs, salvaged gull eggs, and deformed gull chicks. • Examine data for association between reproductive impairment in nesting gulls and selenium concentrations in tissues March 1, 2007 will serve as the deadline for the following deliverable: • Determine body condition and selenium concentrations in eared grebes staging in the fall May 15, 2007 will serve as the deadline for the following deliverable: • Determine body condition and selenium concentrations in ducks overwintering on the GSL

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
2. Decision Statements	**Purpose**: Define the decision(s) that will be resolved using data to address the problem. **Approach**: Identify the key question that the study attempts to address and alternative actions that may be taken, depending on the answer to the key study question. **Outputs From This Step** • A statement of the decision that must be resolved using data in order to address or solve the problem. • A list of possible actions or outcomes that would result from each resolution of the decision statement. *Note from EPA guidance on DQO: If the principal study question is not obvious and specific alternative actions cannot be identified, then the study may fall in the category of exploratory research, in which case this particular step of the DQO Process may not be needed.*	• **Decisions:** The overall questions to be resolved can be stated as "What are the transfer factors for selenium from the diet to birds? Are current selenium loadings to GSL significantly impacting birds (represented by gulls, grebes, and ducks), and if so, at which locations?" **Possible outcomes:** • Current selenium loadings may have no significant impact on California gull productivity, body condition of grebes, or body condition of overwintering ducks, indicating current selenium loadings have no expected impact on these species of aquatic wildlife in the open-water GSL ecosystem. If so, future selenium loadings to GSL can be maintained at this level or increased concurrent with low-intensity water-quality and biological monitoring. • Current selenium loadings may significantly reduce California gull productivity, body condition of grebes, or body condition of overwintering ducks, indicating current selenium loadings may have a significant impact on these species of aquatic wildlife in the open-water GSL ecosystem. If so, steps should be taken to reduce present and future selenium loadings by establishing a more protective site-specific standard for selenium. • Information is not adequate to determine whether current selenium loadings significantly impact California gull productivity, body condition of grebes, or body condition of overwintering ducks. If so, further studies are needed to make a defensible conclusion about the significance of effects.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project

3. Inputs to the Decision	**Purpose**: The purpose of this step is to identify the informational inputs that will be required to resolve the decision, and to determine which inputs require environmental measurements.
	
	Activities
	
	• Identify the information that will be required to resolve the decision.
	• Determine the sources for each item of information identified.
	• Identify the information that is needed to establish the action level for the study.
	• Confirm that appropriate field sampling techniques and analytical methods exist to provide the necessary data.
	
	Outputs From This Step
	
	• A list of informational inputs (including sources and potential action levels) needed to resolve the decision.
	• The list of environmental variables or characteristics that will be measured.
		Informational inputs:
		
		• Estimated selenium concentration in the diet of nesting California gulls based on diet composition and ambient selenium concentrations in food items and water at gull foraging areas. Diet composition will be based on quantitative analyses of crop contents from adults sampled from the nesting population.
		
		• Selenium concentrations in the food items, sediment, and water at California gull foraging areas, and in adult California gulls, California gull eggs with dead or abnormal embryos, and deformed California gull chicks
		
		• Selenium concentrations in tissues (blood and/or liver) of grebes and ducks, along with measures of body condition of those birds
		
		Variables/characteristics to be measured:
		
		• Selenium in the following media:
		  – Brine flies (larvae, pupae, and/or adults) and brine shrimp (whole-body tissues) sampled from each of the areas where California gulls from nesting colonies are foraging
		  – Water and sediment samples from each of the areas where California gulls from nesting colonies are foraging
		  – Blood and/or liver samples from adult California gulls
		  – California gull eggs
		  – Deformed California gull chicks
		  – Blood and/or liver samples from eared grebes
		  – Blood and/or liver samples from ducks
		• Other variables:
		  – Crop contents of sampled adult California gulls
		  – Incidence of California gull embryo mortality and abnormalities in embryos and chicks
		  – Body condition of grebes and ducks

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
4. Study Boundaries	**Purpose**: Specify the spatial and temporal circumstances that are covered by the decision. **Activities** • Define the domain or geographic area within which all decisions must apply. • Specify the characteristics that define the population of interest. • When appropriate, divide the population into strata that have relatively homogeneous characteristics. • Define the scale of decision making. • Determine when to collect data. • Determine the time frame to which the study data apply. • Identify any practical constraints on data collection. **Outputs From This Step** • Characteristics that define the domain of the study. • A detailed description of the spatial and temporal boundaries of the decision. • A list of any practical constraints that may interfere with the study.	**Spatial:** The project area is defined as the open waters of the Great Salt Lake (also referred to as Gilbert Bay) located north and west of Farmington Bay, west of the Weber River input, and south of Promontory Point, Bear River Bay, and the North Arm (bounded by the railroad causeway). We will concentrate our work on nesting California gulls at three gull colonies. There are four nesting colonies of gulls on the South Arm of the Great Salt Lake that are consistently active: Hat Island colony, GSL Mineral colony, Egg Island colony, and White Rock Island colony. However, the Egg Island and White Rock colonies are so close together that the foraging areas for gulls in these two colonies probably overlap. Hence, we will consider them a single colony but will collect gulls, their eggs and deformed hatchlings (if found) from both of them. **Temporal:** During 2006 and 2007, the maximum period of data collection will be from mid-April 2006 through March 2007. Later sampling during 2007 will be largely determined by what we learn in 2006 and early 2007 and what additional species or populations need to be examined. Hence, we cannot at this point accurately provide a time table for activities after March 2007. The 2006 Interim Final Report concerning gulls will be completed by October 1, 2006, and will provide a summary of the data collected and initial results of analyses. The 2006 Interim Final Reports for grebes and overwintering ducks will be complete 60 days after completion of sampling of those birds and submittal to the lab, or 30 days after the lab provides their analyses to USU, whichever comes last. Target dates for the reports are March 1, 2007 for grebes and May 15, 2007 for ducks. **Practical constraints on data collection:** Weather is the major constraint. Because storms can limit our ability to conduct any of the sampling activities on the lake, we describe the number of samples that will be collected by particular deadlines instead of detailed sampling schedules. The availability of aircraft and boats for surveys, technical expertise for identifying abnormal embryos and obtaining tissue samples, and costs of conducting selenium analyses on samples also may limit some activities.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
5. Decision Rules	**Purpose**: The purpose of this step is to integrate the outputs from previous steps into a single statement that describes the logical basis for choosing among alternative actions. **Activities** • Specify the parameter that characterizes the population of interest. • Specify the action level for the study. • Combine the outputs of the previous DQO steps into an "if...then..." decision rule that defines the conditions that would cause the decision maker to choose among alternative actions. **Outputs From This Step** • An "if...then..." statement that defines the conditions that would cause the decision maker to choose among alternative courses of action.	In all cases described below, transfer factors for selenium from diet to bird tissue and/or eggs will be determined. • If there is a significant association between ambient selenium concentrations and selenium concentrations in the diet of nesting California gulls and/or in the blood or liver samples from nesting gulls that exceed expected threshold effect levels, then selenium exposure will be considered a factor of concern during egg-laying. If not, then selenium exposure will be considered negligible. • If there is a significant association between ambient selenium concentrations and selenium concentrations in California gull eggs with dead or abnormal embryos and/or in deformed gull chicks that exceed threshold effect levels, then current selenium loadings will be considered to be negatively affecting California gull productivity. Also, if there is a significant association between selenium concentrations in the diet and/or the blood or liver of nesting gulls and selenium concentrations in their eggs with dead or abnormal embryos and/or deformed chicks, then current selenium loadings will be considered to be negatively affecting California gull productivity. If neither of the above associations occurs, then current selenium loadings will be assumed to have no significant impact on California gull productivity. • If there is a significant association between selenium concentration in fall-staging grebes or overwintering ducks and their body condition, then current selenium loadings will be considered to be negatively affecting grebe and/or duck survival. If these associations do not occur, then current selenium loadings will be assumed to have no significant impact on fall-staging grebes or overwintering ducks. • If selenium exposure is found to be a factor of concern during egg-laying and current selenium loadings are found to have a significant negative effect on California gull productivity or on body condition of fall-staging grebes or overwintering ducks, then it is expected that the Science Panel will assist the Utah DEQ and the Steering Committee in establishing a site-specific selenium standard to reduce selenium loading. • If selenium exposure is not found to be factor of concern during egg-laying but current selenium loadings are found to have a significant negative effect on California gull productivity or on body condition of fall-staging grebes or overwintering ducks, then it is expected that the Science Panel will assist the Utah DEQ and the Steering Committee in establishing a site-specific selenium standard to reduce selenium loading. In addition, future studies should examine why selenium exposure was not associated with selenium concentrations in the diet and blood of nesting California gulls. Are there alternative mechanisms for selenium absorption? • If selenium exposure is found to be a factor of concern during egg-laying but current selenium loadings are found to have no significant effect on California gull productivity or on body condition of fall-staging grebes or overwintering ducks, then it is expected that the Science Panel will assist the Utah DEQ and the Steering Committee in establishing a site-specific selenium standard, presumably maintaining the current level or increasing it, concurrent with low-intensity water-quality and biological monitoring. In addition, future studies should determine whether continued (long-term) exposure to selenium loadings in the GSL negatively impacts gull productivity. • If selenium exposure is not found to be factor of concern during egg-laying and current selenium loadings are found to have no significant impact on California gull productivity or on body condition of fall-staging grebes or overwintering ducks, then it is expected that the Science Panel will assist the Utah DEQ and the Steering Committee in establishing a site-specific selenium standard, presumably maintaining the current level or increasing it, concurrent with low-intensity water-quality and biological monitoring.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
6. Tolerable Limits on Decision Rules	**Purpose**: Specify the decision maker's acceptable limits on decision errors, which are used to establish appropriate performance goals for limiting uncertainty in the data. **Activities** • Determine the possible range of the parameter of interest. • Define both types of decision errors and identify the potential consequences of each. • Specify a range of possible parameter values where the consequences of decision errors are relatively minor (gray region). • Assign probability values to points above and below the action level that reflect the acceptable possibility for the occurrence of decision errors. • Check the limits on decision errors to ensure that they accurately reflect the decision maker's concern about the relative consequences for each type of decision error. **Outputs From This Step** • The decision maker's acceptable decision error rates based on a consideration of the consequences of making an incorrect decision.	Because of the judgmental nature of the sampling approach used in this study, no acceptable limits for decision error rates were determined for the sampling design. Specifications of tolerable limits on decision errors through the use of standard statistical methods are not applicable for these parameters. Data quality may also be specified under Measurement Quality Objectives. This quality assessment typically involves specifying performance criteria in terms of the precision, accuracy, representativeness, completeness, and comparability of the data. These performance criteria provide a measure of how well the established Measurement Quality Objectives were met. For this investigation, Measurement Quality Objectives for chemical measurements will be specified in the Quality Assurance Project Plan (QAPP); in general, the Measurement Quality Objectives for selenium are about ±20% and for non-selenium measurements they are ±10%. The QAPP will specify all QA/QC objectives for sample measurement based on each matrix and may be more restrictive or less restrictive than ±20%.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
7. Optimization of the Sampling Design	**Purpose**: Identify the most resource-effective sampling and analysis design for generating data that are expected to satisfy the DQOs. **Activities** • Review the DQO outputs and existing environmental data. • Translate the information from the DQOs into a statistical hypothesis. • Develop general sampling and analysis design alternatives. • For each design alternative, formulate the mathematical expressions needed to solve the design problems. • For each design alternative, select the optimal sample size that satisfies the DQOs. • Select the most resource-effective design that satisfies all of the DQOs. • Document the operational details and theoretical assumptions of the selected design in the Sampling and Analysis Plan. **Outputs From This Step** • The most resource-effective design for the study that is expected to achieve the DQOs, selected from a group of alternative designs generated during this step.	After detailed consideration of reasonable alternatives, the following design is the most resource effective: • For measurement of selenium concentrations in the blood or liver and the diet of adult California gulls: collect 10 adults near 3 colonies during the 2006 breeding season to address individual variability in uptake and deposition of selenium, and spatial variability in selenium concentrations in the sediment, water, and forage items. Diet composition will be based on established sampling methodologies for conducting quantitative analyses of crop contents. All blood, liver, and crop samples will be analyzed for selenium. • For measurement of ambient selenium concentrations: during the egg-laying period, collect 5 samples of brine flies (for each life stage being consumed to a significant degree by gulls), 5 samples of brine shrimp, a sample of sediment, and a water sample from each of the areas where gulls from the 3 colonies are foraging during the 2006 breeding season to address spatial variability in selenium concentrations in the water and forage items. All samples will be analyzed for selenium. • For measurement of selenium concentrations in California gull eggs: collect one egg from up to 20 nests in each of the 3 colonies and examine up to 50 salvaged eggs from each colony for dead or abnormal embryos. Collection efforts will be conducted during the 2006 breeding season at all 3 colonies with a focus on collecting eggs with late-stage embryos, because they are most readily assessed for the adverse effects of selenium. Up to 10 randomly collected eggs and up to 10 non-random eggs with dead or abnormal embryos from each location will be analyzed for selenium. If more than 10 eggs with dead or abnormal embryos are available from a particular colony, the eggs for analysis will be selected at random from the eggs that are available. This design addresses individual variability in uptake and deposition of selenium, and spatial variability in selenium concentrations in the water and forage items. • For measurement of selenium concentrations in deformed California gull chicks: after chicks have hatched, collect all deformed chicks from up to 20 nests in each of the 3 colonies during the 2006 breeding season to address individual variability in uptake and deposition of selenium, and spatial variability in selenium concentrations in the water and forage items. Up to 10 deformed chicks from each location will be analyzed for selenium. • For measurement of selenium concentrations in the blood or liver and the diet of adult eared grebes and male common goldeneyes: collect up to 20 grebes and 20 goldeneyes when they first arrive on the GSL and 20 more of each species within four weeks of their expected departure date from GSL. We will attempt to collect these birds from the same three areas where we are sampling gulls (Gilbert Bay, near Egg Island, and near the Great Salt Lake Mineral colony). If we are unable to collect 20 male goldeneyes per sampling period, we may borrow specimens collected during the appropriate time of year during the winter of 2005-2006 for another project. All blood, liver, and crop samples will be analyzed for selenium. Birds will also be analyzed for body condition. If there is a downing during the winter of 2006-2007, up to 20 downed grebes will be collected and analyzed for selenium and body condition.

Data Quality Objectives for Great Salt Lake Project 2A: Synoptic Survey of Selenium in Periphyton and Brine Fly Larvae from the Benthic Zone of the Great Salt Lake (Preliminary Study)

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
1. Problem Statement	**Purpose:** Clearly define the problem that requires new environmental data so that the focus of the study will be clear and unambiguous. **Outputs From This Step** • A concise description of the problem. • A list of the planning team members and identification of the decision maker. • A summary of available resources and relevant deadlines for the study.	**Problem:** Larval and pupal brine flies are likely important dietary components of birds utilizing the Great Salt Lake and thus provide an important mechanism for selenium uptake (Conceptual Model Components (CMC) 11, 12, 13). Larval brine flies feed on periphyton (CMC 19) and likely on phytoplankton and detrital food resources that settle onto the lake's littoral zone (CMC 40). We know very little about this benthic food web, and nothing in relation to the bioaccumulation of selenium in the food web leading to birds. Quantitative sampling procedures for the periphyton, detrital material and brine flies in the benthic zone have not yet been established for the Great Salt Lake. To determine the importance of the benthic food web for bioaccumulation of selenium in birds, we need to (1) determine how to sample this zone of the lake; and (2) make preliminary estimates of concentrations of selenium in the periphyton/detrital material and in the brine flies. This, in conjunction with the bird diet study (Project 1), will determine transfer factors for selenium from the diet to birds and whether it is important to go forward with a more ambitious spatial-temporal analysis of selenium in this component of the food web. **Planning team members:** Dr. Wayne Wurtsbaugh (Principal Investigator), Dr. Earl Byron (Project Advisor), with ultimate decision authority by Utah Department of Environmental Quality, considering input by the GSL Steering Committee and GSL Science Panel. **Resources:** Estimated budget for sampling year 2006 is $39,200, including lab costs. Field and laboratory equipment is available at USU or through rental (e.g., boat, diving equipment, computers, software). Analytical laboratories will be used for chemical analysis of samples. Selenium-related expertise will be provided by CH2M Hill staff scientists. **Deadlines:** April 30, 2006 — Order all necessary equipment and supplies May 15, 2006 — Field reconnaissance of two study areas completed June 30, 2006 — Field sampling of benthic food web completed, samples sent to analytical lab for selenium analysis Aug. 15, 2006 — Laboratory analyses of periphyton and brine flies completed in USU lab; selenium results obtained from analytical laboratory Sept. 30, 2006 — Report submitted to CH2MHill for review Oct. 30, 2006 — Report revised and ready for submission to Science Panel

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
2. Decision Statements	**Purpose**: Define the decision(s) that will be resolved using data to address the problem. **Approach**: Identify the key question that the study attempts to address and alternative actions that may be taken, depending on the answer to the key study question. **Outputs From This Step** • A statement of the decision that must be resolved using data in order to address or solve the problem. • A list of possible actions or outcomes that would result from each resolution of the decision statement. *Note from EPA guidance on DQO: If the principal study question is not obvious and specific alternative actions cannot be identified, then the study may fall in the category of exploratory research, in which case this particular step of the DQO Process may not be needed.*	**Decisions:** 1. Can brine fly larvae and pupae be sampled quantitatively using a SCUBA-operated vacuum sampler on stromatolite substrates? 2. Can soft substrates be sampled quantitatively using Ponar dredge? 3. What is the time cost for each of these sampling procedures? 4. What is the selenium content in periphyton/detrital material? 5. What is the selenium content in brine fly larvae? 6. What is the selenium content in the overlying water above the benthic substrates? **Possible outcomes:** 1, 2. Brine flies can/cannot be sampled quantitatively using proposed methodologies of 1 & 2 above. If they cannot, alternative procedures must be explored before spatial-temporal analyses of benthic habitats should be undertaken. 3. Sampling using the stated procedures is cost-effective and can therefore be implemented. Sampling is too costly to be implemented given available State budget. If bird diet analyses find that brine flies are an important dietary component, then additional funding will need to be located. 4, 5, 6. The preliminary analyses could find that selenium concentrations are very high or very low in the benthic periphyton and brine flies. This should help guide our team and managers to determine the importance of further work on this part of the food web.
3. Inputs to the Decision	**Purpose**: The purpose of this step is to identify the informational inputs that will be required to resolve the decision, and to determine which inputs require environmental measurements. **Activities** • Identify the information that will be required to resolve the decision. • Determine the sources for each item of information identified. • Identify the information that is needed to establish the action level for the study. • Confirm that appropriate field sampling techniques and analytical methods exist to provide the necessary data. **Outputs From This Step** • A list of informational inputs (including sources and potential action levels) needed to resolve the decision. • The list of environmental variables or characteristics that will be measured.	**Informational inputs:** • Time measurement of each type of sampling • Variability of replicate measurements of periphyton, brine fly larvae, brine fly pupae • Concentrations of selenium in benthic food web components **Variables/characteristics to be measured:** • Periphyton/detrital biomass – Chlorophyll a concentration – Organic carbon • Brine fly larval density (number/square m) • Brine fly pupae density (number/square m) • Selenium concentration (mg/kg) in aggregate periphyton detrital material • Selenium concentration in brine fly larvae (mg/kg) • Selenium concentration in brine fly pupae (mg/kg) • Selenium (dissolved) concentration in overlying water (ug/L)

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
4. Study Boundaries	**Purpose**: Specify the spatial and temporal circumstances that are covered by the decision. **Activities** • Define the domain or geographic area within which all decisions must apply. • Specify the characteristics that define the population of interest. • When appropriate, divide the population into strata that have relatively homogeneous characteristics. • Define the scale of decision making. • Determine when to collect data. • Determine the time frame to which the study data apply. • Identify any practical constraints on data collection. **Outputs From This Step** • Characteristics that define the domain of the study. • A detailed description of the spatial and temporal boundaries of the decision. • A list of any practical constraints that may interfere with the study.	**Spatial:** Two stations on opposite sides of Gilbert Bay **Temporal:** June, when populations of brine fly larvae and pupae are known to be present **Practical constraints on data collection:** • Weather can limit timing of collection. • Methodology has not yet been tested on the lake.
5. Decision Rules	**Purpose**: The purpose of this step is to integrate the outputs from previous steps into a single statement that describes the logical basis for choosing among alternative actions. **Activities** • Specify the parameter that characterizes the population of interest. • Specify the action level for the study. • Combine the outputs of the previous DQO steps into an "if...then..." decision rule that defines the conditions that would cause the decision maker to choose among alternative actions. **Outputs From This Step** • An "if...then..." statement that defines the conditions that would cause the decision maker to choose among alternative courses of action.	If preliminary selenium analyses of brine fly larvae, pupae and brine shrimp, combined with the diet data from the birds suggests that 20 percent or more of selenium intake is via the benthic food web, then full-scale spatial temporal analyses of selenium in the benthic food web will be undertaken in Year 2 of the study. This suggested decision would be made by the State, who would need to take into account cost-benefit issues, sampling methods to be used, frequency and spatial extent of sampling, etc.), and funding availability to determine whether this work can be undertaken.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
6. Tolerable Limits on Decision Rules	**Purpose**: Specify the decision maker's acceptable limits on decision errors, which are used to establish appropriate performance goals for limiting uncertainty in the data. **Activities** • Determine the possible range of the parameter of interest. • Define both types of decision errors and identify the potential consequences of each. • Specify a range of possible parameter values where the consequences of decision errors are relatively minor (gray region). • Assign probability values to points above and below the action level that reflect the acceptable possibility for the occurrence of decision errors. • Check the limits on decision errors to ensure that they accurately reflect the decision maker's concern about the relative consequences for each type of decision error. **Outputs From This Step** • The decision maker's acceptable decision error rates based on a consideration of the consequences of making an incorrect decision.	The variability in selenium concentrations in the brine flies between the two regions and multiple depths where they will be sampled will, in part, determine the confidence of predicting how import the benthic food web is for dietary accumulation in birds. Preliminary sampling of brine fly larvae that were presumably found washed to shore had relatively low selenium concentrations and a narrow range (0.8-1.1 mg/kg dry weight) that was within that found for brine shrimp (0.3 – 4.5 mg/kg) (W. Adams, unpublished data). Diets of birds at the Great Salt Lake are largely unknown, but studies at Mono Lake indicate that gulls rely extensively on larvae and pupae for food. Diets of birds in saline California ponds indicated that birds relied much more heavily on brine fly larvae and pupae than on brine shrimp. Because of the judgmental nature of the sampling approach used in this study, no acceptable limits for decision error rates were determined for the sampling design. Specifications of tolerable limits on decision errors through the use of standard statistical methods are not applicable for these parameters. Data quality may also be specified under Measurement Quality Objectives. This quality assessment typically involves specifying performance criteria in terms of the precision, accuracy, representativeness, completeness, and comparability of the data. These performance criteria provide a measure of how well the established Measurement Quality Objectives were met. For this investigation, Measurement Quality Objectives for chemical measurements will be specified in the Quality Assurance Project Plan (QAPP); in general, the Measurement Quality Objectives for selenium are about +/- 20% and for non-selenium measurements they are +/-10%. The QAPP will specify all QA/QC objectives for sample measurement based on each matrix and may be more restrictive or less restrictive than +/-20%.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
7. Optimization of the Sampling Design	**Purpose**: Identify the most resource-effective sampling and analysis design for generating data that are expected to satisfy the DQOs. **Activities** • Review the DQO outputs and existing environmental data. • Translate the information from the DQOs into a statistical hypothesis. • Develop general sampling and analysis design alternatives. • For each design alternative, formulate the mathematical expressions needed to solve the design problems. • For each design alternative, select the optimal sample size that satisfies the DQOs. • Select the most resource-effective design that satisfies all of the DQOs. • Document the operational details and theoretical assumptions of the selected design in the Sampling and Analysis Plan. **Outputs From This Step** • The most resource-effective design for the study that is expected to achieve the DQOs, selected from a group of alternative designs generated during this step.	Sampling and Analysis Plan components: • Field sampling – Sample two regions of lake (east and west) – At each, sample at 3 depths on stromatolites where brine flies are reported to be most abundant. Sample mud and sand substrates, each at a single mid-depth. Less emphasis is placed on these substrates, as brine flies are less likely to be abundant there. • Review variability of each type of sampling (vacuum sampling; Ponar dredge). • Calculate time cost and monetary cost per sample. • Do power analysis to determine the number of stations that would need to be sampled to determine: – Benthic organic matter with 50% error – Brine fly densities with 30% error – Selenium concentrations of brine fly prey with 30% error • Analyze data from QA/QC selenium samples to determine if analytical data quality goals are being met. • Working with Mike Conover, do a preliminary estimate of the relative importance of brine flies as a dietary source of selenium for bird species of interest. • Compare selenium pool (mass) in brine flies, brine shrimp, periphyton, phytoplankton and water (in collaboration with Brad Marden). • Work with Dave Naftz and Bill Johnson to understand movement of selenium from the water column into the benthic food web (sedimentation (CMC 40); selenium uptake by benthic biofilm (CMC 48).

Data Quality Objectives for Great Salt Lake Project 2B: Synoptic Survey of Selenium in Water, Seston, and *Artemia*

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
1. Problem Statement	**Purpose:** Clearly define the problem that requires new environmental data so that the focus of the study will be clear and unambiguous. **Outputs From This Step** • A concise description of the problem. • A list of the planning team members and identification of the decision maker. • A summary of available resources and relevant deadlines for the study.	**Problem:** The State of Utah, Department of Environmental Quality, Division of Water Quality and North Davis County Sewer District need additional critical information for the establishment of a defensible site-specific standard (SSS) for selenium in the open waters of the Great Salt Lake (GSL). Essential components of the SSS have been identified in a detailed conceptual model of selenium cycling in the GSL (Bill Johnson et al., CWECS, University of Utah). This task specifically addresses trophic transfer of selenium within food webs from water to particulate matter (seston) to the dominant zooplankton species *Artemia franciscana.* With respect to the conceptual model these linkages reflect the following pathways: • Water column (excluding deep brine layer) selenium to seston (particulates including phytoplankton): Pathway 39 • Seston to *Artemia*: Pathways 17 and 18 • *Artemia* to avian predators: Pathways 11, 12, and 13. Information from this task will complement avian studies as set forth in Project 1, as well as selenium loading research defined in Project 3. The following high-priority questions will be addressed by this task: 1. What are the concentrations of selenium in GSL water, seston, and *Artemia* tissue? a) What is the correlation between waterborne concentrations of selenium and levels found in seston and *Artemia*? b) What is the potential dietary selenium risk to avian species from consuming *Artemia*? 2. What are the temporal and spatial patterns of isotopic carbon (^{13}C) and nitrogen (^{15}N) in particulate organic matter (POM) and *Artemia* tissue? a) Do ^{13}C and ^{15}N correlate with selenium concentrations in POM and *Artemia*? b) Do selenium, ^{13}C, and ^{15}N in *Artemia* correlate with seston (i.e., phytoplankton abundance)? c) Do the stable isotope fractions in diet indicate discrete sources of selenium that account for Artemia tissue levels of selenium? Do the sources supporting the Artemia body-burdens of selenium vary seasonally? 3. What are the population size, age-structure, and biomass of *Artemia* in the GSL? a) What is the total selenium load in the GSL *Artemia* population? b) How do changing *Artemia* tissue concentrations of selenium and the abundance of adults or cysts correlate with avian consumers and avian seasonality and nesting at GSL? **Planning team members:** Brad Marden (Principal Investigator), Dr. Earl Byron (Project Advisor), with ultimate decision authority by Utah Department of Environmental Quality, considering input by the GSL Steering Committee and GSL Science Panel. **Resources:** Estimated budget for sampling year 2006 is $124,100, including lab costs. Vessels, vehicles, and laboratory facilities necessary for sample collection, preparation, and *Artemia* enumeration will be made available through an agreement with the Utah Strategic Alliance (USA), Mountain Green, UT (MtG). USA is an alliance of brine shrimp industry members. They have a dedicated research vessel that will be provided for the sampling component of this project. The USA will also make available its *Artemia* laboratory facility in MtG. A laboratory analyst, field sampling assistant, and mechanic will also be provided by the USA for this project. Technical support for water and particulate sampling and analysis will be available through Dr. Bill Johnson at the University of Utah, Dr. Dave Naftz at the USGS and Dr. Earl Byron at CH2M HILL. **Deadlines:** April 21, 2006: SOPs, QA/QC protocols, equipment acquisition and testing, sampling methodology, sample site verification. April 30, 2006: first sampling program. May 1 through November 30, 2006: Monthly or semi-monthly sampling programs and bi-monthly reports. August 31, 2006: 6-month summary January 31, 2007: Final Report

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
2. Decision Statements	**Purpose**: Define the decision(s) that will be resolved using data to address the problem. **Approach**: Identify the key question that the study attempts to address and alternative actions that may be taken, depending on the answer to the key study question. **Outputs From This Step** • A statement of the decision that must be resolved using data in order to address or solve the problem. • A list of possible actions or outcomes that would result from each resolution of the decision statement. *Note from EPA guidance on DQO: If the principal study question is not obvious and specific alternative actions cannot be identified, then the study may fall in the category of exploratory research, in which case this particular step of the DQO Process may not be needed.*	**Decisions:** • Results will be used to support an interim selenium standard for the GSL that is protective of wildlife species. More specifically, trophic transfer of selenium within the food web, and bioaccumulation factors from water to seston to *Artemia*, can be used to define a waterborne concentration of selenium that serves to keep the aquatic organism/prey-base tissue value within an adequately protective range for waterfowl and shorebirds. **Possible outcomes:** 1. Determination of an interim water quality standard for the GSL that is partially based upon trophic transfer statistics, and bioaccumulation factors, and can be used for discharge permitting procedures and watershed management decisions. 2. Artemia tissue selenium concentration that is equal to, or below, the acceptable risk level for aquatic-dependent birds: no immediate need for management action. Alternative: Artemia tissue concentration is above acceptable risk level and management action is necessary. 3. Artemia cyst selenium concentration that is equal to, or below, the acceptable risk level for aquatic-dependent birds: no management action becomes necessary. Alternative: Artemia cyst selenium concentration is above acceptable risk level and management action is necessary. 4. Prudent GSL watershed management decisions are made based upon an understanding of selenium cycling dynamics and isotopic nutrient assessments within three components of the GSL food web during an eight-month period.
3. Inputs to the Decision	**Purpose**: The purpose of this step is to identify the informational inputs that will be required to resolve the decision, and to determine which inputs require environmental measurements. **Activities** • Identify the information that will be required to resolve the decision. • Determine the sources for each item of information identified. • Identify the information that is needed to establish the action level for the study. • Confirm that appropriate field sampling techniques and analytical methods exist to provide the necessary data. **Outputs From This Step** • A list of informational inputs (including sources and potential action levels) needed to resolve the decision. • The list of environmental variables or characteristics that will be measured.	**Informational inputs:** Selenium concentrations in pelagic food web components: water, particulates, *Artemia* tissue, and *Artemia* cysts. ^{13}C and ^{15}N in particulates, *Artemia* tissues, and *Artemia* cysts. *Artemia* population dynamics. **Variables/characteristics to be measured:** • Zooplankton assessment: Artemia population characteristics (e.g., biomass, abundance, age-structure); cyst abundance and characteristics. • Total selenium concentrations: Artemia tissue, Artemia cysts, dissolved selenium in water column, selenium burden in particulate phase in water column. • Isotopic nutrients: ^{13}C and ^{15}N in Artemia tissue and POM. • Abiotic assessments: Secchi disk depth, dissolved oxygen, chlorophyll A, temperature.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
4. Study Boundaries	**Purpose**: Specify the spatial and temporal circumstances that are covered by the decision. **Activities** • Define the domain or geographic area within which all decisions must apply. • Specify the characteristics that define the population of interest. • When appropriate, divide the population into strata that have relatively homogeneous characteristics. • Define the scale of decision making. • Determine when to collect data. • Determine the time frame to which the study data apply. • Identify any practical constraints on data collection. **Outputs From This Step** • Characteristics that define the domain of the study. • A detailed description of the spatial and temporal boundaries of the decision. • A list of any practical constraints that may interfere with the study.	**Spatial:** • GSL pelagic zone. • Samples taken throughout water column. • Three regions of lake: North (Antelope Island/Ogden Bay entrance in Gilbert Bay); Central (Hat Island); and South (southern end of Gilbert Bay). • Three depth/substrate profiles with each sampling region: 1) Shallow/Stromatolite; 2) Medium/Sandy; 3) Deep/Unconsolidated and deep brine layer. **Temporal:** Sampling frequency: • Monthly: April, August, September, October, November • Semi-Monthly: May, June, July **Practical constraints on data collection:** • Inclement weather. • Equipment malfunction and failure. • Brine shrimp industry cooperation (i.e., equipment, vessel, facility, and staff from Utah Strategic Alliance)
5. Decision Rules	**Purpose**: The purpose of this step is to integrate the outputs from previous steps into a single statement that describes the logical basis for choosing among alternative actions. **Activities** • Specify the parameter that characterizes the population of interest. • Specify the action level for the study. • Combine the outputs of the previous DQO steps into an "if...then..." decision rule that defines the conditions that would cause the decision maker to choose among alternative actions. **Outputs From This Step** • An "if...then..." statement that defines the conditions that would cause the decision maker to choose among alternative courses of action.	If *Artemia* tissue and cyst selenium concentrations are at acceptable dietary levels for aquatic-dependent wildlife (currently proposed to be 5 mg/kg dry weight), then no management actions are necessary and SSS can be based on current conditions. If *Artemia* tissue and cyst selenium concentrations are relatively consistent both temporally and spatially, then distribution and bioavailability of selenium in the open water of the GSL will be considered uniform. Alternative: If there is a strong spatial or temporal component, then further analysis or study may be necessary to determine predominant factors influencing selenium tissue concentrations. If there is bioaccumulation of selenium through trophic levels, then bioaccumulation factors or regression relationships will be used to calculate a selenium water standard that is protective for aquatic-dependent wildlife. If there is a correlation among ^{13}C, ^{15}N, and selenium in *Artemia* tissue, then isotopic nutrient profiles may be used to prioritize inflow sources or food items for further investigation or water management decisions.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
6. Tolerable Limits on Decision Rules	**Purpose**: Specify the decision maker's acceptable limits on decision errors, which are used to establish appropriate performance goals for limiting uncertainty in the data. **Activities** • Determine the possible range of the parameter of interest. • Define both types of decision errors and identify the potential consequences of each. • Specify a range of possible parameter values where the consequences of decision errors are relatively minor (gray region). • Assign probability values to points above and below the action level that reflect the acceptable possibility for the occurrence of decision errors. • Check the limits on decision errors to ensure that they accurately reflect the decision maker's concern about the relative consequences for each type of decision error. **Outputs From This Step** • The decision maker's acceptable decision error rates based on a consideration of the consequences of making an incorrect decision.	*Artemia* tissue concentrations below 3 mg Se/kg are within a range that is considered representative of background conditions for many kinds of invertebrates and is anticipated to be “relatively safe” from decision errors and also for bird diets. However, further details are needed from Project 1 (avian dietary contents) to determine likely consumption amounts of *Artemia* by GSL birds. A range of 4 to 5 mg Se/kg is considered to represent a dietary threshold level for possible adverse effects, so measurements in that range are more critical. Tissue concentrations exceeding 5.0 mg Se/kg also are more susceptible to decision errors that may adversely affect wildlife if made incorrectly. Because of the judgmental nature of the sampling approach used in this study, no acceptable limits for decision error rates were determined for the sampling design. Specifications of tolerable limits on decision errors through the use of standard statistical methods are not applicable for these parameters. Data quality may also be specified under Measurement Quality Objectives. This quality assessment typically involves specifying performance criteria in terms of the precision, accuracy, representativeness, completeness, and comparability of the data. These performance criteria provide a measure of how well the established Measurement Quality Objectives were met. For this investigation, Measurement Quality Objectives for chemical measurements will be specified in the Quality Assurance Project Plan (QAPP); in general, the Measurement Quality Objectives for selenium are about +/- 20% and for non-selenium measurements they are +/-10%. The QAPP will specify all QA/QC objectives for sample measurement based on each matrix and may be more restrictive or less restrictive than +/-20%.
7. Optimization of the Sampling Design	**Purpose**: Identify the most resource-effective sampling and analysis design for generating data that are expected to satisfy the DQOs. **Activities** • Review the DQO outputs and existing environmental data. • Translate the information from the DQOs into a statistical hypothesis. • Develop general sampling and analysis design alternatives. • For each design alternative, formulate the mathematical expressions needed to solve the design problems. • For each design alternative, select the optimal sample size that satisfies the DQOs. • Select the most resource-effective design that satisfies all of the DQOs. • Document the operational details and theoretical assumptions of the selected design in the Sampling and Analysis Plan. **Outputs From This Step** • The most resource-effective design for the study that is expected to achieve the DQOs, selected from a group of alternative designs generated during this step.	Site Designation: Geographic regions have been designated to represent distinct and diverse input sources of surface water into the GSL. The North-Antelope Island region is strongly influenced by inflow from Farmington Bay and Ogden Bay and to a lesser extent the Bear River drainage. The Hat Island region is distant from any known surface flow input into the GSL. The South-end region is influenced by surface inflow from the Goggin Drain, Jordan River overflow canal, industrial discharges (e.g., Kennecott), and surface flows from Tooele Valley. These regions were assigned to provide a suitable cross representation of the GSL/Gilbert Bay hydrological system. Within each region, depth and substrate profiles were selected due to probable influences of temperature, light penetration, microalgal communities, and geochemical cycling factors. Sample pooling will be used to improve sampling accuracy of site conditions without increasing sample number. **Sample Size.** Sample size was determined to a large extent by logistical and financial constraints. Power analysis can be used to determine optimal sample size and to define alternatives for sample program modifications or subsequent years of research. **Hypotheses:** • Selenium bioaccumulates upward via trophic transfer mechanisms (though not necessarily increasing at each higher trophic level). • There is a correlation between waterborne selenium concentration and levels measured in seston, Artemia tissue and cysts. • There is a correlation between 13C, 15N, and selenium in Artemia tissue and POM. • Artemia population size and age structure are correlated with direct and indirect measures of zooplankton food availability (seston/phytoplankton and Chlorophyll A). • Artemia selenium tissue concentration is correlated with food availability.

Data Quality Objectives for Great Salt Lake Project 3: Measurement and Modeling of Selenium Loads to Great Salt Lake

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
1. Problem Statement	**Purpose:** Clearly define the problem that requires new environmental data so that the focus of the study will be clear and unambiguous. **Outputs From This Step** • A concise description of the problem. • A list of the planning team members and identification of the decision maker. • A summary of available resources and relevant deadlines for the study.	**Problem:** One of the steps required to establish a site-specific standard for selenium in the open waters of GSL is to determine the amount of selenium entering the open water of GSL through surface water, ground water, and atmospheric deposition. With respect to surface water, most rivers that flow into GSL are monitored with respect to discharge and concentration of chemical constituents by the U.S. Geological Survey. Unfortunately, all of the established gaging sites are located significant distances upstream of where the outflow actually enters the open water of GSL. Significant changes in the selenium concentration, as well as other chemical constituents, can occur between the established gaging stations and where the inflow enters into the open water of GSL. New stream gaging station locations are needed that facilitate the measurement of selenium loads entering the open water of GSL. Data gathered from the new gaging infrastructure will allow for the modeling of mean daily selenium loads from all input sources to GSL. The modeling results will be used to determine an annual selenium budget for the open water of GSL. In addition, the modeling results will allow for a comparison of the seasonal and geographic variations in selenium loadings with respect to seasonal biological cycles in the GSL ecosystem (projects 1 and 2). Results from this project will measure the following selenium fluxes identified in the conceptual model: 27 to 33, 68 to 74, and 77. Selenium loadings to the open water of GSL via ground-water discharge and atmospheric deposition are assumed to be small and will not be measured. An ongoing study by researchers at the Duke University is attempting to quantify ground-water discharge to GSL. If successful, their results will be used for the ground-water loading component. **Planning team members:** Dr. David Naftz and Dr. William Johnson (Principal Investigators), and Dr. Earl Byron (Project Advisor), with ultimate decision authority by Utah Department of Environmental Quality, considering input by the GSL Steering Committee and GSL Science Panel. **Resources:** Estimated budget for sampling years 2006-8 is $302,600, including USGS cost-sharing ($89,000) and lab costs. Equipment needed for stream gage installation available through USGS Hydrologic Instrumentation Facility in Mississippi. Trained hydrologic technicians are available among current staff at the USGS Utah Water Science Center for gage installation, operation, and water-quality sampling. Sampling equipment, vehicles, and laboratory trailers used for sampling and sample processing are available from current equipment resources at the USGS Utah Water Science Center in Salt Lake City. Modeling software (LOADEST) and personnel trained in its application are available from current staff at the USGS Water Science Center in Salt Lake City. Finally, the database infrastructure for reporting real-time discharge from the gage sites is operating and available, as are the technical staff and database software (NWIS) for data input and QA/QC of discharge and water-quality data collected from each site. **Deadlines:** Stream gages installed and operating **within 3 weeks of a signed joint funding agreement (on or about** April 15, 2006**).** Preliminary selenium load estimate due on February 28, 2007. Final selenium loading model and associated report due on July 15, 2008.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
2. Decision Statements	**Purpose**: Define the decision(s) that will be resolved using data to address the problem. **Approach**: Identify the key question that the study attempts to address and alternative actions that may be taken, depending on the answer to the key study question. **Outputs From This Step** • A statement of the decision that must be resolved using data in order to address or solve the problem. • A list of possible actions or outcomes that would result from each resolution of the decision statement. *Note from EPA guidance on DQO: If the principal study question is not obvious and specific alternative actions cannot be identified, then the study may fall in the category of exploratory research, in which case this particular step of the DQO Process may not be needed.*	**Decisions:** A specific decision will not be made with the selenium loading data; however, these data will be used in the overall decision of determining a scientifically defensible selenium standard for the open water of GSL. **Possible outcomes:** 1. Variability in current selenium loadings to GSL has no measurable impact on selenium concentrations in the open-water GSL ecosystem (including food organisms for birds). Future selenium loadings to GSL can be increased concurrent with low intensity water-quality and biological monitoring. 2. Variability in current selenium loadings to GSL has a measurable impact on selenium concentrations in the open-water GSL ecosystem (including food-web organisms). Steps must be taken to reduce present and future selenium loadings (as appropriate, based on other results associated with the lake-wide selenium budget).
3. Inputs to the Decision	**Purpose**: The purpose of this step is to identify the informational inputs that will be required to resolve the decision, and to determine which inputs require environmental measurements. **Activities** • Identify the information that will be required to resolve the decision. • Determine the sources for each item of information identified. • Identify the information that is needed to establish the action level for the study. • Confirm that appropriate field sampling techniques and analytical methods exist to provide the necessary data. **Outputs From This Step** • A list of informational inputs (including sources and potential action levels) needed to resolve the decision. • The list of environmental variables or characteristics that will be measured.	**Informational inputs:** Annual, seasonal, and mean daily selenium loadings contributed to the open-water of GSL from surface water inflows. Inflows to be considered include North Arm inflow (2 culverts and 1 causeway breach, Bear River, Farmington Bay, Weber River, Goggin Drain, Lee Creek, and KUCC outfall. **Variables/characteristics to be measured:** Stream stage at 15-minute intervals using automated equipment. Dissolved and total selenium concentration on monthly to daily intervals depending on stream hydrograph and gage site. Selected samples will be analyzed for selenium species (selenate, selenite, and organic selenium). Field pH, specific conductance, and water temperature during selenium sample collection. At 4- to 6-week intervals, measurement of stream discharge and development of stage/discharge relationship. At gages with hydroacoustic equipment, stream discharge will be measured at a similar time interval using acoustic doppler profiling equipment that will be used to develop and index velocity rating curve.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
4. Study Boundaries	**Purpose**: Specify the spatial and temporal circumstances that are covered by the decision. **Activities** • Define the domain or geographic area within which all decisions must apply. • Specify the characteristics that define the population of interest. • When appropriate, divide the population into strata that have relatively homogeneous characteristics. • Define the scale of decision making. • Determine when to collect data. • Determine the time frame to which the study data apply. • Identify any practical constraints on data collection. **Outputs From This Step** • Characteristics that define the domain of the study. • A detailed description of the spatial and temporal boundaries of the decision. • A list of any practical constraints that may interfere with the study.	**Spatial:** All major surface-water inflow sources to the open water of GSL (south arm) will be gauged and sampled. These sites will include KUCC outfall, N. Arm culverts (2), N. Arm causeway breach, Bear River, Weber River, Farmington Bay, Lee Creek, and Goggin Drain. **Temporal:** The period of data collection will be from on or about April 15, 2006 through February 28, 2008. Stage elevation (converted to discharge) will be collected every 15 minutes using automated equipment. Data packages of discharge and stream stage will be uploaded to the USGS real-time web page via satellite at 4-hour intervals. Discharge measurements by trained technical staff will occur at approximately 6-week intervals at each gage site. After QA/QC, discharge data (mean daily values) will be entered into the USGS National Water Information System and published in the USGS Annual Data Report for the state of Utah, by water year (October 1 thru September 30). Water-quality data (dissolved and total selenium, specific conductance, water temperature, and pH) will be collected on a monthly basis during gage operation. Increased sample frequency will occur during spring runoff and in conjunction with biological sampling frequencies. Selected samples (approximately 4 times per year) will be analyzed for the selenium species of selenite, selenate, and organic selenium for forensic information on selenium sources to GSL. **Practical constraints on data collection:** Continuous discharge records can be impacted by equipment malfunction and natural conditions. Because of the near real-time data streams from each gage site, equipment malfunctions are usually repaired within 48 hours of breakdown. Hazardous conditions such as floods and storms can delay or limit the collection of water quality and discharge data due to safety concerns. Discharge equipment installed at the Bear River and Farmington Bay sites is removed annually from December thru mid-February because of the potential damage to equipment from ice flows.
5. Decision Rules	**Purpose**: The purpose of this step is to integrate the outputs from previous steps into a single statement that describes the logical basis for choosing among alternative actions. **Activities** • Specify the parameter that characterizes the population of interest. • Specify the action level for the study. • Combine the outputs of the previous DQO steps into an "if...then..." decision rule that defines the conditions that would cause the decision maker to choose among alternative actions. **Outputs From This Step** • An "if...then..." statement that defines the conditions that would cause the decision maker to choose among alternative courses of action.	If the annual, seasonal, and/or daily selenium loads to the open water of GSL measured during the study period appear to cause associated changes in the lake's selenium concentrations and result in biological effects, then action should be taken to reduce selenium loads in the GSL watershed (as indicated by studies of sediment storage and other aspects of the lake-wide selenium budget). If the annual, seasonal, and/or daily selenium loads to the open water of GSL measured during the study period result in no associated changes in the lake's selenium concentrations or measurable biological effects, then consideration should be given to allowing an increase in selenium loads to GSL. If increased selenium loads are permitted, low-intensity hydrologic and biological monitoring should be executed.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
6. Tolerable Limits on Decision Rules	**Purpose**: Specify the decision maker's acceptable limits on decision errors, which are used to establish appropriate performance goals for limiting uncertainty in the data. **Activities** • Determine the possible range of the parameter of interest. • Define both types of decision errors and identify the potential consequences of each. • Specify a range of possible parameter values where the consequences of decision errors are relatively minor (gray region). • Assign probability values to points above and below the action level that reflect the acceptable possibility for the occurrence of decision errors. • Check the limits on decision errors to ensure that they accurately reflect the decision maker's concern about the relative consequences for each type of decision error. **Outputs From This Step** • The decision maker's acceptable decision error rates based on a consideration of the consequences of making an incorrect decision.	Measured parameters that will impact the decision errors will include stream stage, stream discharge, and selenium concentration (total, dissolved, and selenium species). Measurement error for stream stage and discharge are generally +/- 10 percent; however, certain conditions such as loss of record from equipment malfunction can increase the error range for short time periods. Missing records are qualified in the data base and subsequent selenium loading values calculated with estimated records are also qualified. With the exception of selenium species, measurement error for the analysis of selenium is generally between +/- 5 to 10 percent. Because of the experimental nature of selenium species determination, the analytical error may exceed +/- 20 percent. Sampling error will be minimized by stringent equipment cleaning procedures and sampling methods that integrate samples from the entire stream cross section in equal discharge increments. Policy decisions will be primarily based on dissolved and total selenium loadings; the overall error in discharge measurement and selenium analysis of +/- 10 percent will be within acceptable limits for arriving at accurate and defensible decisions.
7. Optimization of the Sampling Design	**Purpose**: Identify the most resource-effective sampling and analysis design for generating data that are expected to satisfy the DQOs. **Activities** • Review the DQO outputs and existing environmental data. • Translate the information from the DQOs into a statistical hypothesis. • Develop general sampling and analysis design alternatives. • For each design alternative, formulate the mathematical expressions needed to solve the design problems. • For each design alternative, select the optimal sample size that satisfies the DQOs. • Select the most resource-effective design that satisfies all of the DQOs. • Document the operational details and theoretical assumptions of the selected design in the Sampling and Analysis Plan. **Outputs From This Step** • The most resource-effective design for the study that is expected to achieve the DQOs, selected from a group of alternative designs generated during this step.	After detailed consideration of reasonable alternatives, the following design is the most resource effective: 1. Utilize trained USGS stream gaging technicians that are locally available for gage installation, gage servicing, and sample collection. 2. Utilize established USGS methods, discharge equipment, and software for gage operation, data transmission, and data archiving. 3. Utilize existing and local sampling infrastructure (sampling equipment, sampling protocol, vehicles, and laboratory trailers) to execute the sampling plan. 4. Utilize existing technical, database, and publication resources for data QA/QC, real-time data transmission, data archiving, and publication and distribution of results to all interested parties.

Data Quality Objectives for Great Salt Lake Project 4: Measurement of Selenium Flux

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
1. Problem Statement	**Purpose:** Clearly define the problem that requires new environmental data so that the focus of the study will be clear and unambiguous. **Outputs From This Step** • A concise description of the problem. • A list of the planning team members and identification of the decision maker. • A summary of available resources and relevant deadlines for the study.	**Problem:** The development of a selenium standard for the open water of the Great Salt Lake must be supported by a budget for selenium, which is provided in this project. The selenium inputs determined in Project 3 must be balanced against selenium outputs, which are expected to occur mainly via two mechanisms: 1) release of selenium vapor to the atmosphere; 2) permanent burial of selenium in the sediment. These output fluxes cannot be estimated from published literature because these two release processes in the Great Salt Lake have not been heavily investigated. Furthermore, the existing literature for other systems does not address a system of the size, salinity, vertical and spatial heterogeneity, and temporal variability as represented in the Great Salt Lake. The execution of Project 4 requires well-conceived field measurements that are not widely available, but which can be completed locally via the combination of university, federal, and private analytical capabilities as pooled in the CWECS group. High-priority questions to be answered in Project 4: 1. What are the rates of volatilization and ebullition for selenium from the Great Salt Lake? 2. What is the rate of permanent sequestration of selenium via sedimentation? 3. Do transient suspension events re-suspend and re-solubilize selenium into the water column to an extent that has biological significance? 4. Do lake level rises re-introduce selenium into the water column to an extent that has biological significance? **Planning team members:** Dr. William Johnson and Dr. David Naftz (Principal Investigators), and Dr. Earl Byron (Project Advisor); with ultimate decision authority by Utah Department of Environmental Quality, considering input by the GSL Steering Committee and GSL Science Panel. **Resources:** Estimated budget for sampling years 2006-7 is $382,000, including USGS cost-sharing ($35,000) and lab costs. Sampling equipment, vehicles, and laboratory trailers used for sampling and sample processing are available from current equipment resources at the USGS Utah Water Science Center in Salt Lake City. Analytical facilities and technical support for selenium vapor analyses are available at the University of Utah. Analytical facilities and technical support for particulate selenium analyses are available at the University of Utah. Equipment and expertise for sediment coring are available via an agreement made between Dr. David Naftz and Dr. Peter van Metre at the USGS. Expertise and equipment needed for dissolved gas probes and total dissolved gas samplers are available via an agreement made between Dr. W.P. Johnson and Dr. D. Kip Solomon at the University of Utah. The database infrastructure for reporting analytical results (NWIS) is available via Dr. David Naftz at the USGS. **Deadlines:** March 2007 will serve as the deadline for the following deliverables: 1) preliminary estimate of selenium flux to atmosphere via vaporization and volatilization 2) preliminary estimate of selenium flux to lake bottom via sedimentation 3) preliminary estimate of selenium permanent burial flux and remobilized flux during diagenesis 4) preliminary estimate of selenium remobilization flux via lake area change

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
2. Decision Statements	**Purpose**: Define the decision(s) that will be resolved using data to address the problem. **Approach**: Identify the key question that the study attempts to address and alternative actions that may be taken, depending on the answer to the key study question. **Outputs From This Step** • A statement of the decision that must be resolved using data in order to address or solve the problem. • A list of possible actions or outcomes that would result from each resolution of the decision statement. *Note from EPA guidance on DQO: If the principal study question is not obvious and specific alternative actions cannot be identified, then the study may fall in the category of exploratory research, in which case this particular step of the DQO Process may not be needed.*	**Decisions:** A specific decision will not be made with the selenium output data; however, these data will be used in the overall decision of determining a scientifically defensible selenium standard for the open water of GSL. **Possible outcomes:** 1. Selenium removal fluxes may indicate that current selenium loadings to GSL have no expected impact to the open-water GSL ecosystem. If so, future selenium loadings to GSL can be increased concurrent with low intensity water-quality and biological monitoring. 2. Selenium removal fluxes may indicate that current selenium loadings to GSL have significant impact to the open-water GSL ecosystem. If so, steps should be taken to reduce present and future selenium loadings.
3. Inputs to the Decision	**Purpose**: The purpose of this step is to identify the informational inputs that will be required to resolve the decision, and to determine which inputs require environmental measurements. **Activities** • Identify the information that will be required to resolve the decision. • Determine the sources for each item of information identified. • Identify the information that is needed to establish the action level for the study. • Confirm that appropriate field sampling techniques and analytical methods exist to provide the necessary data. **Outputs From This Step** • A list of informational inputs (including sources and potential action levels) needed to resolve the decision. • The list of environmental variables or characteristics that will be measured.	**Informational inputs:** Dissolved volatile selenium concentrations in the water column. Selenium concentrations among biological and mineral phases ranging from molecular to particulate in the water column, newly accumulating sediment, and accumulated sediment. **Variables/characteristics to be measured:** Semi-monthly measurements of dissolved volatile selenium concentrations at 3 locations and 3 depths below surface. Semi-monthly measurements of total dissolved vapor pressure at 20 locations and 5 depths. If total dissolved vapor pressure exceeds hydrostatic pressure, selenium vapor concentrations will be measured via floating flux chamber. Selenium vapor concentrations via quadrupole mass spectrometry (available at University of Utah). Sediment samples from 20 locations will be measured for total organic carbon and total selenium (to support determination of vapor sources). Semi-monthly measurements of sediment flux (via sediment traps) at 2 locations. Analysis of accumulating sediment for total selenium (via hydride generation AA after extraction) as well as selenium burden among the biological and mineral particulates according to size fraction ranging from molecular through colloidal (via field flow fractionation coupled to collision cell-inductively coupled plasma mass spectrometry). Semi-monthly measurements of selenium burdens in particulate phase in water column overlying sediment traps. Continuous measurement of extent of mixing of Deep Brine Layer with Shallow Layer between and during storm and wind events (turbidimeter and thermistor strings) at 2 locations and 5 depths, with additional characterization of water column (2 depths) immediately following storm events at these locations. Meteorological data are available from the National Weather Service. Total Se and Se burdens on particulate size-fractions from submerged sediment cores (10-15 locations). Extractable Se from submerged sediment cores. Total Se extracted via fresh water leaching from exposed sediment samples (10-15 locations). Total Se in three cores (3 locations) as a function of depth (age via ^{137}Cs) at 8 depths per core. Additional elemental information (e.g. Cs or Al) via ICP-MS.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
4. Study Boundaries	**Purpose**: Specify the spatial and temporal circumstances that are covered by the decision. **Activities** • Define the domain or geographic area within which all decisions must apply. • Specify the characteristics that define the population of interest. • When appropriate, divide the population into strata that have relatively homogeneous characteristics. • Define the scale of decision making. • Determine when to collect data. • Determine the time frame to which the study data apply. • Identify any practical constraints on data collection. **Outputs From This Step** • Characteristics that define the domain of the study. • A detailed description of the spatial and temporal boundaries of the decision. • A list of any practical constraints that may interfere with the study.	**Spatial:** The boundaries of the system are as described in the conceptual model. The number of locations proposed for sampling sediment and water column selenium is described above. **Temporal:** The initial period of data collection will be from on or about April 15, 2006 through February 28, 2007. **Practical constraints on data collection:** The major constraint is weather. Since storms can impact our ability to measure and sample on the lake, we have described the samples as “semi-monthly” to reflect the fact that weather will likely impact a strict monthly sampling plan. A secondary constraint is boat availability, which is being negotiated through Dr. David Naftz. An additional potential constraint is sediment coring equipment availability and technical expertise. Dr. David Naftz is negotiating aid from Dr. Peter van Metre, who is a USGS researcher focused on sediment coring.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
5. Decision Rules	**Purpose**: The purpose of this step is to integrate the outputs from previous steps into a single statement that describes the logical basis for choosing among alternative actions. **Activities** • Specify the parameter that characterizes the population of interest. • Specify the action level for the study. • Combine the outputs of the previous DQO steps into an "if...then..." decision rule that defines the conditions that would cause the decision maker to choose among alternative actions. **Outputs From This Step** • An "if...then..." statement that defines the conditions that would cause the decision maker to choose among alternative courses of action.	1. If the measured volatile selenium concentrations are significant, then the selenium flux to the atmosphere via volatilization will be included in the selenium budget. If the measured dissolved volatile selenium concentrations are below detection at all locations and depths during the summer and fall months, then selenium volatilization will be considered negligible. 2. If the measured total dissolved gas pressure is significantly greater than hydrostatic over a significant time at any location, then funds will be requested for a floating flux chamber to collect vapor at these locations for selenium analysis and estimation of ebullition flux. In this event, the ebullition flux of selenium to the atmosphere will also be added to the selenium budget. 3. If mixing of the Deep Brine Layer into the Shallow Layer is significant during storm events, then this redistribution of selenium between these layers will be added to the selenium budget. 4. If the selenium flux to sediment (via sediment traps) exceeds the flux of selenium permanently buried (via dated cores) the difference will be assumed to represent loss of sediment selenium to the water column during diagenesis. This diagenetic loss will be factored into the rate of permanent selenium burial in the selenium budget. 5. If the proportion of selenium to biological and mineral particulate phases differs between sediment cores and sediment traps, these differences will improve understanding of the processes operating during diagenesis, and these findings will guide the refinement of the sedimentation flux terms in the selenium budget. 6. If the extraction of selenium from exposed sediment via representative surface water is significant, then this flux will be included into the selenium budget to reflect the influence of lake area change on the selenium budget. Likewise, if the extraction of selenium from submerged anoxic cores and submerged Littoral Sediment cores show significant extractability of selenium, this information will be used to refine selenium flux terms related to lake area change.

Step	DQO Guidance of Purpose and Outputs of Step	Great Salt Lake Project
6. Tolerable Limits on Decision Rules	**Purpose**: Specify the decision maker's acceptable limits on decision errors, which are used to establish appropriate performance goals for limiting uncertainty in the data. **Activities** • Determine the possible range of the parameter of interest. • Define both types of decision errors and identify the potential consequences of each. • Specify a range of possible parameter values where the consequences of decision errors are relatively minor (gray region). • Assign probability values to points above and below the action level that reflect the acceptable possibility for the occurrence of decision errors. • Check the limits on decision errors to ensure that they accurately reflect the decision maker's concern about the relative consequences for each type of decision error. **Outputs From This Step** • The decision maker's acceptable decision error rates based on a consideration of the consequences of making an incorrect decision.	Because of the judgmental nature of the sampling approach used in this study, no acceptable limits for decision error rates were determined for the sampling design. Specifications of tolerable limits on decision errors through the use of standard statistical methods are not applicable for these parameters. Data quality may also be specified under Measurement Quality Objectives. This quality assessment typically involves specifying performance criteria in terms of the precision, accuracy, representativeness, completeness, and comparability of the data. These performance criteria provide a measure of how well the established Measurement Quality Objectives were met. For this investigation, Measurement Quality Objectives for chemical measurements will be specified in the Quality Assurance Project Plan (QAPP); in general, the Measurement Quality Objectives for selenium are about +/- 20% and for non-selenium measurements they are +/-10%. The QAPP will specify all QA/QC objectives for sample measurement based on each matrix and may be more restrictive or less restrictive than +/-20%.
7. Optimization of the Sampling Design	**Purpose**: Identify the most resource-effective sampling and analysis design for generating data that are expected to satisfy the DQOs. **Activities** • Review the DQO outputs and existing environmental data. • Translate the information from the DQOs into a statistical hypothesis. • Develop general sampling and analysis design alternatives. • For each design alternative, formulate the mathematical expressions needed to solve the design problems. • For each design alternative, select the optimal sample size that satisfies the DQOs. • Select the most resource-effective design that satisfies all of the DQOs. • Document the operational details and theoretical assumptions of the selected design in the Sampling and Analysis Plan. **Outputs From This Step** • The most resource-effective design for the study that is expected to achieve the DQOs, selected from a group of alternative designs generated during this step.	After detailed consideration of reasonable alternatives, the following design is the most resource-effective: • For total dissolved gas pressure measurements: plan for 20 locations and 5 depths to allow measurement across a large area, to address spatial variability in ebullition rates. Monitor on a semi-monthly basis to address temporal variability. • For measurement of vapor selenium in equilibrium with dissolved selenium in the water column, choose three depths that represent the vertical zone where mass transfer to the lake surface is limited (occurs via diffusion rather than mixing). Utilize established sampling methodologies for dissolved volatile compounds. • For measurement of settling flux, sediment traps should be deployed at 2 or more locations, and this information should be supplemented with water column samples at these locations plus an additional 6 locations. Two sediment traps are deployable under an existing monitoring project (USGS-DWQ). For measurement of re-suspension flux, thermistor strings should be deployed at 5 locations, with at least three over the deep brine layer. Thermistor strings should span a vertical distance to bracket the interval over which sediment and Deep Brine Layer suspension are expected to occur. Turbidimeters on the thermistor strings should be placed at depths expected to be representative of mixing over significant distances, rather than immediately adjacent to interfaces. • Exposed and submerged core samples should be sufficient in number to reflect spatial variability in the system. Hence, 20-30 cores (submerged and exposed) will be taken to meet this requirement. These cores will undergo tests for extractability of selenium via geochemical shifts that correspond to expected effects from lake level variation. Three sets of replicate cores from distinct locations will be used to determine Se sedimentation rates and elemental information as a function of depth. This number represents a tradeoff between the need to capture spatial variability and the expense associated with ^{137}Cs and elemental analyses.

APPENDIX B

Laboratory Standard Operating Procedures

APPENDIX C

Sampling Standard Operating Procedures

Avian Diet Sampling

PREPARED FOR: State of Utah, Division of Water Quality

PREPARED BY: Dr. Michael Conover, Utah State University
Dr. John Cavitt, Weber State University

COPIES: CH2M HILL

DATE: May 11, 2006

Food Items for Gulls

We will use boats, ground observations and fixed-wing aircraft to identify the locations on the GSL where the birds from each colony or nesting site are foraging (henceforth called the food-item sampling area, or FISA). FISAs will be named after their respective nesting site, and each nesting site will have one FISA associated with it.

We will collect food items from a FISA by seining behind a boat. By using a seine with a proper mesh size, we can collect a pure sample of adult brine shrimp. At those sites where the water is less saline, some corixids may be mixed in with the shrimp. If so, corixids are large enough that they will be removed individually. To collect a sample of brine fly larva, we will seine with a smaller mesh net that collects both brine shrimp and brine fly larva. Once brought back to the boat, this net is placed in a tray containing water from the GSL. The brine fly larvae are small enough to wiggle out of the net, but the shrimp are too large and immobile to do so. The contents of the water container are then poured through a finer mesh that strains the larva from the water. We will collect up to 5 brine shrimp, 3 brine fly larva, and 3 corixid (when present in a FISA) samples per FISA. Samples will be collected in a systematic manner across each FISA. Each sample will be frozen in a Whirl-pak or new Nalgene bottle. Each sample will be labeled with its location and collection date. All food items from a single colony will be stored together in a 9 X 12 envelope upon which is ascribed the date and FISA where the enclosed samples were obtained.

Food Items for Shorebirds

FISAs will be delineated from the point birds were first detected foraging to the point where they are collected. During a 15-min. feeding observation, we will record the amount of time each bird spends within each foraging microhabitat (e.g., exposed mudflat, shallow water, moderate water, deep water). After each shorebird observation/collection, invertebrates will be collected from the mudflat, benthos, and water column within each foraging area. Invertebrate food items (brine fly adults and/or larvae or pupae and brine shrimp, depending on what the birds are eating) will be collected opportunistically in the general area of each foraging area. If available, three samples of each species and life stage (i.e., larvae, pupae or adult of brine flies) will be collected at each area, with sufficient biomass for analysis (target 5 grams) and additional biomass when that is feasible. However, the

numbers and types of invertebrate samples will be based on what the birds are eating. Each sample will be frozen in a Whirl-pak or new Nalgene bottle. Each sample will be labeled with its location and collection date. All food items from a single FISA will be stored together in a 9 X 12 envelope upon which is ascribed the date and FISA where the enclosed samples were obtained.

Water Samples

We will collect 1–5 water samples from each FISA. Each water sample will be a composite water sample with 20% of the composite water sample coming from 5 different sites systematically distributed across the FISA. Water will be filtered through a 1-mm mesh to remove large items from the sample. All samples will be collected in new Nalgene bottles and stored at room temperature. After 48 hours, the water in each bottle will be decanted and placed in a new Nalgene bottle to separate the water sample from any sediment in the sample.

Sediment Samples

We will collect 1–3 sediment samples for each colony. The sediment sample will be a composite sample with 20% of the composite sample coming from each of 5 sediment core samples collected from 5 sites systematically distributed across each FISA. Each sediment samples will be taken to a maximum depth of 5cm being careful to collect any fine organic matter at the surface. The sediment sample will be stored under refrigeration or frozen until they are shipped to the laboratory for selenium and total organic carbon analyses.

Avian Egg Collection

PREPARED FOR: State of Utah, Division of Water Quality

PREPARED BY: Dr. John Cavitt, Weber State University
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COPIES: CH2M HILL

DATE: April 11, 2006

Introduction

Avian eggs are a common sample matrix for contaminants analysis. An accurate analysis depends upon getting the egg contents from the shell to a clean sample jar without introducing other sources of contamination.

Materials and Equipment

1) GPS unit
2) permits
3) field data sheets, writing instruments (pencils/pens/permanent markers)
4) padded egg collection boxes (hard-sided container, e.g. egg cartons, Tupperware or tackle box, with foam padding)

Procedures

1) Collected eggs should be whole and not cracked. Depending upon your sampling scheme, you may collect fresh eggs or eggs with well-developed embryos. Eggs with late-stage embryos can be recognized at time of collection using egg floatation methods (Custer et al. 1992), collecting from unfinished clutches, etc.), or you may target addled eggs (eggs that failed to hatch), or all of these types of eggs. The best eggs for contaminants analysis are not cracked, since cracking increases variation in percent moisture, and may lead to leakage or contamination of the contents. Eggs with well-developed embryos can be examined for gross abnormalities and malpositions of the embryo.
2) A preformatted field data sheet will be filled out that will include a unique nest/egg identification code, location (using GPS coordinates for the nest), date, number of eggs in the clutch, and initial estimation of incubation stage.
3) In the field, mark eggs with unique identification code, date, and number of eggs in the clutch and place in egg container.
4) Transport to lab in hard container with sufficient padding.

5) Refrigerate eggs until opened, ideally no longer than seven days.

References

Custer, T.W., G.W. Pendleton, and R.W. Roach. 1992. Determination of hatching date for eggs of black-crowned night-heron, snowy egrets, and great egrets. J. Field. Ornithol. 63:145-154.

Egg Breakout

PREPARED FOR:	State of Utah, Division of Water Quality
PREPARED BY:	University of California Davis, Avian Sciences Department, CH2M HILL, Sacramento Fish and Wildlife Office, Environmental Contaminants Division
COPIES:	CH2M HILL
DATE:	April 21, 2006

Introduction

Store eggs in a refrigerator if they cannot be processed immediately after collection. Do not freeze whole eggs because this will crack the shell. Ideally, eggs should be processed as soon as possible after collection, and within seven days of collection. However, because refrigeration arrests development, the vascularization and bright red color of the blood in an egg collected with a living embryo is preserved for a longer period of time.
The following describes the process of harvesting avian eggs in the laboratory. The goal of this description is standardize procedures for processing avian eggs in order to collect a standardized set of data on whole eggs, embryos, and shells while minimizing the possibility of laboratory contamination of samples. The types of containers and instruments as well as cleaning procedures will vary with the contaminant that is being investigated. Field collection protocols are considered separately and vary with species and study objectives.

Required Supplies

The supplies needed for the procedures include:

1. WHOLE EGG MEASUREMENTS: distilled-deionized water, volumeter (immersion chamber or graduated cylinder), egg candler, Kimwipes, laboratory balance (to 0.05 g increments), vernier caliper (graduated to 0.0l mm).
2. EGG HARVEST: glass jars of appropriate size (chemically-cleaned and with TFE cap-liners) or Nalgene jars (depending on contaminant), weigh boats, stainless steel surgical scissors, forceps, blunt probe, lead pencil or waterproof marker.
3. SHELL THICKNESS: Micrometer modified for measuring eggshell thickness such as Federal 35 comparator with rounded contacts (graduated measurement to 0.01 mm - estimatable to nearest 0.001 mm) or modified Starrett micrometer (graduated measurement to 0.01 mm - estimatable to nearest 0.001 mm).

Egg Measurement Procedure

1) If possible, eggs should be candled to determine if cracks are present in the shell. Any cracked egg should not be rinsed or immersed in water as this may contaminate the sample.

2) If an egg is not cracked and is dirty (soil, feces) it should be cleaned with a Kimwipe and distilled-deionized water that is at or near the temperature of the egg.

3) Write the sample ID number on both ends of the eggshell with a dull pencil or waterproof marker (both IDs must be legible).

4) Record any remarkable characteristics of the egg (e.g., cracked, dented, discolorations, small in size, etc.).

5) Record the mass (g) of the whole egg, then measure the length (mm) and breadth (mm) of the egg at their greatest dimensions with calipers. (To obtain an accurate measurement of length, one must ensure that the caliper jaws are parallel to the longitudinal axis of the egg. For the breadth measurement, the jaws must be held perpendicular to the longitudinal axis of the egg.)

6) Determine and record the egg volume (cm^3), the method of choice will depend on whether the shell is intact or cracked and what contaminants are being investigated. If determining the fresh weight of the egg is important (e.g., investigating organochlorine contaminants) the "Intact Shell" method is recommended, for investigating contaminants such as selenium the volume can be calculated from measurements (i.e., "Cracked Shell" method).

7) INTACT SHELL: For eggs with intact shells, determine the egg volume using the water displacement technique outlined below.

    a) If using an immersion chamber, place it next to and above the pan of a laboratory balance. Set a collection vessel on the balance's pan under the side arm of the volumeter. Next, place a wire loop in the volumeter. Fill the volumeter with distilled-deionized water that is slightly warmer than the egg temperature until it flows freely from the volumeter side arm (remember, the temperature of the water should be as close to the temperature of the egg as possible as this will minimize water movement across the eggshell pores). When the water stops flowing, empty the receptacle and return it to the balance pan. Tare the water receptacle. Gently raise the wire loop and place the egg on it. Gently lower the egg until it is completely submersed (lower the egg as quickly as possible without overflowing the volumeter, or breaking the egg). The weight of the displaced water equals the volume (cm^3) of the egg. Repeat this procedure three (3) times for each egg and report the average value.

    b) If using a graduated cylinder, fill it with distilled-deionized water and note the starting volume. Using a wire loop, immerse the egg into the graduated cylinder until top of the egg is just below the water surface. Note the final volume and subtract starting volume to determine egg volume. Repeat this procedure three (3) times for each egg and report the average value.

8) CRACKED SHELL (or if an immersion chamber or graduated cylinder is not available): For eggs that are cracked or dented, egg volume is estimated using the length and breadth measurements and an equation from the published literature (e.g. Westerskov 1950, Stickel et al. 1973, Hoyt 1979).

Egg Harvest

(Note: All tools used in egg harvest and embryo exam must be cleaned between egg exams. Investigators should wear surgical gloves and change gloves between eggs.)

1) VENT EGG IF NECESSARY. For eggs with a strong odor (indicating advanced decomposition of the contents), it is advisable to vent the egg before attempting to open it (explosions are possible). With safety glasses in place, gently insert a chemically-clean needle into the blunt end of the egg. Use gentle but steady pressure to pierce the shell.

2) OPEN WINDOW AT BLUNT END OF THE EGG. Tare a chemically- clean jar and loosen the lid and tare the jar. Work over a c lean glass Petri dish or weigh boat. Method 1- using surgical scissors, apply gentle pressure while rotating the scissors so a small hole is made in the shell at the blunt end of the egg just above the air cell. Continue cutting from the hole and cut around the entire egg above the air cell. Method 2- Rest the egg lengthwise on an appropriate surface (compatible with the analyses requested). Using a clean sharp scalpel, gently score the egg about the blunt end of the egg. Apply gentle, steady pressure and make several rotations. If candling of the egg revealed an advanced state of incubation with air cell development, try to remove shell from just above the air cell. Membrane may need to be peeled back to allow further inspection of the embryo.

3) INSPECT EMBRYO POSITION IN THE EGG. Visually inspect the egg contents through the window and note the size of the air cell. This window is used to assess whether the position of the embryo in the egg is normal. Note embryo position and whether the embryo has pipped into the air cell. Determination of embryo position is not accurate until the embryo is ready to pip the air cell (i.e., the last 4-5 days of incubation). Shedding the nare caps is a good landmark for avocets and stilts. Normal position of the embryo during the final stages before pipping is with the head in the blunt end of the egg, with the head under the right wing and with the beak pointed toward the air cell. If incubation stage is very late (i.e., just prior to pipping from the shell), the embryo beak is in the air cell to allow pulmonary respiration to begin. There are six malpositions of the avian embryo, as follows:

    i) head between thighs,

    ii) head in small end of egg,

    iii) head under left wing,

    iv) embryo rotated so that the beak is not directed toward air cell,

    v) feet over head,

    vi) beak over right wing

4) Malpositioned embryos usually do not hatch, and positions I, III, and V are usually lethal.

5) Usually the egg contents can be poured out into the container from the window opened for embryo inspection. If necessary, use surgical scissors and make transverse cuts from the blunt end to the narrow end of the egg to facilitate egg opening.

6) OPEN EGG. Inspect embryo position and note age of the embryo. To estimate age of the embryo use stages of incubation from literature. The model reference for aging embryos is Lillie's development of the chick (Hamilton 1952) Chapter 3. Good day-by-day embryo stage data with pictures exist for chickens, mallards (Caldwell and Snart 1974), kestrels (Pisenti et al. 2001), and cockatiels (Abbott et al. 1991). If no embryo can be found, examine the yolk for the presence of a blastodisc. If fertile and the yolk is intact, this will appear as a white donut shape floating on top of the yolk. If infertile, no distinct donut will be apparent. Note presence (and whether they are of normal size for the stage of development) or absence of eyes and of limbs or limb buds; note presence and number of digits on the feet; measure length of tarsus and upper mandible. Look for evidence of internal hemorrhage, edema, brain swelling, or failure of the body wall to completely close. Minimize handling of the embryo to the degree possible and conduct as much as possible of the above exam in the half shell. Use clean forceps, and beware of cross contamination. Pour the contents into the opened jar. If necessary, use a clean spatula to scrape any remaining contents into the jar (be careful not to tear the shell membrane when using spatula). Record presence or absence of an embryo, estimated age of embryo, other measurements taken, and abnormalities (if any).

7) 4 EGG CONTENTS MASS (g): Measure and record the weight in grams of the tared jar.

8) Label jar with SAMPLE ID and SAMPLE MASS (place one label on the lid and the other on the jar itself), and immediately store the sample in the freezer.

9) Rinse the interior of the shell halves with tap water being careful not to tear the membrane, or erase the sample IDs. After the shells dry, use a waterproof marker to remark the shells with their sample ID. Store the shells in a cool dry place for at least 30 days, or until they have attained a constant mass. Recycled egg cartons serve as excellent storage containers for egg shells. One tip to ensure that shells do not migrate from their respective compartments, is to place a folded sheet of paper over the shells before closing the carton.

Shell Thickness Measurement

1) Determine the eggshell mass (to nearest 0.001 g) of dried shells.

2) Allow eggshells to air dry for at least 30 days and measure eggshell thickness using an appropriate micrometer. Take thickness measurements of each shell along the equator at five places. Minimize influence of shell shape and curvature on the measurement taken. Report the average of all five measurements as the final thickness measurement. If the membrane has separated from the shell, take measurements without the membrane but be sure to make note of this on the data sheet. If possible then obtain measurement of membrane fragments.

3) Calculate the Ratcliffe Index (Ratcliffe 1967) with the following formula:
   THICKNESS INDEX = EGGSHELL MASS (mg)/ EGG LENGTH (mm) x EGG WIDTH (mm)

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Harvest of Adult Birds

PREPARED FOR: State of Utah, Division of Water Quality

PREPARED BY: Dr. Michael Conover, Utah State University
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COPIES: CH2M HILL

DATE: May 11, 2006

Harvest of Adult Gulls

The intent is to collect a sample of gulls from each colony to establish their diet and collect samples of liver, blood, and food in their crops. Because food samples are desired, gulls will be shot with a 12-gauge shotgun as they are returning to the colony from foraging. These birds can often be identified by their straight-line, rapid flight directly towards the colony. Gulls often leave foraging sites in small groups and travel back together. Hence, we will randomly select one gull in each group and kill it. We will then wait at least 5 minutes before selecting another returning gull to collect. Gulls will be shot far enough away from the colony (0.5–1.0 km) so as not to attract gulls from the colony because then it will be hard to distinguish between them and returning foragers. Birds returning to the colony after foraging use flight lines where updrafts occur. Gulls will be shot as they travel along these flight lines so that we will be blind to their foraging locations and therefore cannot bias the results. When there are multiple flight lines coming into a single colony, we will collect 4 gulls from 3 flight lines located on different sides of the colony. We will collect 12 gulls from each colony in case we are unable to draw blood from some of them or in case a couple of them contain no food.

Harvest of Adult Shorebirds

Dietary information will be obtained by direct examination of gut contents. Five adults of each species will be collected at each site at the beginning of the nesting season (USFWS Permit #MB043593-0; UT Division of Wildlife Resources COR# 1COLL7037). Collections will be made as early in the season as possible to minimize disturbance of incubating birds. American avocet and black-necked stilt will be collected after individuals have been observed feeding for >15min. This will ensure that food items are present within the esophagus. Material collected from the ventriculus is less reliable as an indicator of diet since easily digested items are quickly passed to the intestines whereas hard material can be retained for weeks.

Collection of Samples

Blood

As soon as the adult bird is collected, blood will be collected from the heart or thoracic cavity using a sterile, non-heparinized syringe. We will attempt to collect 1–2 cc of blood. Once the blood is collected, the syringe will be closed with its cap. To reduce the possibility of contamination, the blood will be stored in the syringe and the syringe will be placed in a freezer or will be transferred to sterile, Nalgene, cryogenic vials and then frozen for analysis.

Food

California Gulls

Either in the field (preferably) or back in the lab, all food in the bird's esophagus from its gizzard to its mouth will be collected and weighed. The major types of food items in the sample will be identified at this time. The sample will then be divided in half. One half will be placed in a container with 95% alcohol to preserve it. This sample will be examined later using a dissecting microscope to more accurately assess the composition of the food sample. Special attention will be given to assess the proportion of the sample made up of brine shrimp, corixids, brine fly adults, brine fly larva, and food from a non-GSL source. The volume composition of samples (as percent) will also be determined. The rest of the food sample will be frozen in a Whirl-pak or new Nalgene bottle for selenium analysis.

Shorebirds

Immediately following collection, esophageal, proventricular, and ventricular contents will be removed, separated, and placed in individual containers with 80% ethanol. In addition the mouth (pharynx) will be rinsed with 80% ethanol and wash collected. These samples will be examined later using a dissecting microscope to more accurately assess the composition of the samples. Special attention will be given to assess the proportion of the samples made up of brine shrimp, corixids, brine fly adults, and brine fly larva. The volume composition of samples (as percent) will also be determined.

Liver

At least 2 grams of the liver will be removed, weighed, and frozen in a Whirl-pak or new Nalgene bottle.

Sample Labels

All samples (food, blood, and liver) will be labeled on the outside with the bird ID number. No internal labels will be used to guard against contamination. For each bird, its blood, liver, and food samples will be placed together in an envelope that also contains the bird's ID number, date, and place collected. Hence, each sample will be doubly labeled. Samples from all birds collected at a single colony will be stored together.

Bird Carcass

Each bird will be placed in a plastic freezer storage bag and frozen. Before doing so, it will be weighed, sexed, and aged (adult or sub-adult). Females will be checked to see if they are actively producing eggs. Physical measurements will also be taken (body length, wing length, head length and width, and bill length and width).

Flow Measurement

PREPARED FOR:	State of Utah, Division of Water Quality
PREPARED BY:	Dr. David Naftz, USGS
COPIES:	CH2M HILL
DATE:	May 1, 2006

Standard operating procedures will be per the following references.

References:

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Sampling of Benthic Zone

PREPARED FOR: State of Utah, Division of Water Quality

PREPARED BY: Dr. Wayne Wurtsbaugh

COPIES: CH2M HILL

DATE: June 28, 2006

The objective of Project 2A is twofold. First, we will develop methods for collecting the benthic periphyton/detrital mass that brine flies feed on, and the larval and pupal flies themselves. Secondly, these benthic samples and the overlying water taken in the production zones (water at 1-5 m depth) will be used for selenium analyses.

Sampling Sites

1. Bridger Bay on NW corner of Antelope Island near shorebird study area.
2. SW corner of Gilbert Bay near Kennecott outfall and additional shorebird study area.

Sampling Substrates and Depths

In each zone we will focus on sampling stromatolites, the principal habitat of brine flies, but we will also sample on sand and mud substrates.

1. Stromatolites (3 depths/zone): 1, 3, 5 m
2. Sand (1 depth/zone): 3-5 m
3. Mud (1 depth/zone): ca. 5 m

Sampling procedures

1. Water samples (lab preparations):
   a. Bottles, 250 mL polyethylene:
      - Label (Note that the label should be covered with clear packaging tape to protect it.)
      - Wash with 1N hydrochloric acid in lab
      - Rinse 4 times with deionized water (DI), cap & place bottle in plastic bag

   b. Sampling syringes, 60 mL (4/depth; Prepare 16 total)
      - wash in Liquinox
      - rinse 4 times with DI
      - fill with 1N hydrochloric acid and let sit for 30 minutes
      - eject acid and rinse 4 times with DI
      - place in new, clean plastic bags

   c. Clean syringe filters
      - Soak 47-mm filter holder in 1-N hydrochloric acid for 30 minutes
      - rinse 4 times with DI

- place in plastic bag
- in field, remove syringe filters, insert 47-mm, 0.45 um membrane filters with acid-cleaned and DI-rinsed forceps. Fill syringe with 60 mL DI, attach filter holder and eject 60 mL of water through filter to rinse.

d. Field sampling by SCUBA divers:
- First collect water samples at each site to minimize bottom stirring by divers.
- Divers will take 4 syringes to each site in plastic bags.
- Approximately 0.5 m above substrate rinse syringe 3 times by repeated plunges of plunger. Eject all rinse water. Move to undisturbed bottom.
- Place syringe intake 1 cm above stromatolite, sand or mud and draw sample. Place filled syringe in bag. Move 1 m laterally and draw second sample. Repeat until 4 syringes are filled. Bring syringes to surface.
- In boat, attach filter holder to sampling syringe and eject 40 mL of sample water through filter to rinse. Use this water to rinse the sample bottle. Shake vigorously and discard water from bottle. Fill bottle with remaining 20 mL. Attach 3 other syringes and filter all 60 mL water from each remaining syringe into bottle for a total sample of 200 mL.
- Add 1% (2-mL HNO_3 (Ultrex grade)) to each bottle using acid-rinsed disposable pipette tip. Cap bottle and place in plastic bag then in cooler.

2. Stromatolites: Periphyton, larval, and pupal brine flies

a. Containers:

i. Periphyton. Rinse ten 500-mL plastic jars with 1-N HCl. Rinse 4 times with DI. Place label tape on each jar.

ii. Brine flies. Rinse 50 heavy-duty 1.5-gallon zip-lock bags with DI.

b. Rinse two 500-µm screen sieves repeatedly with surface lake water to remove any sediments

c. Brine flies will be sampled on hard stromatolite surfaces by SCUBA divers using a vacuum pump sampler similar to that of Voshell et al. (1992). The sampler consists of an inverted plastic canister with a port and glove attached to the side of the canister so that a diver can agitate the substrate. A hose attached to the bucket allows the sample to be brought to the surface with a hand-powered pump and to be collected in a net.

i. *Site selection.* A weighted marker line will be dropped from each side of the boat. Divers will deploy down this line, bringing the canister with them. Sampling will commence on the nearest stromatolite surface large enough to accommodate the whole canister so that it covers only stromatolite and not other substrates.

ii. *Sampling at depth*: Scrub stromatolite surface with 3" diameter brush until “all” organic material, including flies, has been removed from stromatolite surface (ca. 1 minute). Release a float to advise boat observer to start pumping. Clear all initial water in hose (between the bucket and the pump) from the line, then pump a 12-L sample into a bucket or until pumped water is free of benthic organic material.

iii. *Sieve the sample* through a 500-µm sieve in boat. Next rinse sample into clean enamel pan. Assess how many pupae and larvae are present. We will need approximately 2000 of each life stage in order to get a 0.2-0.5 g (dry weight sample). If there are not enough brine flies or periphyton, advise divers to take a second sample at the same site.

iv. *Store samples* in labeled zip-lock bags and in cooler on ice (H_2O).

v. *Brine fly processing* in lab or on boat.

- place sample in acid-washed/DI-rinsed enamel pan
- Count and identify all larvae and pupae in sample. Only *Ephydra cinerea* are expected, but insure that no *E. hians* are present.
- Randomly pick ca. 2000 of each life stage (larvae, pupae) and place in acid-washed, DI-rinsed plastic scintillation vials for Se analyses. Rinse organisms 3 times with DI to remove salts. Place labeled vials with organisms in freezer.
- Place ca. 100 larvae (100 mg dry wt) in scintillation vial, rinse 3 times with DI and place in drying oven at 70° C for 24 hr for 13C/15N analyses. Grind and encapsulate for mass-spectrometer analyses.

vii. *Periphyton processing* in lab.
- Weigh entire sample of organic matter from the bucket.
- Homogenize sample and take sub-samples for:
    1. **Selenium**. If only a small amount of material is present rinse 3 times with DI and freeze for subsequent Se and AFDW analysis. If adequate material is present, preserve one as just described. The second sample can be treated to remove carbonates by placing sample in a 200-mL beaker and coving with ca. 160-mL, 1-N HCl to digest carbonates. Rinse 3 times with DI. Freeze in scintillation vial.
    2. **Chl a.** Take ca. 1 g of material, weigh it. Place in scintillation vial and freeze. Hold < 1 week. Cover with 15 mL, 95% ethanol. Extract overnight in dark. Measure chlorophyll fluorescence. Dilution may be required to stay on scale.
    3. **13C/15N.** Place ca. 5 g (mL) of material in 50-mL beaker. Add 40 mL, 1-N HCl. Leave for ca. 4 hr to allow carbonates to digest. Rinse resulting "pure" organic matter 3 times with DI. Examine with dissecting scope to insure that no carbonates are present. Dry at 70° C for 24 hr. Cool in desiccator. Grind and encapsulate samples.
    4. **Ash-free dry mass**. Rinse salts from approximately 5 g of organic material in tared crucible. Place in drying oven at 70° C for 24 hrs. Measure dry weight. Dry 1-2 hrs more and re-weigh to insure that all water has evaporated

from sample. Record weight. Combust in muffle furnace according to Standard Methods (use protocol for when carbonates present). Cool in desiccator and reweigh.

3. Sand & Mud: Periphyton/detritus, larval and pupal brine flies
   a. Sampling device: Ponar Dredge
   b. After locating sampling site, drop dredge from a distance of 1 m above the substrate
   c. Bring dredge to surface and place in sieve
   d. Carefully open dredge and remove ca. 50 mL of the substrate from the top 3 mm of the surface with a spatula. Place in whirlpac. Process as described above for:
      1. Selenium
      2. Chl a
      3. $^{15}N/^{13}C$
      4. Ash free dry mass
   e. Open dredge completely into sieve and sieve contents over side of boat to remove brine flies. Place in zip-lock bag and in ice box.
   f. Repeat until ca 1000 pupae and larvae are collected.

4. Adult flies - Collect with fine-meshed, loose-meshed net that can be grabbed and closed. Immerse net-end with flies in dry ice container with ca. 5 lbs dry ice. Place ca. 5 g. of frozen flies in labeled scintillation vial. Freeze.

Equipment and Supplies

1. 100 heavy-duty, 1.5-gallon zip-lock bags.
2. Butterfly net, fine, loose mesh
3. Large (1 ft^3) soft foam dry ice container w/ 5 lbs dry ice
4. Bucket samplers
   - buckets, hose, pump (2)
   - scrub brushes (2)
   - 1-L squeeze bottles (2)
   - 500-mL sieves (2)
5. fine tweezer for picking brine flies (4); 1 clean set for changing filters
6. Scintillation vials (25/site)
7. Water sample bottles, 250 mL (10) EPA/top of cabinets
8. Buckets (size of bucket samplers) (2)
9. Large ice chest (?)
10. Block ice
11. Ponar dredge
    - rope (10-m)
12. 60-mL syringes
13. 47-mm filter cartridge
14. 47-mm, 0.45 membrane filters (20)
15. Nitric acid, Ultrex grade
16. enamel pan
17. 50 mL beakers
18. Ethanol
19. Mortar & pestle
20. Spatula

Boat

1. Table, 2 chairs
2. First-aid kit
3. Drinking/washing water 15 gallons in jugs
4. Dive ladder
5. 50' of 3/8" braided (not twisted) nylon anchor rope
6. 10', 3/8" nylon corner ropes for stern tie-downs of Poncho (10' each)
7. 2 marker lines for divers
8. 2 dive signal buoys for divers

SCUBA

1. wet or dry suits
2. weight belts (4)
3. tanks, filled (8)
4. mask, snorkels, fins
5. Regulators
6. Buoyancy compensators

7. depth gauge
8. dive flag
9. dive tables

Pump sampler

1. Hose
2. Sieve, 500 µm (buy)
3. Sampler

Ponar Dredge w/ rope

Eckman Dredge, rope, messenger

Periphyton (for chlorophyll & Se analyses; Organic carbon analysis

1. Urine cups (20) with lids
2. Spatula for scraping surface

Adult brine flies

1. Butterfly net
2. Dry ice

Larval & pupal flies

1. 500-mL plastic jars 25

Total and Dissolved Water Samples

PREPARED FOR:	State of Utah, Division of Water Quality
PREPARED BY:	Dr. David Naftz, USGS
COPIES:	CH2M HILL
DATE:	May 1, 2006

Sample Preparation

Verify that tubing, processing chamber, and sampling equipment are clean. If not clean, follow procedures below:

Tubing

Office or laboratory cleaning

Clean equipment using NFM protocols (See TWRI book 9, Chapter A3.2.1)

1. Soak in 0.2% Liquinox solution for 30 minutes. Scrub with brush.
2. Change gloves.
3. Rinse 3 times with tap water*.
4. Change gloves.
5. Soak in 5% HCl solution for 30 minutes.
   (skip this step if your equipment has ANY non-removable metal)
6. Change gloves.
7. Rinse 3 times with deionized water (DIW)*.
8. Double bag equipment.

*To facilitate flow of solutions thru the tubing, use a peristaltic pump or large syringe.

Field cleaning

1. Pump 1 L of DIW through tubing and rinse tubing ends.
2. Inspect tubing
   a. If tubing is visibly dirty or sampling site is contaminated continue to step 3.
   b. If dirt is not visible continue to step 5.
3. Pump 1 L of 0.1% Liquinox solution through tubing and on ends.
4. Pump 1 L of tap water or DIW
5. Carefully pump 1 L of 5% HCl solution through tubing and on ends. Capture and dispose of HCl.
6. Pump 2 L of DIW through tubing and on ends.
7. Double bag equipment.
8. Discard neutralized solutions appropriately.
9. Clean stainless steel connections or metal tubing using detergent wash and tap water/DIW rinse procedures.

Sampling Equipment

Clean equipment using NFM protocols (See TWRI book 9, Chapter A3.2.1)

1. Soak in 0.2% Liquinox solution for 30 minutes. Scrub with brush.
2. Change gloves.
3. Rinse 3 times with tap water.
4. Change gloves.
5. Soak in 5% HCl solution for 30 minutes.
   (skip this step if your equipment has ANY non-removable metal)
6. Change gloves.
7. Rinse 3 times with DIW.
8. Double bag equipment.

Pre-Rinse Sample Bottles

(Polyethylene, glass, and acid-rinsed bottles)
(This step can be done in the lab prior to going into the field)

1. Put on powderless Nitrile gloves.
2. Fill each bottle about ¼ full of DIW and cap.
3. Shake vigorously and decant DIW.
4. Repeat steps 2 and 3 two more times.
5. Following final rinse, fill each bottle half full with DIW and cap.
6. Rinse exterior of bottle with DIW and dry with lint-free laboratory tissue.
7. Store bottles in doubled plastic bags.

Label bottles with site id, date, time, and sample designation code (FA for filtered samples and RA for unfiltered samples).

Clean Hands/Dirty Hands Technique

Clean Hands/Dirty Hands technique will be used for all sample collection and sample processing. Before field work begins, the clean hands (CH) person and dirty hands (DH) person should be designated. Table 4-2 designates the duties of CH/DH. In summary of Table 4-2, the CH person has the only contact with the sample bottle; transfers sample from sampler to splitter; filters, extracts, and preserves sample. The DH person operates sampling equipment and manages any contact with sources of contamination (for examples, the churn carrier and pumps). CH works inside processing chamber while DH works outside processing.

Table 4-2. Clean Hands/Dirty Hands techniques for water-quality sampling

- Clean Hands/Dirty Hands techniques require two or more people working together.
- At the field site, one person is designated as Clean Hands (*CH*) and a second person as Dirty Hands (*DH*). Although specific tasks are assigned at the start to *CH* or *DH*, some tasks overlap and can be handled by either, as long as the prescribed care is taken to prevent contaminating the sample.
- Both *CH* and *DH* wear appropriate disposable, powderless gloves during the entire sampling operation and change gloves frequently, usually with each change in task. (Wearing multiple layers of gloves allows rapid glove changes.) **Gloves must be appropriate to withstand any acid, solvent, or other chemical substance that will be used or contacted.**
- *CH* takes care of all operations involving equipment that contacts the sample; for example, *CH*
  - Handles the surface-water sampler bottle.
  - Handles the discharge end of the surface-water or ground-water sample tubing.
  - Transfers sample to churn or cone splitter.
  - Prepares a clean work space (inside vehicle).
  - Sets up processing and preservation chambers.
  - Places equipment inside chambers (for example, sample bottles, filtration and preservation equipment).
  - Works exclusively inside chambers during collection/processing and preservation.
  - Changes chamber covers, as needed.
  - Sets up field-cleaning equipment and cleans equipment.
- *DH* takes care of all operations involving contact with potential sources of contamination; for example, *DH*
  - Works exclusively exterior to processing and preservation chambers.
  - Prepares and operates sampling equipment, including pumps and discrete samplers, peristaltic pump switch, pump controller, manifold system.
  - Operates cranes, tripods, drill rigs, vehicles, or other support equipment.
  - Handles the compressor or other power supply for samplers.
  - Handles tools such as hammers, wrenches, keys, locks, and sample-flow manifolds.
  - Handles single or multiparameter instruments for field measurements.
  - Handles the churn carrier, including outer protective bags.
  - Handles stream-gaging or water-level equipment.
  - Sets up and calibrates field-measurement instruments.
  - Measures and records water levels and field measurements.

Sample Collection:

1. Field rinse clean sampling equipment including collection bottle, nozzle, bottle head, and churn splitter (if applicable) in the stream
2. Collect grab sample
   a. Record sampling start time.
   b. Locate centroid of flow.
   c. Lower field rinsed sampler into centroid of flow.
   d. Don't let bottle overflow
   e. Select correct nozzle size. If the velocity is causing bottle overflow, use smaller nozzle.
3. Cap bottle and place in transport bag.
4. Record sampling end time.

Sample Processing

Unfiltered Samples

1. *CH/DH*: Put on gloves.
2. *CH*: Prepare a clean processing area and surface.
3. *DH*: Assemble processing chamber.
4. *CH*: Insert processing chamber bag.
5. *CH/DH*: Change gloves.
6. *DH:* Remove capped sample bottle from transport bag and insert in processing chamber.
7. *CH:* Field rinse sample bottles with small amount well mixed raw sample *(raw sample must be well mixed by slowly inverting the capped sample bottle 3-5 times, do not aerate the sample by shaking vigorously)*
    a. If bottles were previously rinsed and half-filled with DIW, discard DIW and rinse once with well mixed autosampler sample.
    b. If bottles were not pre-rinsed with DIW, rinse twice with DIW, followed by one rinse with well mixed autosampler sample.
8. *CH:* Transfer well mixed sample from sampler bottle into appropriate sample bottle and cap.
9. *CH*: Preserve sample using 2-mL HNO_3 vial
10. Remove sticker from HNO3 vial and stick it on the field sheet for acid lot tracking.
11. Dispose of empty HNO_3 vial in waste container.

Filtered Samples

Preparing work space, sample bottles, and capsule filter.

1. *CH/DH*: Put on one or several layers of powder-free gloves.
2. *CH*: Assemble clean processing chamber, attach chamber cover, and change gloves.
3. *CH*: Place capsule filter, sample bottles, and discharge end of peristaltic pump into chamber.
4. *CH*: Open DIW container and cover with plastic bag.
5. *CH*: Insert intake end of peristaltic pump tubing through the plastic covering and into a 1-L container of DIW.
6. *DH*: Attach tubing to peristaltic pump head and pump DIW to fill tubing.
7. Discharge waste rinse water through a sink funnel or a toss bottle.
8. Discard DIW stored in DIW-pre-rinsed sample bottles. If not pre-rinsed, rinse twice with DIW.

Clean capsule filter.

1. *CH*: In the processing chamber, remove capsule filter from protective bags.
2. *CH*: Attach pump tubing to inlet connecter of filter. **Make sure direction of flow through capsule filter matches the direction-of-flow arrow on the side of capsule.**
3. *CH*: Select a short length of clean tubing onto capsule filter outlet extending into the sample bottle.

4. *CH/DH*: Pump 1 L (large-capacity >600cm^2 filter) or 100mL (small-capacity 19.6 cm^2 filter) through capsule filter.
    a. DH operates pump at low speed.
    b. CH inverts capsule filter so the arrow on the housing is pointing up.
5. *DH:* Remove tubing from DIW reservoir and continue operating pump in forward at mid-range speed to drain remainder of DIW in capsule filter.
6. *CH*: Detach capsule filter from tubing.
7. *CH*: Put in clean, sealable plastic bag, and leave in chamber until ready for use.

Filtering a composite sample

1. Field rinse peristaltic pump tubing with the water to be sampled
    a. *CH*: Rinse the outside of each end of the pump tubing.
    b. *CH*: Transfer intake end of pump tubing into composite sample.
    c. *DH*: Start pump to slowly pump sufficient sample to completely fill tubing.
    d. *CH*: Discard rinse water through appropriate receptacle. Prevent water from ponding in processing chamber.
    e. *DH*: Stop pump after tubing is field rinsed.
2. Field rinse capsule filter:
    a. *CH*: Remove cleaned capsule filter from plastic bag and attach discharge end of pump tubing to filter inlet connector.
    b. *DH*: At low speed, pump sample through the tubing to capsule filter.
    c. *CH*: Turn capsule filter so outlet is point up and flow of the sample forces trapped air out of capsule filter. **Do not let sample spray onto chamber cover.**
        -Chamber cover must be changed if sample has sprayed on to it.
    d. *DH*: Stop pump as soon as filter is full of sample.

Collect Sample Filtrate.

1. *CH*: Check that there is a tight connection between the pump tubing and the capsule filter.
2. *DH*: Check the intake tube is properly inserted in the sample and start pump.
3. *CH*: Collect a maximum of 25 mL of the water to be sampled. **Do not exceed 25 mL.**
4. *CH*: Field rinse a precleaned 250-ml FA bottle.
5. *DH*: Stop pump in time to prevent losing filtrate.
6. *CH*: Cap bottle, shake, and discard rinse water.
7. *DH*: Start pump and resume flow.
8. *CH*: **Filter only the next 200 mL of the sample** into the bottle.
9. *DH*: Stop pump after bottle is filled.
10. *CH*: Field rinse any remaining sample bottles. **Use no more that a total of 100 mL of filtrate per capsule filter to field rinse any remaining bottles for filtered samples.**

Sample Preservation.

All *CH* person.

1. Change gloves.
2. Change chamber cover.
3. Move samples requiring chemical treatment to preservation chamber.
4. Place first preservative and its waste container insider chamber.

5. Change gloves.
6. Add 2-mL HNO_3 vial to FA bottles.
7. Change gloves.
8. Disassemble and clean chamber frame.

For filtered samples that do not require preservation.

1. *CH*: Set samples outside processing chamber
2. *DH*: Check that information on bottle is correct and complete.
3. *DH*: Pack samples for shipping or in ice if cooling is required.
4. *CH*: Rinse all reusable equipment with DIW immediately-before equipment dries.
5. **Discard the capsule filter after filtering each sample-do not reuse.**

Equipment Cleaning

Clean equipment using NFM protocols See TWRI book 9, Chapter A3.2.1

1. Soak in 0.2% Liquinox solution for 30 minutes. Scrub with brush.
2. Change gloves.
3. Rinse 3 times with tap water.
4. Change gloves.
5. Soak in 5% HCl solution for 30 minutes.
   (skip this step if your equipment has ANY non-removable metal)
6. Change gloves.
7. Rinse 3 times with DIW.
8. Double bag equipment.

Sediment Trap Samples

PREPARED FOR:	State of Utah, Division of Water Quality
PREPARED BY:	Dr. William P. Johnson
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DATE:	May 1, 2006

1.1 Trap Retrieval

1. Use stage hook to retrieve rope holding marker buoy to suspension buoy.
2. Clip winch line quick link to cable below suspension buoy.
3. Winch the sediment trap upward until the tops of the Plexiglas traps are well above wave height.
4. Remove Plexiglas sediment traps from holders.

1.2 Sediment Retrieval

1. Put on powderless Nitrile gloves.
2. Label cubitainer with site id, date, time, and sample designation code.
3. Gently pour supernatant in Plexiglas trap until approximately 5 parts of water remain relative to the 1 part of sediment.
4. Slurry the sediment with the remaining water and pour into a clean 2 liter cubitainer.
5. Add 50 mL of water to the Plexiglas trap to slurry remaining sediment into cubitainer.

1.3 Sediment Storage

1. Place cubitainer with sediment in cooler with ice while on boat
2. In laboratory, store sediment in freezer (should specify temperature)

1.4 Trap Re-Deployment

1. Rinse Plexiglas traps with lake water.
2. Scrub Plexiglas traps with toilet brush to remove scaling or scum.
3. Rinse again with lake water.
4. Place Plexiglas traps in holders.
5. Lower trap into water using winch.

Sediment via Eckman Dredge

PREPARED FOR: State of Utah, Division of Water Quality

PREPARED BY: Dr. William P. Johnson

COPIES: CH2M HILL

DATE: May 1, 2006

1.1 Dredge Preparation and Deployment

1. Set cleaned dredge (scrubbed and rinsed with tap water) to trigger upon contact with the sediment.
2. Lower the dredge to approximately 2 m above the sediment; then release line to allow free-fall of dredge.

1.2 Dredge Retrieval

1. Recover the dredge using a winch or by hand.
2. Gently pour off supernatant, aspirating the last 4 cm using a syringe.

1.3 Sample Retrieval

1. Put on powderless Nitrile gloves.
2. Label sample jar with site ID, date, time, and sample designation code, and cover label with clear packaging tape.
3. Examine the sediment surface; a brownish ooze should be present on the surface if retrieval was performed correctly.
4. Using a plastic spoon, gently remove the organic-rich ooze from the surface of the sediment.
5. Place the ooze inside a chemically clean jar, preferably leaving only 10% of the volume as headspace by the time the third addition is made (see step 7 below). Replace lid between additions.
6. Collect a sample of the sediment from below the ooze layer to 5 cm sediment depth and put into chemically clean plastic jar for mixing with additional two dredge samples (see step 7 below). Replace lid between additions.
7. Repeat the dredge retrieval and sample retrieval procedure twice at the same location. Mix the samples to form a homogeneous composite of the three samples of

ooze layer and a homogeneous composite of the three samples of mineral sediment to form one sample of each. Fill sample jars to allow about 10% headspace.

8. Thoroughly rinse dredge in lake water before re-deployment.

1.4 Sample Storage

1. Hold samples in cooler with ice while in field.
2. In laboratory, split the sample into 20-mL plastic centrifuge tubes leaving 10% headspace to allow expansion for samples that will be frozen.
3. Ensure that the jar and the bottles are labeled properly with date, time, site ID and sample code.
4. Freeze samples during holding for total Se and TOC analysis, and refrigerate duplicates during holding for FFF analysis.

Total Dissolved Gas

PREPARED FOR:	State of Utah, Division of Water Quality
PREPARED BY:	Dr. William P. Johnson
COPIES:	CH2M HILL
DATE:	May 1, 2006

1.1 Probe Preparation

1. Zero the probe at atmospheric pressure while dry.
2. Handle probe gently to ensure that the fragile membrane is not compromised.

1.2 Total Dissolved Gas (TDG) Measurement

1. Using the dry probe, check the barometric pressure (atm) and the temperature (^{o}C). Record.
2. Place the probe at the depth to be measured. Wait 12 minutes while gently agitating TDG probe cable to break up diffusion boundary layer. 12 minutes equilibration yields <3% error in the TDG measurement. Record the pressure and temperature. Note that waiting for a total of 15 to 20 minutes for a TDG membrane equilibration gives less than 1% error in the measurement.
3. Note that increases in TDG on the order to 0.1 atmospheres per meter of depth indicate that a hole has formed in the TDG membrane, and that the membrane needs to be replaced.
4. Simultaneously measure water pressure, e.g. using a hydrolab probe. Zero the water pressure probe above the water surface before using.

Volatile Selenium

PREPARED FOR: State of Utah, Division of Water Quality

PREPARED BY: Dr. William P. Johnson

COPIES: CH2M HILL

DATE: May 1, 2006

1.1 Purge Vessel Preparation

(This step should be done in the lab prior to going into the field)

1. Put on powderless Nitrile gloves.
2. Place glass purge vessel in 5% HNO_3 and soak for a minimum of two hours.
3. Rinse purge vessel three times in de-ionized water (DIW), place in plastic bag.

1.2 Sample Collection

(In the field)

1. Place the purge vessel inside a clean plastic bucket with sides higher than the vessel.
2. Place the sample intake hose of the pump in the site and depth to be sampled.
3. After purging three line volumes, place the exit hose of the pump inside the purge vessel.
4. Turn on the pump.
5. Fill the vessel and allow the water to overflow the bottle and overflow the bucket. Allow at least 3 volumes of water to fill and overflow the bottle.
6. Under water, place the lid on the purge vessel.

1.3 Purge and Trap System

(In the field)

1. Install a new Chromosorb trap in the purge and trap system.
2. Connect the Ar gas line to the sparging system.
3. Check that all the connections are in place. Check that the cryogenic baths (ice+acetone and liquid nitrogen) are full.
4. Open the Ar valve.
5. Purge the sampled water at 300 mL/min for 1 hour.

6. Close the Ar valve
7. Using a hand vacuum pump and a torch, flame seal the ends of the trap.
8. Place the trap inside of Dewar with liquid nitrogen.

APPENDIX D

Electronic Data Deliverable

Electronic Data Deliverable Format for CH2M HILL

The EDD file from the laboratory will be a comma-delimited ASCII (CDA) file in the format listed below. There will be one file per hard copy report and the filename of the EDD file will be in the format REPORTID.txt or REPORTID.csv, where REPORTID is the hard copy report identifier of sample delivery group.

The first row of the EDD will contain the 47 field name values as listed in the EDD Specification Table

The EDD Specification Table lists the attributes of the columns for each row of the CDA file. The fields should be reported in the order indicated.

The **Data Type** column describes the value in the field as either text (alphanumeric), number (numeric only), date (format: mm/dd/yyyy), or time (24-hour format hh:mm). If the field is conditional or optional and there is no value to be reported, report a null (i.e., no) value. For a text field, do not report a zero-length string (i.e., “”).

The **Data Length** column contains the maximum length of a text value for the particular data field.

The **Rqmt** column contains a code indicating whether the value is required (R) for all rows, optional (O) for all rows, or conditional (C) and depends on the type of result reported.

Modification Notes:

Changes to February 9, 2000 Revision:

1. Change the description of the QAQCType field (Field No. 6) to clarify how diluted samples should be reported.
2. Change the description of the LRType field (Field No. 7) to allow for multiple dilutions, re-analyses, and confirmation sample analyses. Also change the example values to reflect this change.
3. Change the description of the AnalysisMethod field (Field No. 10) to correct grammatical error.
4. Minor typographical/grammatical changes in the descriptions of the ExtractDate and ExtractTime fields (Field Nos. 15 and 16).
5. Change requirement of the LabLotCtlNum field (Field No. 20) from Required to Conditional. If there is no preparation, then the value in this field should be blank.
6. Change data type of the Result field (Field No. 24) from Number to Text, length of 10. Clarify the requirement of a text value in the field description.
7. Change the description of the MDL field (Field No. 28) to clarify the field contents.
8. Change the description for the UpperControlLimit and LowerControlLimit fields (Field Nos. 35 and 36) to explain when a value is required in those fields.
9. Change the description of the MDLAdjusted field (Field No. 39) to clarify field contents.
10. Change the requirement of the SampleDescription field (Field No. 41) from Required to Conditional. Lab QC samples (method blanks, blank spike, blank spike duplicates) do not appear on the COC.
11. Change the description of the CalRefID field (Field No. 47) to clarify field contents.

EDD Specification Table					
Field Number	**Field Name**	**Data Type**	**Data Length**	**Rqmt**	**Description and Comments**
1	VersionCode	text	15	R	Code identifying the version of the EDD deliverable.
2	LabName	text	10	R	Identification code for the laboratory performing the work. This value is used to distinguish among different facilities.
3	SDG	text	8	R	Sample delivery group designation. Always populated for all samples, including QC.
4	FieldID	text	20	R	Client sample ID as appears on COC with optional lab-assigned suffixes and/or prefixes to make it unique. If the sample identifier on the COC and the prefix/suffix is greater than 13 characters, abbreviate the value but make it unique. For laboratory QC samples (i.e., method blanks, lab control samples), use a unique lab sample identifier.
5	NativeID	text	20	R	Client sample ID, exactly as on the COC. No prefix or suffix allowed. Used to identify the native sample from which other samples are derived (e.g., QAQCType = ”LR”, “MS”, or “SD”). For laboratory QC samples (i.e., method blanks, lab control samples), use a unique lab sample identifier. For lab blank spike (and blank spike duplicate) samples, use the FieldID value that was assigned to the associated method blank.
6	QAQCType	text	2	R	This is the code for the sample type. Any field sample that is not used as lab QC and is not otherwise marked on the COC should have the designation of “N” (normal field sample). No suffix allowed (i.e., do not add numbers as suffixes to the QAQCType values as is called for in the ERPIMS guidelines). Note that if all analyses for a given sample are diluted, then the first dilution should be designated as the normal sample. If more dilutions are required, then the next dilution should be designated as the first true dilution with a QAQCType value of “LR” and a LRType value of “DL” (see LRType, below).

EDD Specification Table					
Field Number	**Field Name**	**Data Type**	**Data Length**	**Rqmt**	**Description and Comments**
7	LRType	text	3	C	This is the code for laboratory replicate sample type. Values are: blank (if QAQCType value is not "LR"), "DL" (dilution), "RE" (re-analysis), "D" (inorganic duplicate), "CF" (confirmation). For multiple dilutions or re-analyses of the same sample, append the replicate number after the LRType value (i.e., "RE", "RE2", "RE3", etc.).
8	Matrix	text	5	R	Sample matrix code. Valid values are as follows: "AIR", "WATER", "SOIL", unless otherwise provided by the project data manager and marked on the COC. The use of "liquid", "solid", etc. for lab QC is not allowed.
9	LabSampleID	text	12	R	Laboratory sample ID. Prefix or suffix is allowed. This is where dilutions or re-extractions are noted. Ex: "D97-11111RE" is acceptable.
10	AnalysisMethod	text	20	R	Analysis method code. This is the identifier of the analytical method that was performed on the sample. Example: SW8260A. Generic names such as "EPA" should not be used.
11	ExtractionMethod	text	20	R	Preparation method code. A value in this field is required. If the preparation is described in the method, use "METHOD". If there is no separate preparation required, use "NONE". Note that Total and Dissolved metal analyses are differentiated by the value in this column. Note that Total, TCLP, and SPLP analyses are now differentiated by the value in the LeachMethod column (see below).
12	SampleDate	date		C	Date of sample collection. Value is required for all samples sent to the laboratory and samples derived from those samples. Format: mm/dd/yyyy

EDD Specification Table					
Field Number	**Field Name**	**Data Type**	**Data Length**	**Rqmt**	**Description and Comments**
13	SampleTime	time		C	Time of sample collection. Value is required for all samples sent to the laboratory and samples derived from those samples. 24-hour format: hh:mm
14	ReceiveDate	date		C	Date of sample receipt in the lab. Value is required for all samples sent to the laboratory and samples derived from those samples. Format: mm/dd/yyyy
15	ExtractDate	date		C	Date of sample preparation (extraction or digestion). Value is required if the ExtractionMethod field value is other than "NONE". Format: mm/dd/yyyy
16	ExtractTime	time		C	Time of sample preparation. Value is required if the ExtractionMethod field value is other than "NONE". 24-hour format: hh:mm
17	AnalysisDate	date		R	Date of sample analysis. Value is required for all records. Format: mm/dd/yyyy
18	AnalysisTime	time		R	Time of sample analysis. Value is required for all records. 24-hour format: hh:mm
19	PercentSolids	number		R	Percent solids within the sample. Should be zero for water samples.
20	LabLotCtlNum	text	10	C	Identifier of an autonomous group of environmental samples and associated QC samples **prepared** together. For example, its value can be a digestion or extraction batch ID. If there is no separate extraction or preparation performed, leave this field blank.
21	CAS	text	20	C	CAS number of analyte, if available.
22	ParamID	text	12	R	Parameter identifier code for the parameter listed in the Analyte field.
23	Analyte	text	60	R	Name of analyte, chemical name.

EDD Specification Table					
Field Number	**Field Name**	**Data Type**	**Data Length**	**Rqmt**	**Description and Comments**
24	Result	text	10	R	Result of the analysis. Surrogate analytes will be reported in units of percent. All others will be reported in sample concentration units. If undetected, report the adjusted MDL or adjusted RL, depending on the project. (Reported as a text field to preserve significant figures.)
25	ExpectedValue	number		C	"100" for surrogates; "0" (zero) for blanks; spike level plus parent result for LCS, and MS/MSD; parent value for lab duplicate; etc.
26	Units	text	10	R	Units of measure used in the analysis. Report "PERCENT" for surrogate analytes and concentration units for all others.
27	Dilution	number		R	Total dilution reported in the analysis. Default value should be 1 (one). This value should reflect changes to sample preparation amounts as defined by the method (e.g., less sample used for standard VOC analysis).
28	MDL	number		C	Minimum detection limit adjusted for preparation and dilution. Note that this value may be the method detection limit or the instrument detection limit, depending on the method and the project requirements. This value is **not** adjusted for percent moisture.
29	RL	number		C	Reporting limit adjusted for preparation and dilution. Value is **not** adjusted for percent moisture. Equivalent to PQL.
30	LabQualifier	text	6	R	Lab qualifier for the results, as reported on the hard copy. Use "=" as first (or only) qualifier value for detected results.
31	Surrogate	text	1	R	Is the chemical a surrogate? Report "Y" for yes or "N" for no.
32	Comments	text	240	O	Comment field
33	ParValUncert	text	16	C	Radiological parameter value uncertainty.
34	Recovery	number		C	Percent recovery for MS, SD, LCS, and surrogate compounds.
35	LowerControlLimit	number		C	Lower control limit value for spiked compounds, expressed in units of Percent. A value in this field is required if there is a value in the Recovery field (Field No. 34).

EDD Specification Table					
Field Number	**Field Name**	**Data Type**	**Data Length**	**Rqmt**	**Description and Comments**
36	UpperControlLimit	number		C	Upper control limit value for spiked compounds, expressed in units of Percent. A value in this field is required if there is a value in the Recovery field (Field No. 34).
37	Basis	text	1	R	Weight basis for soil (or solid) sample analysis. Use "D" for dry-weight basis, "W" for wet-weight basis, or "X" if not applicable.
38	ConcQual	text	1	R	Concentration qualifier. Use "=" for detects, "J" for estimated value (value between detection limit and reporting limit), "U" for undetected result, or "E" for exceeded result.
39	MDLAdjusted	number		C	Minimum detection limit adjusted for preparation, dilution **and percent moisture**. See the description of the MDL field (Field No. 28) for an explanation of the contents of this field.
40	RLAdjusted	number		C	Reporting limit adjusted for preparation, dilution **and percent moisture**. Equivalent to PQL
41	SampleDescription	text	20	C	Full sample identifier value as it appears on the COC. In some cases, this may be the name of the sampling location instead of the sample. Required for all samples that are either collected in the field and specified on the COC, or derived from samples that are collected in the field and specified on the COC.
42	LeachMethod	text	20	R	Analytical method used for leaching the sample. This applies to TCLP, SPLP, or other leaching or pre-extraction leaching procedures. Use "NONE" if the sample was not leached.
43	LeachDate	date		C	Date that the leaching method was performed (start date for multi-date leaching procedures). Value is required if the LeachMethod field value is other then "NONE". Format: mm/dd/yyyy.
44	LeachTime	time		C	Time that the leaching procedure started. Value is required if the LeachMethod field value is other then "NONE". 24-hour format: hh:mm.

EDD Specification Table					
Field Number	**Field Name**	**Data Type**	**Data Length**	**Rqmt**	**Description and Comments**
45	LeachLot	text	20	C	Identifier of an autonomous group of environmental samples and associated QC samples **leached** at the same time. If the sample was not leached, leave this field blank.
46	AnalysisLot	text	10	R	Identifier of an autonomous group of environmental samples and associated QC samples **analyzed** together. A value in this field is mandatory (i.e., it should not be blank).
47	CalRefID	text	20	C	Identifier of a group of environmental and QC samples linked by a common set of calibration records. All results with the same CalRefID value will have had the same initial calibration run.

Each row is uniquely identified by the values in the following fields:

- FieldID
- LabSampleID
- AnalysisMethod
- ExtractionMethod
- LeachMethod
- ParamID

If an analytical sample must be diluted or re-analyzed and reported in addition to the original analytical sample, the diluted or re-analyzed sample should have a FieldID value that is different that that of the original sample. This can be accomplished through the addition of a suffix to the original FieldID that establishes a new and unique FieldID for the associated records.

Example Valid Values

The project data manager will provide the laboratory with a list of valid values that the laboratory will use in constructing the EDD. Listed below are some example valid values

Field Name	Valid Value	Meaning
VersionCode	4.00AFCEE3	Format 4.00, AFCEE data values. LabQualifier field contains the laboratory qualifier values defined in the AFCEE QAPP, version 3.0.
VersionCode	4.00EPACLP	Format 4.00, EPA data values. LabQualifier field contains the standard EPA CLP lab qualifiers.
QAQCType	N	Normal, environmental sample
QAQCType	LB	Laboratory method blank
QAQCType	MS	Laboratory matrix spike sample
QAQCType	SD	Laboratory matrix spike duplicate
QAQCType	LR	Laboratory replicate (dilution, re-analysis, duplicate)
QAQCType	BS	Laboratory method blank spike
QAQCType	BD	Laboratory method blank spike duplicate
LRType	DL	First dilution sample
LRType	DL2	Second dilution sample
LRType	DL3	Third dilution sample
LRType	RE	First re-analysis/re-extraction sample
LRType	RE2	Second re-analysis/re-extraction sample
LRType	RE3	Third re-analysis/re-extraction sample
LRType	D	Inorganic duplicate sample
LRType	CF	First confirmation analysis sample

Field Name	Valid Value	Meaning
LRType	CF2	Second confirmation analysis sample
LRType	CF3	Third confirmation analysis sample
AnalysisMethod	SW8260A	Volatiles by method 8260A in EPA SW846.
AnalysisMethod	SW8270	Semivolatiles by method 8270 in EPA SW846.
AnalysisMethod	SW6010	ICP metals by method 6010 in EPA SW846.
AnalysisMethod	SW7060	GFAA Arsenic by method 7060 in EPA SW846.
ExtractionMethod	FLDFLT	Field filtration for dissolved metals analysis
ExtractionMethod	C3050	CLP-modified SW3050 acid digestion for metals analysis in soil samples.
ExtractionMethod	SW1311	TCLP extraction
ExtractionMethod	DISWAT	Distilled water extraction for analytes in soil samples.
ExtractionMethod	SW3510	Separatory funnel extraction
ExtractionMethod	SW3540	Soxhlet extraction
ExtractionMethod	TOTAL	Digestion of unfiltered waters for total metals analysis
ParamID	ACE	Acetone
ParamID	AS	Arsenic
ParamID	BHCGAMMA	gamma-BHC (Lindane)
ParamID	BZ	Benzene
ParamID	CDS	Carbon disulfide

Field Name	Valid Value	Meaning
ParamID	PB	Lead
ParamID	PHENOL	Phenol
ParamID	SE	Selenium
ParamID	TCE	Trichloroethene