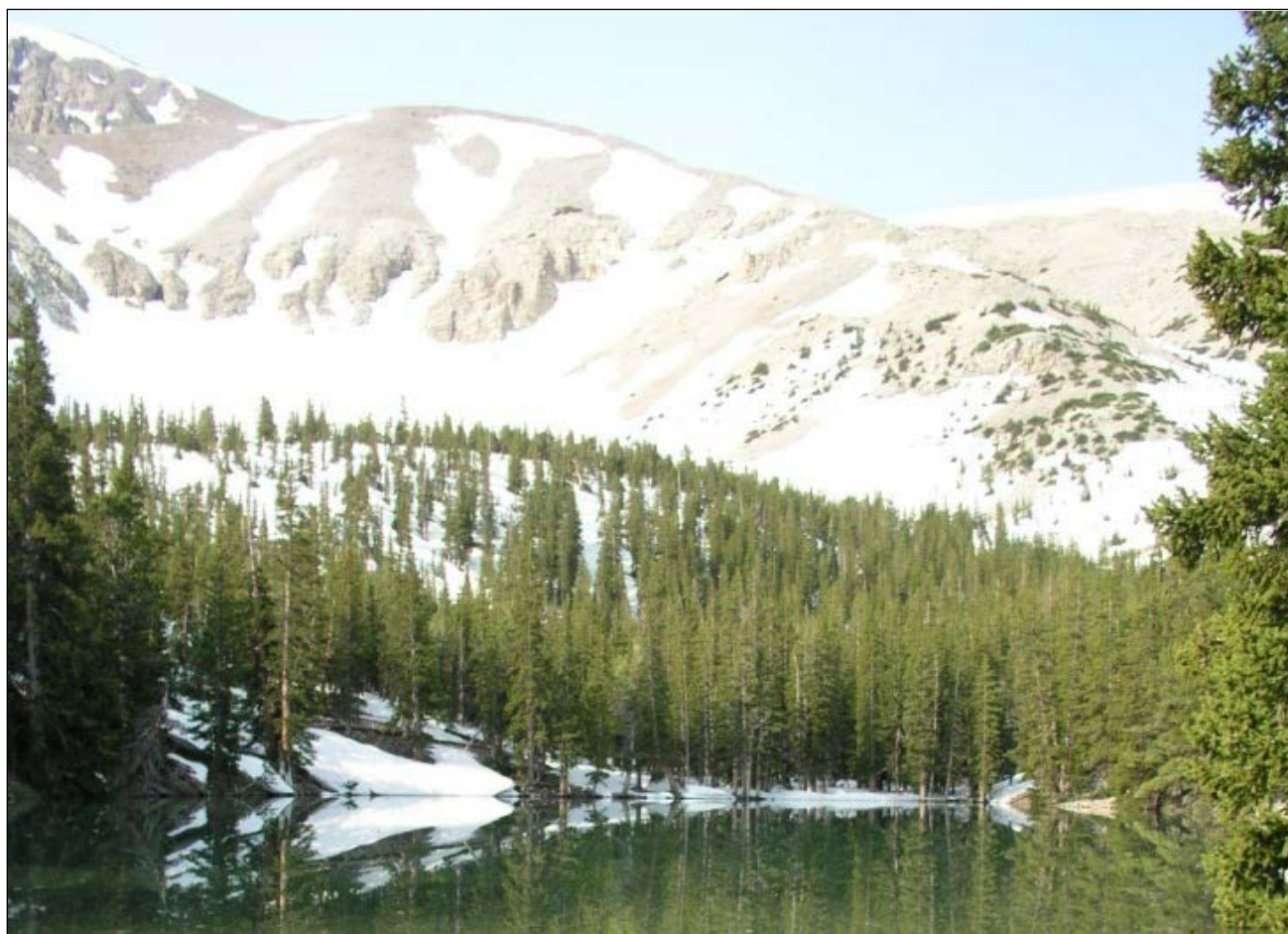




Mojave Desert Network Inventory and Monitoring Streams and Lakes Protocol

Standard Operating Procedures and Supplementary Materials Version 1.0

Natural Resource Report NPS/MOJN/NRR—2012/593.1



ON THE COVER

Subalpine lake, Great Basin National Park
Photograph by: Gretchen Baker

Mojave Desert Network Inventory and Monitoring Streams and Lakes Protocol

*Standard Operating Procedures and Supplementary Materials
Version 1.0*

Natural Resource Report NPS/MOJN/NRR—2012/593.1

Geoff Moret

University of Idaho
Moscow, ID 83844-1136

Christopher C. Caudill

University of Idaho
Moscow, ID 83844-1136

Jennifer Burke

National Park Service
Mojave Desert Network
601 Nevada Highway
Boulder City, NV 89005

November 2012

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal, high-level peer review based on the importance of its content, or its potentially controversial or precedent-setting nature. Peer review was conducted by highly qualified individuals with subject area technical expertise and was overseen by a peer review manager.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the Mojave Desert Inventory & Monitoring Network website (<http://science.nature.nps.gov/im/units/mojn/index.cfm>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm>).

Please cite this publication as:

Moret, G. J. M., C. C. Caudill, and J. Burke. 2012. Mojave Desert Network Inventory and Monitoring streams and lakes protocol: Standard operating procedures and supplementary materials version 1.0. Natural Resource Report NPS/MOJN/NRR—2012/593.1. National Park Service, Fort Collins, Colorado.

Change History

Previous Version	Revision Date	Revised By	Change Description	Justification	New Version Number
	11/13/2012		First published version		1.0

This table reflects changes to this document. Version numbers will be incremented by one (e.g., Version 1.3 to Version 2.0) each time there is a significant change in the process and/or changes are made that affect the interpretation of the data. Version numbers will be incremented after the decimal (e.g., Version 1.6 to Version 1.7...1.10....1.21) when there are changes to grammar, spelling, or formatting, or minor modifications in the process that do not affect the interpretation of the data.

1. Notify the MOJN Data Manager of any changes to the Protocol Narrative or SOP so that the new version number can be incorporated in the Metadata of the project database.
2. Post new versions on the internet and forward copies to all individuals with a previous version of the Protocol Narrative or SOP. A list will be maintained in *SOP 20: Protocol Revision and Review* in this document.
3. Version numbers increase incrementally by hundredths (e.g. version 1.01, version 1.02, ...etc.) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 ...). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, and the reason for making the changes along with the new version number.

Note: The protocol narrative describing the rationale for the selection of these standard operating procedures (SOPs) is bound in a separate accompanying document. The Supplementary Materials are on a CD included with the hard copies of this document.

Contents

	Page
Figures.....	xix
Tables.....	xxiii
Supplementary Materials	xxvii
Acknowledgments.....	xxxix
SOP 1. Safety	SOP 1-1
1.1 Introduction and Objectives.....	SOP 1-1
1.2 Risks Inherent in Field Activity.....	SOP 1-1
1.2.1 Working Alone.....	SOP 1-1
1.2.2 Long road trips	SOP 1-2
1.2.3 Backcountry roads and trails.....	SOP 1-2
1.2.4 Activities in and on the water	SOP 1-2
1.2.5 Varied weather conditions	SOP 1-2
1.2.6 Use of hazardous materials	SOP 1-2
1.2.7 Slips, Trips, and Falls.....	SOP 1-3
1.2.8 Altitude Sickness	SOP 1-3
1.3 Job Hazard Analysis	SOP 1-3
1.4 Routine and Emergency Communication.....	SOP 1-12
1.4.1 Safety contact numbers	SOP 1-13
1.4.2 Park radio	SOP 1-13
1.4.3 Incident Notification	SOP 1-13
1.5 Vehicle Accident Procedure	SOP 1-14
1.6 Water Safety	SOP 1-14
1.7 Chemical Storage and Use.....	SOP 1-14

Contents (continued)

	Page
1.8 Version Information.....	SOP 1-15
SOP 2. Staff Training.....	SOP 2-1
2.1 Training Requirements	SOP 2-1
2.1.1 Aquatic Ecologists	SOP 2-1
2.1.2 Seasonal technicians	SOP 2-1
2.2 Version Information.....	SOP 2-2
SOP 3. Field Season Preparations.....	SOP 3-1
3.1 Annual Review	SOP 3-1
3.2 Procedures.....	SOP 3-1
3.2.1 Scheduling and Organizing Field Work	SOP 3-1
3.2.2 Seasonal Staff.....	SOP 3-1
3.2.3 Expendable Supplies	SOP 3-1
3.2.4 Equipment Checklists	SOP 3-2
3.3 Safety	SOP 3-5
3.4 Pre-Season Instrument Comparisons	SOP 3-5
3.4.1 In-Lab Temperature Sensor Comparison.....	SOP 3-5
3.4.2 In-Stream AMS+ Readings.....	SOP 3-8
3.5 Version Information.....	SOP 3-9
SOP 4. Post Season Activities	SOP 4-1
4.1 Equipment Cleaning/Storage	SOP 4-1
4.1.1 YSI Sondes.....	SOP 4-1
4.1.2 Macroinvertebrate equipment	SOP 4-2
4.1.3 Electronic Equipment.....	SOP 4-2

Contents (continued)

	Page
4.1.4 Miscellaneous Equipment.....	SOP 4-2
4.2 Expendable Supplies Inventory	SOP 4-2
4.3 Seasonal Summary.....	SOP 4-2
4.4 Version Information.....	SOP 4-3
SOP 5. Equipment Disinfection.....	SOP 5-1
5.1 Overview.....	SOP 5-1
5.2 Priority of GRBA Disinfection Procedures	SOP 5-1
5.3 MOJN Disinfection Procedures	SOP 5-1
5.4 Version Information.....	SOP 5-3
SOP 6. Handheld Water Quality Instruments	SOP 6-1
6.1 Overview.....	SOP 6-1
6.2 Procedures for Data Collection- All Instruments	SOP 6-1
6.3 YSI 85.....	SOP 6-1
6.3.1 Dissolved Oxygen Calibration.....	SOP 6-2
6.3.2 Specific Conductance Calibration.....	SOP 6-3
6.3.3 Collecting Readings.....	SOP 6-4
6.4 Eutech pHTestr	SOP 6-4
6.4.1 Calibration.....	SOP 6-4
6.4.2 Collecting Readings.....	SOP 6-4
6.5 YSI 556 MPS	SOP 6-4
6.5.1 DO Calibration.....	SOP 6-5
6.5.2 Specific Conductance Calibration.....	SOP 6-6
6.5.3 pH Calibration.....	SOP 6-6

Contents (continued)

	Page
6.5.4 Collecting Readings	SOP 6-7
6.6 AMS+	SOP 6-7
6.7 Version Information.....	SOP 6-7
SOP 7. Sample Handling, Storage, and Shipping.....	SOP 7-1
7.1 Introduction.....	SOP 7-1
7.2 Water Samples	SOP 7-1
7.3 BMI Samples	SOP 7-1
7.4 Chain of Custody Forms.....	SOP 7-3
7.5 Version Information.....	SOP 7-3
SOP 8. Regulatory Status.....	SOP 8-1
8.1 303(d)-Listed Waters	SOP 8-1
8.1.1 Listed Waters Monitoring Procedure.....	SOP 8-1
8.2 Outstanding Natural Resource Waters.....	SOP 8-4
8.2.1 ONRW Monitoring Procedure.....	SOP 8-4
8.3 Version Information.....	SOP 8-5
SOP 9. Stream Discharge.....	SOP 9-1
9.1 Overview.....	SOP 9-1
9.1.1 Site Access	SOP 9-1
9.2 Discharge Measurement	SOP 9-3
9.3 Continuous Stage Data	SOP 9-3
9.3.1 USGS Data.....	SOP 9-3
9.3.2 Data Download and Logger Setup.....	SOP 9-3
9.3.3 Conversion to Discharge.....	SOP 9-5

Contents (continued)

	Page
9.4 Version Information.....	SOP 9-6
SOP 10. Lakes Field Procedures.....	SOP 10-1
10.1 Overview.....	SOP 10-1
10.1.1 Lake Visit Activities	SOP 10-1
10.1.2 Schedule	SOP 10-1
10.1.3 Site Access	SOP 10-1
10.2 Lake Level and Temperature	SOP 10-5
10.2.1 Logger Setup.....	SOP 10-5
10.2.2 Logger Deployment	SOP 10-5
10.2.3 Data Download	SOP 10-6
10.2.4 Measuring Lake Level	SOP 10-7
10.3 Depth Profiles	SOP 10-9
10.4 Water Sample Collection.....	SOP 10-9
10.5 Water Clarity Measurement.....	SOP 10-10
10.6 Version Information.....	SOP 10-11
SOP 11. Continuous Water Quality Sonde.....	SOP 11-1
11.1 Overview.....	SOP 11-1
11.1.1 Rationale for not Collecting ORP Data	SOP 11-1
11.2 Sampling Plan.....	SOP 11-1
11.2.1 Site Selection	SOP 11-1
11.2.2 Sampling Schedule.....	SOP 11-3
11.3 Field Calibration of Specific Conductance DO, and pH	SOP 11-5
11.4 Cross-Section Surveys	SOP 11-8

Contents (continued)

	Page
11.5 Data Acquisition Setup	SOP 11-9
11.7 Data Download	SOP 11-10
11.8 Sonde Cleaning.....	SOP 11-10
11.9 Calibration Check	SOP 11-11
11.10 Multiprobe Retrieval.....	SOP 11-12
11.11 Version Information.....	SOP 11-12
SOP 12. Stream Chemistry and BMI Sampling.....	SOP 12-1
12.1 Overview	SOP 12-1
12.2 Sampling Sites	SOP 12-3
12.2.1 Navigation.....	SOP 12-3
12.3 Water Quality Cross-Section	SOP 12-8
12.4 Water Chemistry Sample Collection	SOP 12-8
12.5 BMI Sampling	SOP 12-9
12.6 Version Information.....	SOP 12-9
SOP 13. Laboratory Analysis of BMI.....	SOP 13-1
13.1 Overview.....	SOP 13-1
13.2 Procedures.....	SOP 13-1
13.3 Taxonomic Level	SOP 13-1
13.4 QA/QC Procedures	SOP 13-3
13.5 Version Information.....	SOP 13-3
SOP 14. Laboratory Analysis of Water Chemistry.....	SOP 14-1
14.1 Overview.....	SOP 14-1
14.2 Analytes	SOP 14-1

Contents (continued)

	Page
14.3 Analytical Methods.....	SOP 14-2
14.4 QA/QC Procedures	SOP 14-2
14.5 Version Information.....	SOP 14-3
SOP 15. Quality Assurance Project Plan	SOP 15-1
15.1 Introduction.....	SOP 15-1
15.2 Distribution list and contact information	SOP 15-1
15.3 Project Management	SOP 15-1
15.4 Problem Definition/Background.....	SOP 15-2
15.4.1 Monitoring Questions	SOP 15-2
15.4.2 Measurable Objectives.....	SOP 15-3
15.5 Project/Task Description Synopsis	SOP 15-4
15.5.1 Regulatory Status	SOP 15-4
15.5.2 Streams.....	SOP 15-4
15.5.3 Lakes	SOP 15-5
15.6 Data Quality Objectives (DQOs).....	SOP 15-5
15.6.1 Spatial Representativeness.....	SOP 15-5
15.6.2 Temporal Representativeness	SOP 15-7
15.6.3 Completeness	SOP 15-7
15.6.4 Internal Data Comparability	SOP 15-8
15.6.5 External Data Comparability	SOP 15-8
15.7 Measurement Quality Objectives	SOP 15-9
15.7.1 Measurement Sensitivity.....	SOP 15-9
15.7.2 Measurement Precision.....	SOP 15-11

Contents (continued)

	Page
15.7.3 Bias	SOP 15-11
15.7.4 Measurement Quality Objectives for Discharge Measurements	SOP 15-14
15.7.5 Measurement Quality Objectives for Secchi Depth.....	SOP 15-14
15.7.6 Violation of Measurement Quality Objectives	SOP 15-14
15.8 Training Requirements / Certification	SOP 15-15
15.9 Documentation and Records.....	SOP 15-15
15.9.1 Field Data.....	SOP 15-15
15.9.2 Laboratory Data	SOP 15-15
15.9.3 Data management.....	SOP 15-15
15.9.4 Evaluation	SOP 15-15
15.9.5 Reporting.....	SOP 15-15
15.10 Sampling Process Design	SOP 15-16
15.10.1 Program design	SOP 15-16
15.10.2 Type, frequency and timing of sample collection.....	SOP 15-16
15.10.3 Sample site selection.....	SOP 15-16
15.10.4 Sampling constraints.....	SOP 15-16
15.11 Sampling Methods Requirements.....	SOP 15-17
15.12 Sample Handling and Custody Requirements	SOP 15-17
15.13 Analytical Methods Requirements	SOP 15-17
15.14 Quality Control Requirements	SOP 15-17
15.15 Instrument/Equipment Testing, Inspection, and Maintenance Requirements	SOP 15-17
15.16 Instrument Calibration and Frequency	SOP 15-17

Contents (continued)

	Page
15.17 Inspection/Acceptance Requirements for Supplies	SOP 15-17
15.18 Data Acquisition Requirements	SOP 15-17
15.19 Data Management	SOP 15-18
15.20 Assessment and Response Actions	SOP 15-18
15.21 Reports	SOP 15-18
15.22 Data Validation and Verification Requirements.....	SOP 15-18
15.22.1 Verification	SOP 15-18
15.22.2 Validation.....	SOP 15-19
15.22.3 Reconciliation with Data Quality Objectives	SOP 15-20
15.23 Version Information.....	SOP 15-20
SOP 16. Cumulative Measurement Bias.....	SOP 16-1
16.1 Introduction.....	SOP 16-1
16.2 Changes in Personnel.....	SOP 16-1
16.3 Replacement of Instruments	SOP 16-1
16.4 Changes in Field Methods	SOP 16-2
16.5 Changes in Laboratory Methods.....	SOP 16-2
16.5.1 Chemical Analysis	SOP 16-2
16.5.2 Taxonomic Identification.....	SOP 16-2
16.6 Statistical Analysis of Paired Measurements.....	SOP 16-3
16.6.1 Detecting Changes in Precision	SOP 16-3
16.6.2 Detecting Changes in Sensitivity	SOP 16-3
16.6.3 Detecting Measurement Bias	SOP 16-4
16.7 Adjusting Data to Correct for Cumulative Bias	SOP 16-5

Contents (continued)

	Page
16.7.1 Before making adjustments.....	SOP 16-5
16.7.2 Making adjustments	SOP 16-5
16.7.3 Documentation	SOP 16-5
16.8 Record of Paired Measurements Made to Control Bias	SOP 16-6
16.8.1 Change in Laboratory Phosphorus Measurements	SOP 16-6
16.9 Version Information.....	SOP 16-7
SOP 17. Data Analysis and Reporting.....	SOP 17-1
17.1 Overview.....	SOP 17-1
17.2 Continuous Records of Core Water Quality Parameters	SOP 17-1
17.2.1 Introduction to Aquarius Software.....	SOP 17-1
17.2.2 General Whiteboard/Workflow Setup	SOP 17-2
17.2.3 Importing from a File.....	SOP 17-2
17.2.4 Data Corrections	SOP 17-3
17.2.5. Data Grading.....	SOP 17-5
17.2.6 Signal Joining.....	SOP 17-6
17.2.7 Threshold Flagging	SOP 17-6
17.2.8 Graphing	SOP 17-7
17.2.9 Export.....	SOP 17-7
17.2.10 Descriptive Statistics.....	SOP 17-8
17.2.11 Summary Figures and Tables.....	SOP 17-8
17.2.12 Trend Analysis	SOP 17-9
17.3 Discrete Water Quality Measurements	SOP 17-9
17.3.1 Overview	SOP 17-9

Contents (continued)

	Page
17.3.2 Summary Figures and Tables.....	SOP 17-10
17.3.3 Trend Analysis	SOP 17-10
17.4 Discharge	SOP 17-11
17.4.1 Division of Duties	SOP 17-11
17.4.2 Overview	SOP 17-11
17.4.3 Discharge measurements	SOP 17-12
17.4.4 Developing Rating Curves in Aquarius	SOP 17-12
17.4.5 Calculating Continuous Discharge Records in Aquarius.....	SOP 17-13
17.4.6 Shifting Rating Curves.....	SOP 17-14
17.4.7 Summary Figures and Tables.....	SOP 17-15
17.4.8 Trend Analysis	SOP 17-15
17.5 Water Chemistry and Lake Clarity	SOP 17-16
17.5.1 Acid Neutralization Capacity.....	SOP 17-16
17.5.2 Summary Tables	SOP 17-16
17.5.3 Trend Analysis	SOP 17-17
17.6 Lake Level and Temperature	SOP 17-17
17.6.1 Overview	SOP 17-18
17.6.2 Barometric Pressure Correction in HOBOWare.....	SOP 17-18
17.6.3 Data Inspection and Drift Correction in Aquarius	SOP 17-20
17.6.4 Estimating Ice-Over and Ice-Out Dates	SOP 17-21
17.6.5 Summary Figures and Tables.....	SOP 17-21
17.6.6 Trend analysis	SOP 17-22
17.7 Benthic Macroinvertebrates.....	SOP 17-22

Contents (continued)

	Page
17.7.3 Summary Table.....	SOP 17-23
17.7.4 Trend Analysis	SOP 17-23
17.8 Non-Parametric Trend Analysis Using Kendall Tests.....	SOP 17-23
17.8.1 Input Files	SOP 17-24
17.8.2 Output Files.....	SOP 17-25
17.8.3 Censored Data.....	SOP 17-26
17.9 Parametric Trend Analysis Using the Mixed-Model Approach	SOP 17-26
17.10 Annual Reports	SOP 17-27
17.11 EPA STORET.....	SOP 17-28
17.12 Trend Analysis Reports	SOP 17-29
17.13 Version Information.....	SOP 17-29
SOP 18. Database Design	SOP 18-1
18.1 Introduction.....	SOP 18-1
18.1.1 What the Streams database and Lakes Database are and are not.....	SOP 18-1
18.2 Database Design Considerations	SOP 18-2
18.3 Database Design Summary.....	SOP 18-2
18.4 Streams Database Structure	SOP 18-3
18.4.1 Tables	SOP 18-3
18.4.2 Front-end database	SOP 18-8
18.5 Lakes Database Structure	SOP 18-8
18.5.1 Tables	SOP 18-8
18.5.2 Front-end database	SOP 18-12
18.6 Updating the Database Design.....	SOP 18-12

Contents (continued)

	Page
18.7 Version Information.....	SOP 18-13
SOP 19. Information Management Workflow and Tasks.....	SOP 19-1
19.1 Information Management Workflow	SOP 19-1
19.1.1 Introduction.....	SOP 19-1
19.1.2 Scope.....	SOP 19-1
19.1.3 Roles and Responsibilities	SOP 19-1
19.1.4 Stream and Lake Discharge Data.....	SOP 19-1
19.1.5 Stream and Lake Water Quality Data	SOP 19-3
19.1.6 Stream and Lake Data Acquisition and Initial Processing.....	SOP 19-4
19.1.7 Data Delivery	SOP 19-6
19.1.8 Archiving	SOP 19-6
19.2 Tasks and Schedule.....	SOP 19-8
19.3 Project Records Management	SOP 19-10
19.4 Version Information.....	SOP 19-10
SOP 20. Protocol Revision and Review	SOP 20-1
20.1 Overview.....	SOP 20-1
20.2 Protocol Revision Procedures.....	SOP 20-2
20.3 Protocol Review.....	SOP 20-2
20.4 Version Information.....	SOP 20-3
Literature Cited	193

Figures

	Page
Figure SOP 3.1. Temperature sensor comparison data sheet.	SOP 3-6
Figure SOP 3.2. Laboratory set up for temperature sensor comparison.....	SOP 3-7
Figure SOP 3.3. Four continuous water quality sondes deployed in Lehman Creek.	SOP 3-9
Figure SOP 6.1. Diagram of the YSI 85. Image taken from the YSI 85 manual.	SOP 6-2
Figure SOP 6.2. Diagram of YSI 556 MPS. Image taken from YSI manual.	SOP 6-5
Figure SOP 7.1. Chain of custody form.	SOP 7-4
Figure SOP 9.1. Stream gage locations in GRBA.....	SOP 9-2
Figure SOP 9.2. Main screen of the Global Logger II software.....	SOP 9-4
Figure SOP 9.3. Historical Data Viewer screen in Global Water II.....	SOP 9-4
Figure SOP 9.4. Setup screen in Global Water II.....	SOP 9-5
Figure SOP 10.1. Lakes field sheet.	SOP 10-2
Figure SOP 10.2. Trails near GRBA’s northern lakes.	SOP 10-3
Figure SOP 10.3. Trails near GRBA’s southern lakes.	SOP 10-4
Figure SOP 10.4. PVC stilling well used to house logger.....	SOP 10-6
Figure SOP 11.1. Stream gage locations in GRBA.....	SOP 11-2
Figure SOP 11.2. Water quality sonde first deployment field sheet.	SOP 11-4
Figure SOP 11.3. Water quality sonde biweekly visit field sheet.	SOP 11-5
Figure SOP 11.4. MOJN’s multiprobe deployed in Strawberry Creek.	SOP 11-10
Figure SOP 12.1. Streams annual sampling field sheet.....	SOP 12-2
Figure SOP 12.2. Sample locations for Baker Creek, Snake Creek, and South Fork Big Wash.	SOP 12-5
Figure SOP 12.3. Sample locations for Shingle, Pine, and Ridge Creeks.....	SOP 12-6
Figure SOP 12.4. Sample locations for Strawberry, Mill, and Lehman Creeks.....	SOP 12-7

Figures (continued)

	Page
Figure SOP 16.1. Difference between P concentrations measured with the new method (P auto) and the old method (P manual) as a function of P concentrations for streams and lakes in 2010.	SOP 16-7
Figure SOP 17.1. Schematic diagram of discharge measurement geometry.....	SOP 17-12
Figure SOP 17.2. HOBOWare Pro Barometric Compensation window.....	SOP 17-19
Figure SOP 17.3. Workflow for water quality and quantity data upload to EPA STORET	SOP 17-28
Figure SOP 18.1. Relationships among the administrative tables in the streams database.	SOP 18-5
Figure SOP 18.2. Relationships among the laboratory results data and voucher documentation.....	SOP 18-6
Figure SOP 18.3. Relationship among the field data tables for water discharge and water quality parameters.	SOP 18-7
Figure SOP 18.4. Relationships among the summary data generated and imported from Aquarius for the streams database.	SOP 18-8
Figure SOP 18.5. Relationships among the administrative tables in the lakes master database.....	SOP 18-10
Figure SOP 18.6. Relationships among the field data tables, laboratory results, and AMS+ summary in the lakes master database.	SOP 18-11
Figure SOP 18.7. Relationships among the summary data in the lakes master database. Summary data are derived from the continuous logger data.	SOP 18-12
Figure SOP 19.1. Information management work flow for discharge and stream and lake water level data.	SOP 19-2
Figure SOP 19.2. Information management workflow for water quality in streams and lakes and ice data in lakes.	SOP 19-3
Figure SOP 19.3. Upload and process discrete water velocity, stream gage readings, and water quality data for streams.	SOP 19-4
Figure SOP 19.4. Upload discrete water level and water quality data for lakes from field data sheets.	SOP 19-4

Figures (continued)

	Page
Figure SOP 19.5. Upload and process continuous stream and lake pressure data and convert to water levels using discrete water level gage readings.	SOP 19-5
Figure SOP 19.6. Review and uploading water level data for lakes.	SOP 19-5
Figure SOP 19.7. Uploading and quality assurance review of the calculated discharge and continuous water level data.....	SOP 19-5
Figure SOP 19.8. Converting water level to discharge.	SOP 19-5
Figure SOP 19.9. Water quality processing steps for streams and lakes data.	SOP 19-6
Figure SOP 19.10. Workflow for creating archive data files for continuous logger data	SOP 19-7
Figure SOP 19.11. Aquarius archive files.	SOP 19-8

Tables

	Page
Table SOP 1.1. Example of chemical list to be posted on chemical cabinet at GRBA....	SOP 1-15
Table SOP 1.2. Version Information.	SOP 1-15
Table SOP 2.1. Version Information.	SOP 2-2
Table SOP 3.1. Version Information.	SOP 3-9
Table SOP 4.1. Version Information.	SOP 4-3
Table SOP 5.1. Version Information.	SOP 5-3
Table SOP 6.1. Elevations of sampling locations.....	SOP 6-3
Table SOP 6.2. Version Information.	SOP 6-7
Table SOP 7.1. Version Information.	SOP 7-3
Table SOP 8.1. State of Nevada-determined beneficial uses of waterbodies in or adjacent to LAKE and Nevada Class A Waterbodies.	SOP 8-2
Table SOP 8.2. State of Arizona-determined beneficial uses of waterbodies in or adjacent to LAKE.....	SOP 8-3
Table SOP 8.3. Water bodies within and adjacent to LAKE listed as impaired by the State of Nevada and the State of Arizona.	SOP 8-3
Table SOP 8.4. Streams in GRBA classified as Class A by the state of Nevada.	SOP 8-4
Table SOP 8.5. Water Quality Standards for Nevada Class A Waters.....	SOP 8-5
Table SOP 8.6. Version information.	SOP 8-5
Table SOP 9.1. Stream gage locations.....	SOP 9-1
Table SOP 9.2. Version Information.	SOP 9-6
Table SOP 10.1. Permanent benchmark sites at GRBA lakes.....	SOP 10-8
Table SOP 10.2. Version Information.	SOP 10-11
Table SOP 11.1. Multiprobe operation overview.	SOP 11-3
Table SOP 11.2. Version Information.	SOP 11-12

Tables (continued)

	Page
Table SOP 12.1. Sample sites for water chemistry and BMI sample collection.	SOP 12-3
Table SOP 12.2. Version Information.	SOP 12-9
Table SOP 13.1. USU BugLab’s standard taxonomic identification levels.	SOP 13-2
Table SOP 13.2. Version Information.	SOP 13-3
Table SOP 14.1. Methods used by CCAL to analyze MOJN samples.	SOP 14-2
Table SOP 14.2. Version Information.	SOP 14-3
Table SOP 15.1. People who will be aware of the project goals, tasks, and products.	SOP 15-1
Table SOP 15.2. Project tasks and responsibilities.	SOP 15-2
Table SOP 15.3. Manufacturer-specified sensitivities for the YSI multiprobe.	SOP 15-10
Table SOP 15.4. MQOs for field measurements.	SOP 15-12
Table SOP 15.5. MQOs for laboratory analyses.	SOP 15-13
Table SOP 15.6. Version Information.	SOP 15-20
Table SOP 16.1. CCAL measurements of phosphorus made using the old method (manual) and the new method (AutoAnalyzer).	SOP 16-6
Table SOP 16.2. Version Information.	SOP 16-7
Table SOP 17.1. Data correction criteria.	SOP 17-5
Table SOP 17.2. Data grading criteria.	SOP 17-6
Table SOP 17.3. Sample table for reporting mean daily values of water quality parameters	SOP 17-9
Table SOP 17.4. Sample of table used to report depth profile information.	SOP 17-10
Table SOP 17.5. Sample of table used to report discrete measurements of core water quality parameters in streams.	SOP 17-10
Table SOP 17.6. Sample table for reporting mean daily discharge values.	SOP 17-15
Table SOP 17.7. Nutrient concentrations in GRBA streams.	SOP 17-17

Tables (continued)

	Page
Table SOP 17.8. Sample table for daily mean, maximum, and minimum lake levels for each month.	SOP 17-22
Table SOP 17.9. 2009 BMI indices for GRBA streams.	SOP 17-23
Table SOP 17.10. Version information.	SOP 17-29
Table SOP 18.1 Microsoft Access tables for the streams database.	SOP 18-4
Table SOP 18.2. Microsoft Access tables for the lakes database.	SOP 18-9
Table SOP 18.3. Version information.	SOP 18-13
Table SOP 19.1. Information Management Tasks.....	SOP 19-8
Table SOP 19.2. Version information.	SOP 19-10
Table SOP 20.1. Most current versions of MOJN Streams and Lakes documents.	SOP 20-1
Table SOP 20.2. Version information.	SOP 20-3

Supplementary Materials

The Supplementary Materials are on a CD (included with hardcopies of this document) with the folder structure given below. Please contact the MOJN Data Manager for a copy of the CD:

Mojave Desert Network
601 Nevada Way
Boulder City, NV 89005
http://science.nature.nps.gov/im/units/mojn/aboutus_main.cfm

Folder: Administrative Record

PDS_StreamsLakes_093008.pdf

PDS_StreamsLakes_063010.pdf

MOJN Surface Water Dynamics and Water Quality Protocol Review 1-11.doc

MOJN_Streams and Lakes_Response to Peer Review.docx

<Future location of previous versions of narratives and SOPs>

Folder: Data Management

Subfolder: Data_Dictionaries

STLK_LK_MasterDB_DataDictionary.pdf

STLK_ST_MasterDB_DataDictionary.pdf

Folder: Field Sheets

Lakes_FieldSheet.xls

Streams_Annual_Visit_FieldSheet.xls

WQ_Sonde_1st_Visit_FieldSheet.xls

WQ_Sonde_Biweekly_Visit_FieldSheet.xls

Annual_Temperature_Sensor_Test.xls

Head_to_Head_Sensor_Test.xls

Stream_Gaging_Form.pdf

Discharge_Calc.xls

Folder: Laboratory Protocols

Subfolder: CCAL

CCAL QAP Final 2010.pdf

CCAL Conductivity SOP.pdf

CCAL FAAS SOP.pdf

CCAL IC SOP.pdf

CCAL Nitrate SOP.pdf

CCAL pH_Alkalinity SOP.pdf

CCAL Total Nitrogen SOP.pdf

CCAL TP SOP.pdf

Sub-Subfolder: Previous_CCAL_Protocols

CCAL TP SOP-used on 2009 MOJN samples.pdf

Supplementary Materials (Continued)

Folder: Laboratory Protocols (continued)

Subfolder: Buglab

BuglabLaboratoryStandardSampleSortingProcedures.pdf

BuglabQAQC.pdf

BuglabResultsAndReports.pdf

BuglabSampleArchiving.pdf

Folder: Lake Benchmarks

GRBA_LakeLevel_Benchmarks.docx

Folder: Manuals

aquarius_help_manual.zip

GlobalWater.pdf

HOBOWare.pdf

pHTestr.pdf

YSI85handheld.pdf

YSI556handheld.pdf

YSI650controlunit.pdf

YSIcontinuousWQsonde.pdf

Folder: Published Protocols

Continuous_Monitoring_Wagner_et_al_2006.pdf

EMAP_Peck_et_al_2006.pdf

USGS_stream_gaging_Turnipseed_sauer_2010.pdf

Folder: Random Sites On GRBA Streams

baker_random_sites.xls

lehman_random_sites.xls

mill_random_sites.xls

pine_random_sites.xls

ridge_random_sites.xls

sfkbigwash_random_sites.xls

shingle_random_sites.xls

snake_random_sites.xls

strawberry_random_sitest.xls

williams_random_sites.xls

Folder: Safety

Accident_Report_Form.pdf

Excerpts_from_USGS_NFM.doc

GRBA-47_Employee_Backcountry_Travel_Procedures.doc

Supplementary Materials (Continued)

Folder: Trend Analysis

Discharge_Trend_Analysis.doc

Kendall.exe

Kendall_Manual_Helsel_et_al_2005.pdf

Acknowledgments

Funding for this project was provided through the National Park Service Natural Resource Challenge and the Servicewide Inventory and Monitoring Program. This protocol is the result of the work of the MOJN Water Resources Working Group for whose time and effort we are grateful. WRWG participants included the authors, Debra Hughson (MOJN), Gretchen Baker (GRBA), Terry Fisk (DEVA), Bryan Moore (LAKE), Gary Rosenlieb (WRD), Luke Sabala (JOTR), Don Sada (DRI), Kyle Voyles (PARA), and Kari Yanskey (PARA). Kristina Heister's and Alice Chung-MacCoubrey's contributions as the previous MOJN I&M Coordinator laid the groundwork for the water-related protocols. This protocol also drew inspiration and passages from many other surface water monitoring SOPs, and we thank the authors of those SOPs.

SOP 1. Safety

1.1 Introduction and Objectives

[This SOP was adapted from Thoma et al. 2009.]

Encountering hazardous situations is inherent in field activities. Thus, staff members need to be aware of possible hazards and be able to adjust approaches accordingly so that high-quality monitoring can be conducted without injury or property damage.

The objectives for the Mojave Desert Network (MOJN) surface water dynamics and water quality monitoring program, and the specific objectives for operations under this SOP, are:

- To monitor surface water dynamics and water quality conditions, including accessing monitoring sites, deploying and retrieving equipment, making field measurements, and gathering and processing water quality samples in a manner that recognizes hazardous conditions and takes measures to minimize the risk of personnel injury.
- To maintain a high-quality monitoring effort, avoiding missed data collection and undue expense due to personnel injury or property damage.

Some hazardous conditions are inherent to all monitoring activities being undertaken by MOJN staff; others are specific to individual sites. Examples of the former include exposure to winter and summer weather, highway driving, and using hazardous chemicals. Site-specific hazards might include a specific four-wheel drive road. To minimize the possibility of accident or injury, a Job Hazard Analysis will be conducted for each employee engaged in field water quality monitoring. Second, hazards associated with specific sampling sites will be identified in the Field Site Description for each site. These procedures both improve operational safety by identifying hazardous conditions to NPS staff and supervisors and develop approaches to avoid or mitigate the hazards.

Safety always comes first, and because the logistics of field work can require much of a field supervisor's attention, it is the responsibility of everyone in the field to point out safety issues or concerns that otherwise could be overlooked in efforts to complete the field tasks at hand or when distractions occur from problems that may arise.

1.2 Risks Inherent in Field Activity

Risks inherent in water quality monitoring in general, and specifically to monitoring the sites selected in MOJN parks, include the following:

1.2.1 Working Alone

Field staff are discouraged from working alone in the field, although it may be appropriate for sites that are close to well-traveled roads when it is not necessary to enter a stream. If it is necessary to work alone, particular attention must be given to safety. Field staff should never work alone in the back-country, and should never enter any water body while alone.

1.2.2 Long road trips

Travel between parks will require long road trips at all times of the year and under varied weather and road conditions.

1.2.3 Backcountry roads and trails

Backcountry travel in GRBA must be undertaken in accordance with GRBA Park Order 47 (included in the Supplementary Materials). All personnel working in GRBA must be familiar with the Order. The Order states:

“Routine work on and along the Baker Creek Road and its tributaries, Wheeler Peak Scenic Drive, Strawberry Creek Road and Snake Creek Road during the periods of time that the roads are open to public vehicle access is **not considered BACKCOUNTRY travel.**”

All other travel in the park, including travel along established trails, is considered backcountry travel and governed by Park Order 47. In the case of the Streams and lakes protocol, visits to the gaging stations on the second order streams to collect discharge data and continuous water quality data would not be considered backcountry travel, while the annual visits to the lakes and to the randomly selected sites on the streams would be considered backcountry travel.

1.2.4 Activities in and on the water

Sample collection and flow measurements will require entering the main current in streams and boating to sites on lakes and large rivers. Extra care is necessary when wading because many streams are swift, stream bottoms can be loose or slippery, and water temperatures can quickly induce hypothermia at all times of the year. Precautions are needed to (1) recognize and avoid unacceptable risks, (2) use proper techniques to avoid accidents, and (3) be properly equipped for self-rescue. It is recognized that some sites will not be accessible during periods of bad weather. Similarly, it will not be possible to get a wading flow measurement during periods of flood. **If there is any doubt in regard to whether conditions are safe, the correct decision is to forgo sampling until another day.**

Excerpts from USGS Field Manual section 9.4 (included in the Supplementary Materials) give excellent guidance for safety precautions working on, in, and near water.

1.2.5 Varied weather conditions

The region spanned by MOJN is characterized by weather conditions that vary considerably through the seasons, day-to-day, and hour-by-hour. Snow, wind, and temperatures below freezing occur in the winter, and summer temperatures are often well above 100°F. Lightning is common during the summer monsoon storms. Hypothermia and heat-related injury are possible, and occasional discomfort is certain. Successful field work requires preparation for this wide range of conditions.

1.2.6 Use of hazardous materials

Some of the chemicals used to preserve samples are hazardous and require proper storage, handling, and personal protection, including eye and skin protection.

1.2.7 Slips, Trips, and Falls

Field work in GRBA requires hiking on maintained trails, unmaintained trails, and across trail-less areas, with possible areas of mud, snow, and ice. Proper footwear should always be worn, and care should be taken in choosing your footing. **If trail conditions make travel dangerous, the planned field work should be postponed.**

1.2.8 Altitude Sickness

From the GRBA website (<http://www.nps.gov/grba/planyourvisit/yoursafety.htm>):

“Altitude sickness is a condition brought on by high elevations often in conjunction with strenuous activity. Symptoms include difficulty breathing, nausea, incoherent speech, and headache. The cure is to descend immediately. Altitude sickness can be life threatening. To avoid altitude sickness, ascend slowly, eat lightly and frequently, and drink plenty of water.”

1.3 Job Hazard Analysis

Each National Park Service employee performing field inventory and monitoring activities in the MOJN will, in conjunction with his/her supervisor (and, if appropriate, other knowledgeable persons), develop a Job Hazard Analysis (JHA) of the task to be performed. For the Streams and lakes protocol, **the JHA should always be filled out in cooperation with the GRBA Aquatic Ecologist or other permanent member of the GRBA Resource Management Staff.** The procedure to be used is presented in NPS Reference Manual #50B, Occupational Safety and Health Program. Section 13 of that document, a step-by-step procedure for performing a JHA, is presented below. In addition:

- A form for completing a JHA and a list of suggested hazards (to be used in STEP 3) that are known to be associated with field water quality monitoring are presented in the Supplementary Materials.
- An example JHA for backcountry travel in GRBA is included in GRBA Office Order 47 (included in the Supplementary Materials), and reproduced below.
- GRBA-produced and approved JHAs for stream discharge measurements, water quality measurements, and lake work are reproduced below.
- The USGS National Field Manual includes a Chapter for Safety in Field Activities. Pertinent sections are included as a useful reference in the Supplementary Materials.

Excerpt: Section 13 of NPS Reference Manual 50B. Section numbers are maintained as per the original document.

13. JOB HAZARD ANALYSIS (JHA)

13.1 REFERENCE

A. Departmental Manual (DM), Part 485, Chapter 14.

13.2 REQUIREMENTS

A. Each operating unit will develop and implement a system by which major activities and individual jobs are analyzed. The Job Hazard Analysis (JHA) system will be used in the planning and completion of work assignments and projects as to:

- The sequence of work,
- The potential hazards associated with the sequence (action), and
- The methods, procedures, and safeguards to prevent, reduce and or control at-risk behaviors and reinforce safe behaviors.

B. When work is performed by others (e.g., contractors) the contracting officer (CO) will require that the contractor develops appropriate Job Hazard Analyses (JHAs) for the tasks to be performed. This information will be provided to the Contracting Officer (CO) or Contracting Officer's Representative (COR) as part of the accident prevention plan, and will be approved/accepted by the CO/COR prior to permitting the contractor to proceed with the work. The written JHA will be retained at the job site by the contractor, and made available, upon request, to persons evaluating/monitoring the activity.

13.3 PROCEDURES:

A Job Hazard Analysis (JHA) is a procedure used to review job methods and uncover hazards. Employees and supervisors should work together in the development of the JHA to assure that all characteristics of the job are examined, and the most efficient means of addressing the safety factors can be accomplished. A JHA should be used for job clarification, hazard awareness, training, and as an accident investigation tool. The following steps are involved in the development of a JHA:

STEP 1

Identify jobs posing the greatest accident risk, and prioritize selected jobs into three main areas:

- Jobs with highest rates of accidents and disabling injuries.
- Jobs where "close calls" (serious accident potential) have occurred.
- New jobs or jobs where changes have been made.

STEP 2

Targeting the top-priority jobs, break the selected job down into successive steps, actions, or activities and observe how these actions are performed. This is best done by jointly analyzing each step in order of occurrence. Each step should accomplish some major task. The task will consist of a set of behaviors/actions; list all the steps in a job in logical succession.

STEP 3

Identify the hazards, unsafe behaviors, and potential accidents for the job. Identify all hazards produced by the environment, equipment, materials, and those connected with the job procedure, as well as hazards that "might result."

Close observation and knowledge of the particular job, as well as discussion of the job, will help you to develop a reliable list of hazards, unsafe behaviors, and potential accidents. The job observation should be repeated as often as necessary until all hazards have been identified.

STEP 4

Develop safe job procedures to eliminate the hazards and prevent the potential accidents. Produce a written description of how to do each step safely and avoid the identified hazards.

The principal solutions may include:

1. Find a new way to do the job. Determine the work goal and analyze the various ways of reaching this goal to see which way is safest.
2. Change the physical conditions that create the hazard. Ask the question: "What change in physical condition will eliminate the hazard or prevent the accident?" When a change is found, analyze it for other benefits that might also accrue, i.e., cost/time savings.
3. Change the work procedure. Ask, "What should the employee do or not do to eliminate this hazard or prevent this potential accident?" Answers should precisely state what to do and how to

do it; general precautions such as “be alert” or “use caution” are useless.

4. Try to reduce the necessity of doing a job, or at least the frequency with which it must be performed. However, reducing the frequency of the job ONLY limits the exposure; it does not eliminate the hazard.

STEP 5

Established JHAs should be reevaluated periodically to ensure that they reflect the latest, safest, and most efficient way to perform the task. New equipment, tools, methods, and safety standards can require changes in JHAs. All employees concerned with the job should be informed of the changes and instructed in any new procedures. All new employees should be trained on applicable JHAs.

STEP 6

If an accident or injury occurs on a specific job, the JHA should be reviewed immediately to determine whether changes are needed in the job procedure. If the accident results from failure to follow JHA procedures, the facts should be discussed with all those who do the job.

STEP 7

Supervisors are responsible for maintaining JHA records within their work group.

JOB HAZARD ANALYSIS	JOB TITLE OR OPERATION: Backcountry Travel	PAGE <u>1</u> OF <u>2</u>	DATE: January 2007	<u>X</u> NEW _____ REVISED
	EMPLOYEE / OPERATOR: All	SUPERVISOR: Division Chiefs	ANALYSIS BY: Chief Ranger	
ORGANIZATION: NPS	LOCATION: GRBA	DEPARTMENT: All Divisions	REVIEWED BY:	
REQUIRED AND / OR RECOMMENDED PERSONAL PROTECTIVE EQUIPMENT: Refer to Office Order on Backcountry Travel and Footwear JHA.			APPROVED BY:	
SEQUENCE OF BASIC JOB STEPS	POTENTIAL HAZARDS UNSAFE ACTS OR CONDITIONS	RECOMMENDED ACTION OR PROCEDURE FOR ALL: REPORT ALL INJURIES AND ACCIDENTS TO SUPERVISOR.		
BACKCOUNTRY TRAVEL Refer to Office Order on Backcountry Travel.	- Falling or tripping due to wet areas, holes, fences, poor footing, snow and ice, uneven terrain, loose/rolling rocks and heavy pack. Terrain & environmental hazards associated with work that occurs in mountainous and high altitude terrain during all seasons.. - All members must travel together or have separate communications.	- Understand and practice situational awareness & risk management at all times. - Plan ahead & identify necessary PPE for your trip (i.e. Wear proper footwear; ensure protection from environmental conditions such as precipitation, wind, cold, heat; anticipate a full day and even a night out; consider you may have to care for someone else; anticipate whether you might need a helmet for the trip, etc.). - Guard against overloading yourself with unnecessary equipment. Recognize that in a mountain environment speed & the ability to travel quickly & efficiently, at times, may equate to safety. Unnecessarily heavy packs <u>may</u> be hazardous to safe travel in rugged terrain. STRIKE THAT BALANCE between adequate preparedness and excess. Work with supervisors & other experienced personnel to develop your own needs and the ability to adequately assess and prepare. - Be alert to changes in terrain & weather. - Carry the necessary tools required for the patrol. (i.e. avalanche beacon, probes, and shovel, when traveling in winter, etc. etc.). - Stay in shape. Know & monitor your personal fitness level & that of others in your group. Adjust plans accordingly. Carry water or a filter. - Have an approved First Aid Kit on hand. - If possible, take a coworker when traveling in areas of high risk or when conducting high risk activities. - Communications are a life link. Carry a radio & spare battery at all times. Ensure that equipment is working properly; batteries are fully charged, etc. Know and consult radio coverage maps. Be prepared to take a satellite phone if determined necessary. - File a written backcountry route plan with Dispatch and supervisor at least 24 hours in advance of the trip. If you deviate from this plan, notify dispatch. At key points during your trip (i.e. destination reached, decision-making points such as summits, junctions, saddles, etc.) re-contact dispatch & provide a status. Request status checks when traveling through hazardous areas (i.e. when crossing a known or suspected avalanche path).		
COMING INTO CONTACT WITH DANGEROUS AND/OR POISONOUS SNAKES, ANIMALS, INSECTS, AND PLANTS	- Poisonous snake, animal or insect bites. - Piercing of skin by spines or poisons of plants.	- Know dangerous and/or poisonous plants, insects, and animals. - Get medical help as soon as possible. - Maintain First Aid and CPR certifications. - Check clothing and skin regularly for ticks. - Wear long sleeves and gloves to minimize skin irritation from poisonous plants and/or sunburn. - Do not ingest unknown plants as they may be poisonous.		

		• Schedule outdoor activities accordingly if thunderstorms are likely. • If you see or hear a thunderstorm coming, go inside a sturdy building or vehicle. • You are in danger from lightning if you can hear thunder. • Carry a pack or insulating pad if you are not working near a building or vehicle. • If you are caught in a lightning storm, call dispatch to tell them you will be out of radio contact until the lightning storm passes. Call back in after the storm has passed. • If you can't get inside and if you feel your hair stand on end, lightning is about to strike. • Crouch down on your pack or insulating pad on the balls of your feet and keep your feet close together. • Place your hands on your knees and lower your head. • Make yourself the smallest target possible and minimize contact with the ground. • Members of a party should stay separated by at least ten feet. • Stay away from tall things like trees, towers, fences, telephone lines, or power lines. • Stay away from high mountain passes and high open meadows. If caught in these areas rapidly descend to a heavily forested area, however, stay at least 8 feet away from the trunk of the average height tree. • Stay away from metal things that lightning may strike. • Stay away from running water. • Call for help on your radio or on the nearest phone; be prepared to give detailed information of the victim's or victims' status, and when and where the accident happened. • Administer First Aid and CPR if certified or instructed to do so. • Take a Backcountry First Aid and CPR Class.
BACKCOUNTRY MISC.	• Exposure. • Heat Stroke. • Water borne illnesses. • Hantavirus. • Stock Use. • Dangerous wildlife. • Power and hand tools. • Heavy lifting. • Firearms. • Solo travel. • Helicopter.	• Be alert to changes in weather. • Take adequate garments for all possible weather conditions. • Take a coworker when traveling in extreme mountain weather. • Drink adequate amounts of water. Know the signs and symptoms and first aid treatments for heat related illness. • Filter all water. • Employee must have Hantavirus awareness training and use Hantavirus cleanup protocols. • Use precautions around buildings and other infested areas. • Take care around stock animals. Attend training. Use caution at all times. Don't work above your skill level. • Be alert for mountain lions, snakes, etc. Don't hike at night. Attend wildlife training. • Use proper safety gear. Get proper training and instructions on safe use. Use minimum tool necessary. • Get assistance with heavy items. Use proper form and techniques for lifting. • Know the firearms safety rules and always follow them. • Take extra precautions when traveling solo. Always be aware of your surroundings and possible

	- Over-snow travel. - Vehicles and trailers.	problems. - Follow guidelines for helicopter safety. - Receive training for snow and ice travel conditions and/or equipment. Never overestimate your ability. - Receive proper training for vehicles and trailers. Always check vehicle or trailer conditions before each use.
WORKING IN STREAMS	Hypothermia Slips, trips, and falls Being swept downstream	Do not enter streams when working alone. Do not enter streams that are deeper than your knees. Use extreme caution when the streambed is not visible. If you are working at a stream that you will enter, bring a change of clothing. Wear hiking boots over waders.
WORKING IN LAKES	Drowning Hypothermia Slips, trips, and falls	ALWAYS WEAR A PERSONAL FLOTATION DEVICE Never enter a lake when working alone. Bring a change of clothing. Wear hiking boots over waders. Never enter the lake or use the float tube during storms. Ensure the crew member using the float tube is a strong swimmer.
Emergency Evacuation Instructions		
Reference the GRBA Office Order on Backcountry Travel.		
JHA and Emergency Evacuation Procedures Acknowledgement		
We, the undersigned Supervisor and employees, acknowledge participation in the development of this JHA. We have thoroughly discussed and understand the provisions of this document.		
SUPERVISOR'S SIGNATURE		DATE:
EMPLOYEE SIGNATURE	EMPLOYEE SIGNATURE	
EMPLOYEE SIGNATURE	EMPLOYEE SIGNATURE	
DIVISION CHIEF'S SIGNATURE		DATE:

JOB TITLE: Stream Discharge MeasurementsDATE OF ANALYSIS: April, 28 2011JOB LOCATION: All GRBA Streams

SOP 1-9

REQUIRED EQUIPMENT & TOOLS FOR JOB Rubber boots, safety glasses, GPS, map, park radio. Measuring tape, water quality instruments, flow meter, rod, palm pilot.	REQUIRED SAFETY EQUIPMENT Rubber boots, safety glasses, Neoprene Cold Water gloves, adequate clothing park radio.
POTENTIAL HAZARDS	SAFETY CONTROL FACTORS
1) Algae covered rocks and uneven surface in stream or lake causing slips and falls. 2) Uneven surface of stream bank or lakeshore causing one to trip or twist an ankle. 3) Woody vegetation hanging over stream or lake could strike eye or skin. 4) Prolonged exposure to cold water. 5) High flows can knock you over and carry you downstream.	1) Walk slowly and ensure foot has solid placement before putting full weight upon it. 2) Walk slowly and ensure foot has solid placement before putting full weight upon it. Observe differences in vegetation height to indicate holes or rocks and down wood. 3) Wear safety glasses to protect eyes from flying debris or overhanging sticks. Wear long pants and long sleeve shirts to protect from punctures and thorns. Assist others by holding back vegetation and directing them through densely vegetated areas. 4) Dress appropriately and wear neoprene coldwater gloves. 5) Do not take discharge measurements if the flow of water is so high that it is unsafe. If measurements cannot be taken follow the procedures to estimate flow. Work in pairs at high flows.

JOB TITLE: Aquatic Invertebrate SurveyDATE OF ANALYSIS: February 20, 2007JOB LOCATION: All Streams and Lakes in GRBA

SOP 1-10

REQUIRED EQUIPMENT & TOOLS FOR JOB Surber samplers, kick nets, Rubber boots, safety glasses, 5 gallon buckets, trays, hand lenses, ethyl alcohol, sample bottles, sieves. Measuring tapes, meter sticks, water quality instruments, and flow meter.	REQUIRED SAFETY EQUIPMENT Rubber boots, safety glasses, Neoprene Cold Water gloves.
POTENTIAL HAZARDS	SAFETY CONTROL FACTORS
1) Algae covered rocks and uneven surface in stream or lake causing slips and falls. 2) Uneven surface of stream bank or lakeshore causing one to trip or twist ankle. 3) Woody vegetation hanging over stream or lake could strike eye or skin. 4) The drive to survey areas. 5) Chemicals used in water quality and sample preservation. 6) Cold water. 7) Hazardous weather.	1) Walk slowly and ensure foot has solid placement before putting full weight upon it. 2) Walk slowly and ensure foot has solid placement before putting full weight upon it. Observe differences in vegetation height to indicate holes or rocks and down wood. 3) Wear safety glasses to protect eyes from flying debris or overhanging sticks. Wear long pants and long sleeve shirts to protect from punctures and thorns. Assist others by holding back vegetation and directing them through densely vegetated areas. 4) Practice defensive driving methods. Be aware of “washboards” on dirt roads. Think ahead, plan your wheel placement when driving on four wheel drive roads. Carry an ax and shovel on seldom used roads to remove overhanging brush and fill holes. 5) Disburse chemicals needed prior to going in field. When in field disperse chemicals only in areas where you can do so with solid footing. 6) Wear Neoprene coldwater gloves when collecting samples in water. Have extra dry, warm, and rain proof clothing just in case someone falls into the stream 7) Stop work during severe thunderstorms. Follow lightning and flashflood precautions.

JOB TITLE: Water quality survey with float tubeDATE OF ANALYSIS: February 4, 2011JOB LOCATION: All lakes within GRBA

REQUIRED EQUIPMENT & TOOLS FOR JOB	REQUIRED SAFETY EQUIPMENT
Waders and boots, life jacket, float tube, flippers, water quality instruments, sample bottles, GPS, map, park radio, adequate clothing, food, and water.	Life jacket, waders, adequate clothing, park radio.
POTENTIAL HAZARDS	SAFETY CONTROL FACTORS
1. Deep water with possibility of snags and trees under the surface. 2. Uneven and slippery surface of lakeshore causing one to trip or twist an ankle. 3. Climbing in and out of float tube. 4. Cold water/hypothermia 5. Hazardous weather 6. Drive to and from survey sites.	1. Wear a life jacket and work with at least one other person who stays on shore. Be aware of where you are floating. Use flippers or a paddle to move the float tube in the right direction. 2. Walk slowly and ensure foot has solid placement before putting full weight upon it. Observe differences in vegetation height to indicate holes or rocks and down wood and take your time. 3. Get in and out of the float tube on the shoreline. Go slowly and ensure foot has solid placement. Have someone hold the float tube while climbing in/out. 4. Wear appropriate clothing including waders to keep from getting wet. Carry an extra set of warm, dry clothes. 5. Stop work during severe thunderstorms. Get out and away from the water. Follow lightning and flashflood precautions. 6. Practice defensive driving. Be aware of “washboards” on dirt roads. Think ahead; plan your wheel placement when driving on four wheel drive roads. Carry an ax and shovel to remove overhanging brush, fill holes, or dig out.

1.4 Routine and Emergency Communication

Using established lines of communication and a standardized Check-in/Check-out procedure are essential to ensuring that assistance can be provided in case of a mishap or delay.

Communication procedures for GRBA are specified in GRBA Office Order 47 (included in the Supplementary Materials)

MOJN field staff will contact the Chief Park Ranger (Curt Dimmick, as of June 2009) and the park dispatcher (Anita Hansen, as of June 2009) to notify them of the time and location of work in each park (Figure 1). This notification must include a Backcountry Travel Plan. A blank Backcountry Travel Plan is included in GRBA Office Order 47.

To: Curt Dimmick/GRBA/NPS, Anita Hansen/GRBA/NPS
Subject Line: I&M field work notification

I will be in GRBA for water quality sampling in Stella Lake, Teresa Lake, and Brown Lake as part of the Mojave Desert Network NPS inventory and monitoring project.

My vehicle is a white Jeep Cherokee 4 door with Nevada plates.

I will be parked at the Upper Lehman Creek Campground on 6/8/09 and 6/9/09.

I will be working with Gretchen Baker in GRBA resource management. Gretchen will provide a radio with GRBA frequencies.

An electronic copy of my Backcountry Travel Plan is attached.

Thanks,

John Doe

John Doe
Aquatic Ecologist
National Park Service
Mojave Desert Network
601 Nevada Highway
Boulder City, NV 89005
Office Phone: (702) 293-5555

1.4.1 Safety contact numbers

The regional 24-7 emergency number is 702-293-8998, radio call number 700. Use this number after 4:30 PM or on weekends. They can then phone a designated “on-duty” ranger at any regional park.

Contact	Radio Call Number	Telephone	Comments
Park Dispatch	764	775-234-7331 x207	Monday to Friday, 8:00-4:30
Law enforcement	Park dispatch (764 or 700)	774-289-8808	White Pine County Sherriff -dial 911 from park phones -specify whether emergency is inside or outside of park
Medical Emergency	Park dispatch (764 or 700)	775-234-7331 x207 or 702-293-8998 (park dispatch)	Dispatch will summon certified rangers or Baker Volunteer Ambulance.
Regional 24-7 emergency number	700	702-293-8998	Use this number after 4:30 PM or on weekends. They can then phone a designated “on-duty” ranger at any regional park.

1.4.2 Park radio

A personal two-way radio programmed with NPS frequencies is usually the best method for routine field and emergency communication in and near parks. GRBA Office Order 47 requires a radio for all backcountry travel, and recommends one radio per person if possible. Radio coverage is best on the east side of the park in the high areas between drainages.

Cell phones generally do not work in GRBA. However, in some parts of the park cell phone coverage exists and can be used. Cell coverage is best on the west side of the park in high, exposed areas.

When practical, MOJN field staff will carry back-up means of emergency communication, including satellite phones, SPOT locators and signal mirrors.

1.4.3 Incident Notification

In the event that an incident occurs which does not cause injury but which reveals the existence of a greater than anticipated risk of injury (e.g., an avalanche or a slip on an icy trail), the crew should return to the park office and notify the GRBA Ecologist and the protocol lead.

In the event that an incident occurs that results in a minor injury, the crew should return to the park office (if necessary) and notify the GRBA Ecologist and the protocol lead. The protocol lead is then responsible for informing the network program manager.

In the event that an incident occurs that results in a major injury, the crew should notify the GRBA Ecologist and the protocol lead as soon as it is safe to do so (e.g., by satellite phone while

still in the field). The protocol lead will then immediately contact the network program manager, who will immediately contact the regional program manager.

1.5 Vehicle Accident Procedure

In the event of a vehicle accident, ensure the safety of all passengers and move the vehicle from traveled lanes if possible. Contact emergency personnel and seek medical attention. **Contact your supervisor as soon as possible.** Accident reporting forms can be found in the Supplementary Materials.

1.6 Water Safety

Water safety procedures should be an important part of the JHA prepared prior to any field work. The float tube used to paddle to the center of the lake does not constitute a “watercraft” according to federal regulations, so no special certifications or training are required. However, a personal flotation device should always be worn when entering the water. The person operating the float tube must be able to swim, and there must be at least one additional person in the party who is able to swim. **Never enter the water if you are working alone.**

1.7 Chemical Storage and Use

Chemicals must be stored according to their Material Safety Data Sheet (MSDS) information. The MSDS sheets for all chemicals are kept in a clearly marked folder in the GRBA laboratory.

A list of all chemicals must be posted on the outside of the cabinet door (or wherever they are stored). This is done so that: (1) emergency personnel are able to identify the contents in case of an emergency and (2) people who are sensitive to certain materials are able to avoid exposure. The list of chemicals should include the name of the chemical, the quantity of that chemical in storage, and the quantity of that chemical that has been used (this includes anything that has been opened).

One list must be in the lab and a copy of this list must be given to the Chief Park Ranger (Curt Dimmick) at GRBA.

Table SOP 1.1. Example of chemical list to be posted on chemical cabinet at GRBA.

Water Quality Lab Chemical List		
Solution	Quantity stored	Quantity used
pH Buffer Solution 4	500ml-3	500ml-1 Lg-1
pH Buffer Solution 7	500ml-2	Lg-2
pH Buffer Solution 10	500ml-1	500ml-2 Lg-1
In Situ Quick Cal Solution	0	0
Sodium Sulfite Solution	0	0
Deionized Water	0	0
Conductivity Standard 147	0	1
Conductivity Standard 1413*	500ml-1	0
Conductivity Standard 12880	0	1
DO Electrode Filling Solution	0	1
pH Electrode	1	1
Stabcal Formazin Standard 800 NTU	0	0
Stabcal Formazin Standard <0.1 NTU	0	0
Stabcal Formazin Standard 20 NTU	0	0
Stabcal Formazin Standard 100 NTU	0	0
Colilert	0	0
Colilert Comparator	0	0
High Vacuum Grease	1	0
Sodium Sulfite	0	0
Cobalt (II) Chloride	0	0
Potassium Chloride	0	0
10% NH3 Cleaning Solution	0	0
Clorox Bleach	0	0
Arm and Hammer Baking Soda	0	0

Unless otherwise noted all chemicals are in main cabinet for storage.

1.8 Version Information

All literature cited is at the end of the SOPs.

Table SOP 1.2. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 2. Staff Training

2.1 Training Requirements

[This SOP was adapted from Thoma et al. 2009.]

2.1.1 Aquatic Ecologists

The MOJN and GRBA aquatic ecologists must have basic knowledge of the principles of water quality monitoring and experience in the operation of common water quality equipment. These elements will be included in the advertisement of vacancies and ranking of applicants. Any deficiencies in the backgrounds of the scientists will be remedied through a combination of formal training courses and informal instruction from other MOJN scientists. In addition, the scientists will regularly refer to this set of SOPs and the USGS National Field Manual for Water Data Collection. MOJN is ultimately responsible for ensuring that the GRBA aquatic ecologist's training meets MOJN sampling needs.

Training in the Data Management needs specific to the MOJN will be acquired from existing MOJN staff including the Data Manager.

2.1.2 Seasonal technicians

Seasonal technicians will be trained by the GRBA aquatic ecologist and the protocol lead at the beginning of each field season. Basic training should generally take 2-3 days, although it is expected that the field crews will be supervised in the field until they are competent at all aspects of a given task. This training will include, at a minimum, the following topics:

- Purpose and Objectives of Monitoring (*Protocol Narrative*)
- Field Safety (*SOP 1: Safety*)
- Lab Safety (*SOP 1: Safety*)
- Preparing for the Field (various SOPs)
- Proper Use of GRBA Radios
- Navigating with GRBA GPS Units
- Handling of Samples (*SOP 7: Sample Handling, Storage, and Shipping*)
- Field Measurements (various SOPs)
- Multi-parameter Meters (*SOP 6: Handheld Water Quality Instruments*)
- Sonde Care, Cleaning & Calibration (*SOP 11: Continuous Water Quality Sonde*)
- Rationale for Sampling Plan (*Protocol Narrative*)
- Surface-Water and BMI Sample Collection (*SOP 12: Stream Chemistry and BMI Sampling*)
- Data Entry and Sample Tracking (*SOP 19: Information Workflow and Tasks*)
- Field and Laboratory Demonstrations
- Troubleshooting and Contingencies
- Reference Materials (*Supplementary Materials*)

The training will consist of both a review of field procedures and a hands-on demonstration of all field tasks. Seasonal technicians will be supervised by the GRBA aquatic ecologist or the MOJN aquatic ecologist the first time they perform any given task.

If seasonal technicians are used to collect discharge measurements, then they will take the USGS On-Demand Web-stationed Training for discharge estimates (<http://pubs.usgs.gov/fs/2007/3099/>).

Oversight and monitoring by the GRBA aquatic ecologist will continue through the season. Seasonal hires will be made with the expectation that new staff enter duty with basic skills in field procedures and safety, at a minimum, and some knowledge or experience in water quality sampling will be desirable.

2.2 Version Information

Table SOP 2.1. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 3. Field Season Preparations

[This SOP was adapted from Starkey et al. 2009.]

3.1 Annual Review

Key network and park staff should conduct an annual review of the protocol and SOPs prior to spring preparations. This is a central element to season close-out procedures. Review should include training and field procedures, data management, analysis, and reporting, as well as fundamental design issues. Most importantly, careful consideration should be made of the resulting analyses and the overall confidence in results. The adequacy of sampling effort must be evaluated. Any necessary changes should be made to the protocol and SOPs with enough time to circulate updated material to key staff.

3.2 Procedures

3.2.1 Scheduling and Organizing Field Work

The MOJN and its constituent parks are unable to maintain a large field staff for financial and logistical reasons. The field portion of the surface water dynamics and water quality monitoring program must be sustained by the project lead, MOJN staff, and park resource staff. This fact mandates that field work should be scheduled well in advance of the June-October sampling window, and scheduling efforts should begin no later than the previous January. The project lead will coordinate this planning with GRBA and MOJN staff. In general, the MOJN hydrologist will be responsible for collecting data from the lakes, while the GRBA aquatic ecologist will be responsible for collecting discharge data and moving and calibrating the YSI sonde. BMI data collection will be the joint responsibility of the two scientists. Once trained, it is anticipated that the GRBA seasonal staff can perform many of the field activities unsupervised. A minimum of two people will be deployed for any task requiring backcountry travel, defined by GRBA as any travel other than routine work on and along the Baker Creek Road and its tributaries, Wheeler Peak Scenic Drive, Strawberry Creek Road and Snake Creek Road during the periods of time that the roads are open to public vehicle access.”

3.2.2 Seasonal Staff

Much of the field work for the program will be undertaken by seasonal staff based at GRBA. The GRBA resource staff will be responsible for hiring, and scheduling the seasonal staff. The protocol lead and the GRBA Ecologist will be jointly responsible for training. MOJN will provide budgetary support for the seasonal staff to cover the portion of their time that they are engaged in program-related activities. The training of the seasonal staff is described in the *SOP 2: Staff Training*.

3.2.3 Expendable Supplies

In general, expendable supplies for the monitoring effort must be ordered well in advance of the field season to ensure that they arrive before they are needed. An inventory of expendable supplies will be prepared at the end of each field season (*SOP 3: Post-Season Activities*). This inventory can be compared to anticipated needs to create a “shopping list.” Expendable supplies should be ordered by March to ensure delivery prior to the field season. For all chemicals, replacement dates should be written on the labels when they are received or opened.

pH buffer solutions. NIST-traceable buffers should be ordered prior to each field season. Many of the natural waters at GRBA have pH values that exceed 7. Therefore, a two-point pH meter calibration (with buffers of pH 7, and pH 10) is recommended. Two liters of each buffer should be sufficient for all of the pH meter and YSI sonde calibrations in a season. However, the pH of high-pH buffers can drift within one to two months of the bottle being opened due to exposure to atmospheric CO₂. Therefore, the pH 10 buffer should be ordered in four 500 mL bottles, and a different bottle should be used approximately every 30 days. The shelf life of unopened buffers is approximately two years.

Conductivity calibration solution. NIST-traceable conductivity calibration solution should be ordered prior to each field season. The shelf life for this solution is typically one to two years. Two liters of solution should be sufficient for all of the required calibrations.

Optical DO Membrane. YSI recommends that the optical DO membrane be replaced once a year. The membrane should be replaced prior to the start of each field season. **Note: Optical DO membranes are not the same as polarographic DO membrane- please be sure you are ordering the correct membrane.**

BMI sampling supplies. Alcohol and sample bottles must be ordered prior to the BMI sampling events each year, unless sufficient quantities remain from the previous year's field activities. Approximately 5gallons of 95% ethanol and 15 1 L HDPE sample bottles will be needed each year.

Lake and stream water sample bottles. Enough bottles for 15 samples should be ordered from the analytical laboratory.

Batteries. The YSI sonde, handheld YSI multiprobe, handheld pH meter, flowmeter, GPS, and camera are battery operated. If rechargeable batteries are not used for these instruments, then the correct batteries must be purchased to operate them.

3.2.4 Equipment Checklists

The following equipment should be assembled each spring, and sufficient time allowed to construct and/or order replacement equipment. Major equipment purchased by MOJN (e.g., the YSI sonde) will be stored in MOJN office between field seasons. Equipment owned by GRBA and all miscellaneous field supplies will be stored at GRBA.

All Field Work:

- o Digital camera
- o GPS
- o Handheld YSI multimeter
- o pH meter
- o Park Radio
- o Topographic map of park and aerial imagery
- o First Aid Kit
- o Water Jug
- o Sun screen
- o Field safety notebook

- o Bug repellent
- o Field form(s) and backups
- o Clipboard, pens, pencils, permanent markers
- o *SOP 1: Safety*

Lakes:

- o Stilling wells (unless already deployed)
- o Fenceposts, metal stakes, or rebar (unless already deployed)
- o Hobo U20 loggers (unless already deployed)
- o Rope, cord, or cable
- o Hobo optical data shuttle
- o Brush, soap
- o Waders and water boots
- o Sledgehammer
- o Notes on current logger locations
- o Float tube
- o Flippers
- o Personal flotation device
- o waders
- o bottles
- o filter apparatus and filter paper
- o Kemmerer sampler
- o Secchi disk
- o *SOP 10: Lakes Field Procedures*

Stream Core Parameters:

- o Sonde deployment housing
- o Sledgehammer
- o Fenceposts, metal stakes, or rebar
- o Rope, cord, or cable
- o brush and soap
- o New AA batteries (8)
- o Cotton swabs
- o Deionized water
- o Wash Bottle
- o Laptop Computer , with YSI software loaded
- o calibration cable
- o calibration cup
- o calibration solutions
- o *SOP 11: Continuous Water Quality Sonde*

Macroinvertebrate Sampling and Stream Chemistry:

- Initial site visit
 - Rebar #3 (9.525 mm or 0.375 inches) with engraved plastic caps. *Note that the X-site should be marked on both the left and right bank (12/sample reach)
 - Aluminum tags (labeled A through K) * Note that F should also be labeled as the X-Site (12/sample reach)
 - Small sledge hammer
 - 50 m tape measure (1)
 - Randomly-generated sampling points loaded in GPS unit
 - Calculator
 - *SOP 12: Stream Chemistry and BMI Sampling*
- Collection
 - D-frame net 500 μ m mesh and 1 spare
 - Stopwatch
 - Bucket labeled “reach wide” (2)
 - Sieve with 500 μ m mesh (2)
 - Watchmaker’s forceps
 - Wash bottle labeled “stream water”
 - Sample jars, HDPE plastic with screw caps, 1-L capacity, suitable for use with ethanol (6 to 8 / park)
 - 95% ethanol, in a proper container (2 gal)
 - Rubber gloves (optional)
 - Cooler for transporting ethanol and samples
 - Blank labels to be put on sample jar
 - Blank labels on waterproof paper for inside of sample jars
 - Sample collection form / data sheet
 - Permanent marker
 - Clear tape strips (1 box)
 - Plastic electrical tape (2 rolls)
 - Scissors
 - Pocket Knife
 - waders
 - Field Safety Notebook
 - List of randomly-generated X-site coordinates
 - Water chemistry sample bottles
 - *SOP 12: Stream Chemistry and BMI Sampling*

Stream Gaging:

- Waders
- Current meter
- 10 m measuring tape
- *SOP 9: Stream Discharge*

3.3 Safety

Safety is an important, but easily overlooked consideration. The safety information (*SOP 1: Safety*) should be reviewed before any field activity occurs. All information in the field safety notebook should be updated and reviewed this includes: appropriate Job Hazard Analysis, contact phone numbers, Chemical MSDS, and the GRBA office order on backcountry travel. Make sure all persons in the field know where vehicle keys are to be stored during field operations, the location of the nearest pay phone, radio, and/or cellular phone coverage opportunity, and emergency contact and operation procedures for NPS staff.

3.4 Pre-Season Instrument Comparisons

Before the start of the field season in late-May or early June, all of the water quality instruments that will be used for protocol work should be assembled in GRBA to compare the responses of the different sensors. This QA/QC test will ensure that all of the instruments are producing data that meet the data quality objectives described in *SOP 15: Quality Assurance Project Plan*.

Another type of QA/QC measurements, cross-section surveys, need to be collected for the four second-order streams. However, these data are collected at the time of the first sonde deployment, so they are described in *SOP 11: Continuous Water Quality Sonde*.

3.4.1 In-Lab Temperature Sensor Comparison

The water quality sondes measure temperature using National Institute of Standards and Technology-traceable thermistor that does not require calibration. WRD recommends that the thermometers of multiprobe instruments be checked against other NIST-traceable digital thermometers at three different temperatures. The non-traceable thermistors used in the handheld instruments are included in the check to ensure that their readings are acceptable. This check will be performed at the beginning of each field season. All of the temperature comparison and AMS+ data will be entered into the streams database and reported in the QA/QC appendix of the Annual Report.

The following procedure is modified from the USGS National Field Manual Chapter 6.1 v. 2 (Wilde, 2006).

- Note time and the instruments being tested on the temperature sensor comparison data sheet (Figure SOP 3.1). A Microsoft Excel version of this data sheet is included in the *Supplementary Materials*.

MOJN I&M STREAMS AND LAKES PROTOCOL- TEMPERATURE SENSOR COMPARISON LAB SHEET

DATE: _____ TIME: _____

CREW: _____

TEMPERATURE BATH 1 DESCRIPTION: _____ TEMPERATURE BATH 2 DESCRIPTION: _____ TEMPERATURE BATH 3 DESCRIPTION: _____

Instrument Code:													
Handheld/Sonde?:													
Manufacturer:													
Serial Number:													
Bath 1 Reading													
Bath 2 Reading													
Bath 3 Reading													

Ensure simultaneous measurements by setting sondes to logging mode, then reading data from files.

NOTES:

Figure SOP 3.1. Temperature sensor comparison data sheet.

- Program all the sondes to collect readings every minute. The procedure for programming the sondes is described in *SOP 11: Continuous Water Quality Sonde*.
- Fill a large cooler half-full of ice, and enough water so that ice water can be easily stirred. Set the sondes in the cooler in a such a way that the temperature probes are all at approximately the same depth. Place the probes from the handheld water quality instruments in the cooler at the same depth. An example of this procedure is shown in Figure SOP 3.2.



Figure SOP 3.2. Laboratory set up for temperature sensor comparison.

- When the handheld water quality instrument temperature readings have stabilized, stir the ice water for two minutes. During this time, record readings from each of the handheld instruments, and note the time. These readings will be compared to the readings recorded by the sondes during the same time span.
- Remove the ice water from the cooler, and fill it half full with room temperature water from a hose or tap. Replace the water quality instruments in the cooler in the same positions.
- When the handheld water quality instrument temperature readings have stabilized, stir the room temperature water for two minutes. During this time, record readings from each of the handheld instruments, and note the time.
- Remove the ice water from the cooler, and fill it half full with heated water from the hot water tap. Replace the water quality instruments in the cooler in the same positions.
- When the handheld water quality instrument temperature readings have stabilized, stir the hot water for five minutes. During this time, record three readings from each of the handheld instruments, and note the time.

- Download the records from the sondes, and extract the temperature readings from each sonde taken during the time when each of the temperature baths was being stirred. These should be compared to the handheld readings taken in each temperature bath. **If any of the instruments are giving temperature readings more than 0.2°C from the mean value for any of the temperature baths, then they should not be used in MOJN Streams and lakes protocol field work.**

3.4.2 In-Stream AMS+ Readings

As described in *SOP 15: Quality Assurance Project Plan*, Alternative Measurement Sensitivity Plus (AMS+) is a concept used to evaluate measurement sensitivity in an ambient condition such as a well-mixed flowing stream. It includes instrument noise and natural heterogeneity. AMS+ is calculated using:

$$AMS+ = t \times s ,$$

where

s = sample standard deviation of 7 in-situ measurement values, and

$t = 3.708$, the 99% confidence middle (two-sided) t-value for a sample size of 7.

AMS+ does include some natural variability in water-quality parameters between the seven measurements, but it is intended primarily as a measurement of instrument precision rather than the variability of a particular stream. Therefore, AMS+ measurements need to be collected for each sonde, **once near the beginning of the field season and once near the end of the field season.**

- Travel to a stream segment that has enough water to cover all the sondes, but where the flow is low enough that the sondes will not be swept downstream if they become unmoored. In June 2011, Lehman Creek near the Upper Lehman Creek campground was used, but flow conditions will vary from year to year.
- Calibrate all sensors, and program all the sondes to collect readings every minute. The procedure for calibrating and programming the sondes are described in *SOP 11: Continuous Water Quality Sonde*.
- Deploy the sondes in the stream by running a single cord through each sonde's bail. Bunch the sondes together near the center of the stream where there will be little variation in the measured parameters (Figure SOP 3.3)



Figure SOP 3.3. Four continuous water quality sondes deployed in Lehman Creek.

- Stand in the stream downstream of the sondes. Note the time, then collect seven readings of the four core parameters from each of the handheld instruments. Each reading should be collected approximately 10 seconds after the previous reading.
- Remove the sondes from the stream, and download the records. Seven consecutive readings from each instrument should be used to calculate a mean value and AMS+ value for each instrument. The mean values for each instrument should differ from the mean values across all instruments by less than the Bias MQOs given in Table SOP 15.4. The AMS+ values should meet the sensitivity MQOs given in Table SOP 15.4.

3.5 Version Information

Table SOP 3.1. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 4. Post Season Activities

[This SOP was adapted from Starkey et al. 2009.]

4.1 Equipment Cleaning/Storage

It is important to clean all equipment and to have equipment ready for the next sampling season. Following the June-to-September field season at GRBA, all equipment will be cleaned and stored as described below. The cleaning described in this SOP should be performed in addition to, not instead of, the equipment disinfection described in *SOP 5: Equipment Disinfection*.

Major equipment purchased by MOJN (e.g., the YSI sondes) will be stored in MOJN office between field seasons. Equipment owned by GRBA and all miscellaneous field supplies will be stored at GRBA. Non-electrical equipment, including nets, stakes, buckets, etc. should be stored in well-marked plastic bins. Electronic equipment, including; GPS units, YSI sondes, and current meters should have the batteries removed during the winter months to prevent corrosion and leaking, and will be stored in plastic bins in the MOJN office. Major equipment will be stored in hard plastic cases, such as Pelican cases, to prevent any damage.

Equipment used year-round by GRBA should be inspected before and after each MOJN field season.

4.1.1 YSI Sondes

- The YSI sondes should be cleaned according to manufacture guidelines given in the YSI 6-Series User Manual. Generally this means cleaning the external surface of the YSI sonde with a clean brush, soap and water. Any sediment or algae on the sensors should be gently brushed off with a toothbrush. **It is important that only water be used to clean the optical DO probe.** After washing with soap rinse the YSI sonde with clean tap water and allow the outside of the probe casing (NOT the sensors) to dry.
- All sealing surfaces such as O-rings should be **lightly** lubricated using silicone grease. Any O-rings that appear to be damaged should be replaced.
- Remove the batteries from the sonde prior to storage.
- Remove the pH sensor from the sonde, and use the appropriate plug to seal the port in the sonde. Store the pH sensor in the provided bottle filled with a solution of 2M KCl.
- Use the sonde's storage cup (filled with one inch of tap water) to protect the sensors from damage, and especially from drying out. If the sensors dry out they will no longer be useable, so make sure the storage cup has water and has been screwed on tightly enough to form an airtight seal before storing the unit.
- The YSI sonde should be stored in a hard plastic case in the MOJN office to prevent damage and to prevent the water in the storage cup from freezing.
- The cable should be stored in the same case as the sonde, and should be in coils of at least 15cm (6 inches) in diameter. If cable is coiled tighter than 15cm in diameter it will be damaged.

- The deployment housing and the fenceposts used for deployment should be scrubbed thoroughly with a clean brush, soap and water, and if necessary a 10% bleach solution. A toilet brush works well to reach inside the deployment housing.

4.1.2 Macroinvertebrate equipment

- In general, the guidelines for equipment care after each stream visit established by the EPA-EMAP protocol (Peck et al. 2006) will be followed.
- At minimum all macroinvertebrate equipment; nets, sieves, buckets etc. should be soaked in a 10% bleach solution for 10 minutes, or should be sprayed with a 50% solution and let stand for 5 minutes. After soaking or being sprayed with bleach, the equipment should be thoroughly rinsed with fresh tap water. Each piece of equipment should be allowed to dry in direct sunlight (84°F) for at least 4 hours.
- Torn nets should be repaired if possible, and replaced if damage will create a potential for sample bias.
- Macroinvertebrate gear will be stored in a plastic container in the GRBA storage shed.

4.1.3 Electronic Equipment

- All electronic equipment should have pertinent data removed and stored as a hard copy or on a computer.
- Batteries should be removed.
- Electronics should be wiped down according to manufacture instructions to remove dust.

4.1.4 Miscellaneous Equipment

All other equipment used during the field season (e.g. coolers, measuring tapes, Secchi disk, etc.) should be wiped down and stored inside the laboratory or storage shed at GRBA.

4.2 Expendable Supplies Inventory

At the end of each field season a list should be prepared detailing the amount of expendable supplies remaining and how much material should be ordered in the spring. Expendable supplies are listed in *SOP 3: Field Season Preparations*. Any expendable supplies that will expire before the beginning of the next field season (e.g. calibration standards, batteries) should either be used by MOJN or GRBA in other field programs or properly disposed of. The inventory list should be conducted by the project lead and filed in the MOJN office to speed ordering of supplies in the spring.

4.3 Seasonal Summary

To adequately prepare for the following sampling season, notes should be taken on where improvements to the sampling protocol or data sheets can be made, records kept on the condition of each YSI sonde, and notes of any other problems or issues that occurred during the field season.

4.4 Version Information

Table SOP 4.1. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 5. Equipment Disinfection

5.1 Overview

[This SOP was adapted from Schweizer 2007.]

Field personnel have the potential to introduce and spread parasites and non-native organisms. Currently, there are no known invasive species likely to be spread between the streams and lakes of GRBA by monitoring activities. However, MOJN recognizes the need for caution. Therefore, MOJN personnel will sterilize equipment prior to sample collection if logistically possible.

MOJN personnel will use chlorine bleach disinfection procedure. The alternative disinfectant is Quat-128®. Quat-128® is not used in this protocol because it is a source of nitrogen contamination. Chlorine bleach is a source of sodium and chloride ion contamination, but the biological and chemical effects of inputs of sodium and chloride ions should be minimal compared to the potential effects of any nutrient addition. Therefore, bleach was chosen as the disinfectant.

5.2 Priority of GRBA Disinfection Procedures

GRBA has disinfection procedures in place that vary from water body to water body, and may vary from year to year. These procedures take priority over the MOJN disinfection procedures described below. In all cases, park staff should be consulted regarding the appropriate disinfection procedures. **The procedures described below should only be used when none of the field personnel are aware of the GRBA procedures, and it is necessary to disinfect equipment immediately.**

5.3 MOJN Disinfection Procedures

Chlorine bleach disinfection is needed whenever equipment is moved between lakes or streams. Between sites in the same lake or stream, all equipment should be rinsed of organic debris.

Equipment will be disinfected upon reaching the sampling site. Equipment should not be disinfected in advance, as trace amounts of bleach can remain on the equipment, possibly causing damage. When you arrive at the new site take cautions to not allow the ‘contaminated’ equipment to contact water until it has been disinfected.

Granulated chlorine bleach is preferred because it is lighter and easier to transport than liquid bleach, and, unlike liquid bleach, it does not lose its effectiveness within 2 weeks. Granulated chlorine bleach can be purchased at swimming supply stores.

Use the following equipment to disinfect between sampling locations:

- Stiff scrub brush (if needed)
- Latex gloves
- Spray bottle
- 3 gallon collapsible bucket or dry bag
- Dry bleach (this should be in pre-measured, labeled packages for each sample site)

The following equipment should be cleaned and disinfected:

- Boots, shoes, waders, and sandals
- Float tubes
- Secchi disk
- Fins
- Kick nets
- Measuring tape
- Wading rod
- Kemmerer sampler
- Current meter
- Any other equipment that contacts the water

Equipment that could be adversely affected by exposure to bleach (e.g., pH electrodes) can be rinsed thoroughly with water from the lake or stream. Careful consideration of the tradeoff between potential contamination and potential equipment damage must be made prior to deciding not to disinfect any piece of equipment.

Prior to going into the field, package and label the disinfectant.

1. Get labels and containers to package the dry bleach. Containers can be plastic storage bags, plastic bottles, etc. If using plastic storage bags, put all bags for the trip into one dry bag, stuff sack, or hard sided container that can protect the plastic storage bags from being punctured.
2. Measure 1 cup of 56% available dry chlorine bleach (to get a 2% bleach solution when added to a 60% full 3 gallon bucket of water in the field).
3. Place dry bleach in plastic storage bag.
4. Label plastic storage bag.
5. Label the puncture resistant bag (stuff sack, dry bag, or hard sided container).
6. Repeat to have individual pre-measured containers for each lake or stream to be monitored.

The first step in the field is to thoroughly clean equipment.

1. Remove all organic matter (mud, plants, algae, etc.). Particular attention should be given to the treads of boots, sandals, and waders. A stiff brush should be used if needed.
2. Ensure no water remains in any equipment by removing any residual water from all pumps, hoses, etc.
3. Dry as thoroughly as possible. When practical and appropriate, wipe dry.
4. Let all equipment air dry as long as possible.

After the equipment is thoroughly cleaned, use the following steps to disinfect.

1. For small items, such as ropes:
 - a. Use a 2% solution of bleach.
 - b. Fill the 3 gallon collapsible bucket a little over half (60% full) with water at the new survey site.

- c. Mix the pre-measured quantity of dry bleach into the water in the bucket.
 - d. Soak all items (that have been cleaned of mud, etc.) for 2 minutes.
 - e. If the solution becomes noticeably dirty, dispose of it and mix a new batch.
 - f. After disinfecting your gear, rinse with water from the new survey site.
2. For large equipment that cannot be soaked, such as float tube, boat, and waders:
 - a. Use the 2% solution of bleach.
 - b. Fill spray bottle with solution.
 - c. Spray cleaned surfaces. If needed, use a sponge to make sure all surfaces get covered with the spray solution.
 - d. Let air dry.
 - e. Rinse thoroughly with water from the new survey site to remove all disinfectant to avoid sample contamination, and getting bleach on clothing, etc.
 3. Dispose of bleach solution at least 100 meters from water.

5.4 Version Information

Table SOP 5.1. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 6. Handheld Water Quality Instruments

6.1 Overview

The NPS Water Resources Division (WRD) requires four core water quality parameters at all freshwater monitoring sites. These parameters are dissolved oxygen, specific conductance, temperature, and pH. GRBA uses the YSI 85 to measure dissolved oxygen, specific conductance, and temperature and the Eutech pHTestr to measure pH. These instruments will be used in the streams because GRBA owns multiple units, ensuring they will be available for all stream work. MOJN's handheld instrument, the YSI 556, will be used in the lakes due to its longer cable and more accurate DO calibration procedure. The use of these three instruments is described below.

WRD requires that conductivity sensors be calibrated a minimum of once a day, while **pH and DO sensors must be calibrated at each site, immediately prior to data collection.**

Temperature sensors do not need to be calibrated. However, their performance should be regularly compared to a separate NIST-traceable thermometer. It is common practice to calibrate instruments less frequently than described above for other programs. **However, these protocols must be followed in order to collect credible data that could be defended in court or be used to detect long-term changes in water quality.**

6.2 Procedures for Data Collection- All Instruments

The four core parameters (pH, temperature, DO, and specific conductance) must be reported for each site. The instruments actually measure electrical conductivity, and use a temperature correction algorithm to compute specific conductance. Because these algorithms vary between instruments, the uncorrected electrical conductivity of the water must be reported as well.

In order to ensure that the measurement is representative of the entire stream, specific conductivity and temperature measurements should be made across a cross-section of the stream. For streams on the order of 1 meter wide, three measurements are sufficient (P. Penoyer Personal Communication). The measurements should be made at mid-water column in the center of the stream and near each bank. All parameters should be recorded for each measurement. The widest streams in GRBA are less than three meters wide. Five to seven measurement locations are sufficient for these streams. For streams greater than ~30 cm deep, measurements should be made near the surface, at mid-water column depth, and near the streambed at each location.

In lakes and ponds, depth profiles of core parameters should be collected. The procedures for the collection of depth profiles are outlined in *SOP 10: Lakes Field Procedures*.

6.3 YSI 85

GRBA owns five YSI 85 units, numbered 1 through 5. As of June 2010, unit 1 did not have a functional DO sensor. A diagram of the unit is shown in Figure SOP 6.1, and a copy of the manual is included in the Supplementary Materials. The instructions in this section are adapted from the manual.

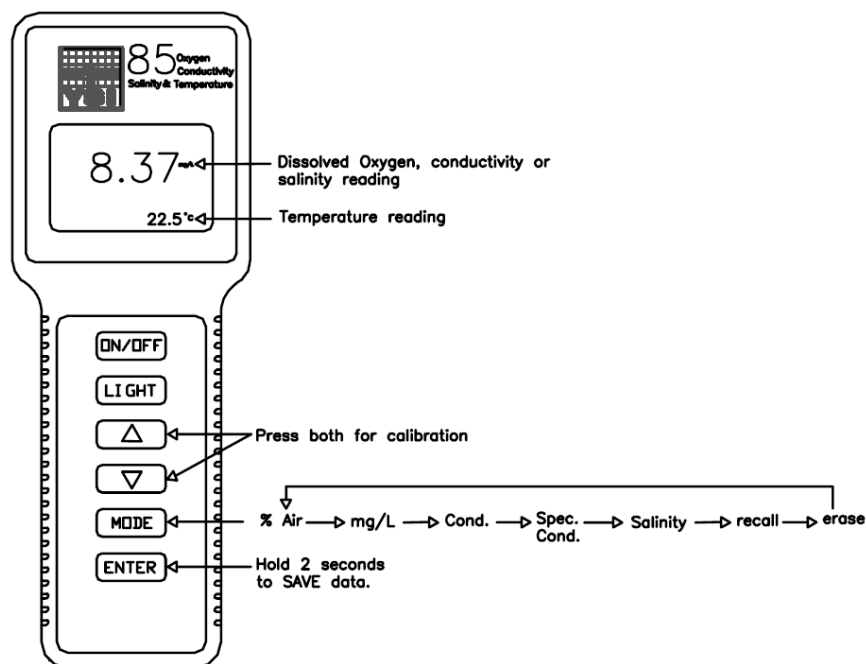


Figure SOP 6.1. Diagram of the YSI 85. Image taken from the YSI 85 manual.

6.3.1 Dissolved Oxygen Calibration

The DO meter on the YSI 85 is calibrated using elevation. This is less accurate than using a measured air pressure (it assumes a simple relationship between elevation and air pressure) but the calibration is easy to perform. The DO calibration should be performed at each site, and each time the probe is turned on.

1. Ensure the sponge inside the calibration chamber (the orifice on the right side of the instrument) is moist. Insert the probe into the calibration chamber.
2. Turn the instrument on, and hit the mode button until the DO reading (either % or mg/L) is displayed. Wait until the readings have stabilized, then hit the “up arrow” and “down arrow” buttons simultaneously to begin calibration.
3. The screen will display the elevation used for calibration in hundreds of feet (e.g., “67” for 6700 feet). Use the “up arrow” or “down arrow” button to adjust this elevation until it is at the 100-foot increment closest to the elevation of the site. The elevations of the stream gages and random stream sites are given below. For other sites, determine the elevation in the office prior to field work using GIS, or read the elevation from a map.

Table SOP 6.1. Elevations of sampling locations.

Sampling Site	Elevation (feet)
Baker Creek Stream Gage	6729
Lehman Creek Stream Gage	6699
Strawberry Creek Stream Gage	6795
Snake Creek Stream Gage	6188
Upper Snake Creek Stream Gage*	7598
Strawberry Creek Random Site	7274
Mill Creek Random Site	8045
Lehman Creek Random Site	9203
Baker Creek Random Site	9199
Snake Creek Random Site	8474
South Fork Big Wash Random Site	6998
Shingle Creek Random Site	8340
Pine Creek Random Site	8609
Ridge Creek Random Site	8369

*Upper Snake stream gage used by GRBA fisheries crew- not used in Streams and lakes protocol.

4. Hit the “ENTER” button. The display should read “SAVE”, then return to normal operation mode.

6.3.2 Specific Conductance Calibration

While the YSI 85 manual indicates that its conductivity sensor rarely needs calibration, WRD recommends that the probe be calibrated each day. There is no need to recalibrate conductivity when the instrument is turned off and on.

The NPS WRD recommends the use of a 1,413 $\mu\text{S}/\text{cm}$ conductivity calibration solution for all fresh water measurements (P. Penoyer, Hydrologist, NPS WRD). Therefore, MOJN uses a NIST-traceable calibration standard with a conductivity of 1,413 $\mu\text{S}/\text{cm}$. Use enough calibration solution to cover the entire probe head, as the inlet for conductivity measurements is near the top.

1. Dry the probe head with a Chem-Wipe or other tissue intended for laboratory use and rinse it with a small amount of the conductivity standard. Wait for approximately 60 seconds to allow the temperature sensor to equilibrate with the solution. Shake the probe to dislodge air bubbles from the electrode.
2. Turn the instrument on, and hit the mode button until the conductivity reading is displayed. Wait until the readings have stabilized, then hit the “up arrow” and “down arrow” buttons simultaneously to begin calibration.
3. The screen will display the target conductivity for the calibration. Use the “up arrow” or “down arrow” button to adjust this conductivity to match the standard (1,413 $\mu\text{S}/\text{cm}$, or a temperature-corrected value read from the bottle’s label).
4. Hit the “ENTER” button. The display should read “SAVE”, then return to normal operation mode.

6.3.3 Collecting Readings

After calibration, use the “MODE” button to cycle through the readings the different sensors. When specific conductivity is displayed, the “°C” icon in the temperature reading at the bottom of the screen flashes to indicate that a temperature correction is being applied. This icon does not flash when raw conductivity is displayed. Record the values on the appropriate field sheet.

6.4 Eutech pHTestr

The Eutech pHTestr is a robust field instrument designed for ease of use rather than for accuracy. Field tests indicate that pH values measured with the units are generally within 0.2 units of the pH values measured with the YSI continuous monitoring sondes, a level of deviation that is within the MQO for pH for the protocol. The readout screen and the pH electrode are integrated into one unit, so the instrument cannot be used to measure pH below the surface. GRBA has two functional pHTestrs labeled 2 and 3. The unit labeled A is not functional. The following sections have been adapted from the pHTestr manual, included in the Supplementary Materials.

6.4.1 Calibration

The manual indicates that the pHTestr should be calibrated once a week. However, WRD recommends that pH probes be calibrated at each site. Preliminary measurements of the pH of the streams and lakes at GRBA have generally been between 7 and 9, so a two-point pH calibration with pH 7 and pH 10 buffers is appropriate. However, the only two point calibration that can be performed on the pHTestr is with pH 7 buffer and pH 4 buffer. Because GRBA does not generally maintain a stock of pH 4 buffer, and because the instruments are not particularly accurate regardless of calibration, a one point pH calibration will be used.

1. Dry the probe head with a lint-free paper towel and rinse it with a small amount of the pH 7 buffer.
2. Turn the instrument on, and dip it into a small container of pH 7 buffer. Press the “Cal” button. Two numbers will appear on the screen: the top number is the reading, and the bottom number is the pH of the standard (7.00). The bottom number cannot be changed to reflect the dependence of pH on temperature, so the calibration should be performed with the buffer near 25 °C.
3. Wait until the readings stabilize, approximately 2 minutes. Hit the “Hold/Ent” button to calibrate the instrument. Hit the “Cal” button to exit calibration mode.

6.4.2 Collecting Readings

After calibration, place the instrument in the water body, allowing it to equilibrate with the water until the readings are stable. Record the pH value that appears on the readout screen. Do not remove the unit from the water while taking the reading.

6.5 YSI 556 MPS

MOJN owns a YSI 556 MPS, an instrument that measures temperature, conductivity, pH, and DO. A diagram of the instrument is shown below (Figure SOP 6.2). The YSI 556 MPS should be used for all measurements made at the lakes. The YSI 556 is similar in appearance to the YSI 650 control unit used with the sondes, but the two units are NOT interchangeable. The manual for the YSI 556 MPS is included in the Supplementary Materials. The instructions below are taken from the manual.

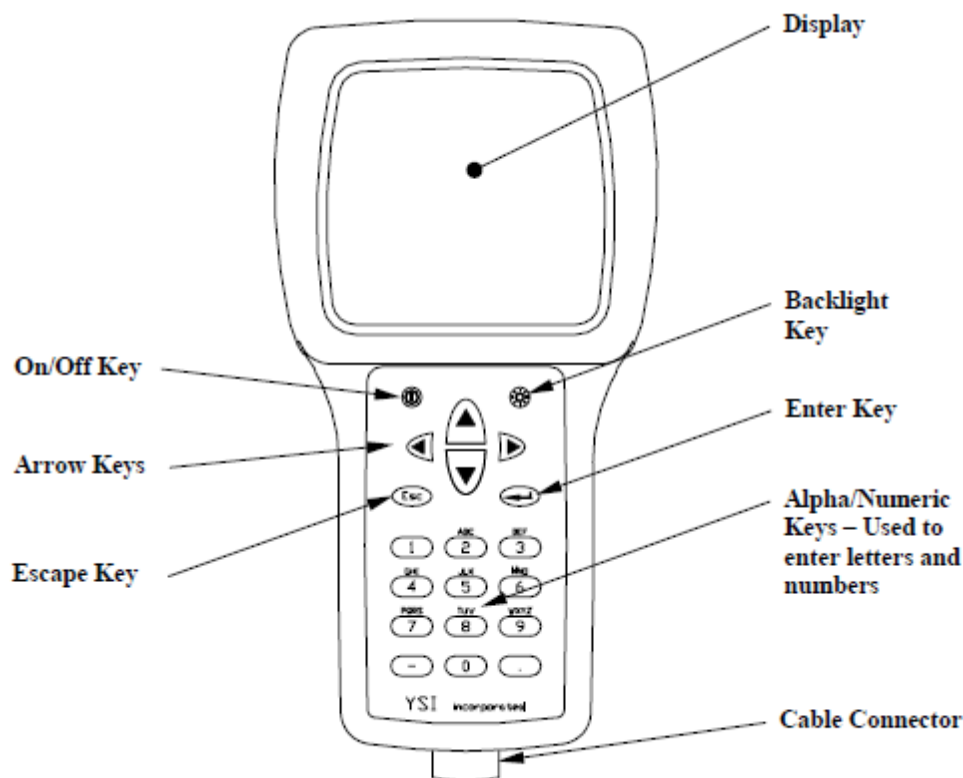


Figure SOP 6.2. Diagram of YSI 556 MPS. Image taken from YSI manual.

It is common practice to calibrate the multiprobe sensors in the office or laboratory prior to deployment. However, the instruments on the multiprobe can be affected by jostling and pressure changes, so it is strongly recommended that the sensors be calibrated at the sampling site just prior to deployment. WRD requires that, at a minimum, the pH and DO sensors be calibrated in the field.

6.5.1 DO Calibration

Errors in DO calibration are common, so care should be taken to follow these instructions carefully. The objective of the procedure is to use water-saturated air as a calibration standard. However, the saturation point changes as a function of temperature and pressure. The multiprobe automatically corrects for temperature, and pressure is measured by a barometer built into the control unit. If the control unit is not available, pressure can be read from a handheld barometer.

1. Place the sensor in a calibration cup containing 3 mm (1/8 inch) of water. The intent of the procedure is to perform the measurement in water-saturated air, so the sensor should not be underwater. Loosely thread the calibration cup onto the probe housing, ensuring that the air pressure inside the cup is the same as the atmospheric pressure. Wait 10 minutes to allow the water and air in the cup to reach the ambient temperature and equilibrate.

2. From the main menu, select “Calibrate”. From the Calibrate Menu, select “ODOsat %,” then “1-point.” Accept the barometric pressure in mm of Hg displayed as the default option on the control unit (or enter a value read from a handheld barometer).
3. All of the enabled sensor readings will be displayed on the screen. Once the DO readings have been stable (defined by WRD as less than or equal to 0.3 mg/L of variation) for 30 seconds, accept the calibration by pressing “Enter.” It may take as long as 15 minutes for the readings to stabilize.

6.5.2 Specific Conductance Calibration

The NPS WRD recommends the use of a 1,413 $\mu\text{S}/\text{cm}$ conductivity calibration solution for all fresh water measurements (P. Penoyer, Hydrologist, NPS WRD). Therefore, MOJN uses a NIST-traceable calibration standard with a conductivity of 1,413 $\mu\text{S}/\text{cm}$. It is important that the calibration cup and the probe are clean and dry prior to calibration.

1. Rinse the conductivity sensor and calibration cup with a small amount of the calibration solution. Discard the rinsate. Repeat.
2. Fill the calibration cup with approximately 200 mL of the calibration solution. Enough solution should be used to cover the vent hole on the side of the sensor. Allow one minute for the temperature to equilibrate.
3. From the main menu, select “Calibrate”. From the Calibrate Menu, select “Conductivity,” then “SpCond.” Enter the specific conductivity of the calibration solution (1 mS/cm).
4. All of the enabled sensor readings will be displayed on the screen. Once the specific conductivity readings have been stable (defined by WRD as less than 3% variation) for 30 seconds, accept the calibration by pressing “Enter.”

6.5.3 pH Calibration

Preliminary measurements of the pH of the streams and lakes at GRBA have generally been between 7 and 9. Therefore, a two-point pH calibration with pH 7 and pH 10 buffers is appropriate. The USGS NFM recommends that specialized buffers and pH electrodes be used for waters with specific conductivities below 0.1 mS/cm (Ritz and Collins, 2008). However, YSI has demonstrated that the pH sensor on the multiprobe performs well in low-conductivity water when calibrated with standard buffers (YSI, 2005). Therefore, no specialized pH electrodes or buffers will be used.

The buffers should be as close as possible to the temperature of the water body at the time of calibration. This can be achieved by submerging the buffer bottles in the water body prior to calibration.

Note: If the response of the pH sensor appears to be slower than normal, then the sensor should be cleaned according to the instructions given in the manual.

1. Pour enough pH 7 buffers into the calibration to immerse the pH sensor (approximately 125 mL). Do not thread the cup onto the probe. Allow one minute for temperature to equilibrate.

2. Measure the temperature of the buffer in the cup using a digital thermometer. Use the table on the buffer bottle to determine the temperature-corrected pH of the buffer.
3. Thread the cup onto the probe. From the main menu, select “Calibrate”. From the Calibrate Menu, select “ISE1 pH,” then “2-point.” Enter the temperature-corrected pH.
4. All of the enabled sensor readings will be displayed on the screen. Once the pH readings have been stable (defined by WRD as less than or equal to 0.1 pH units of variation) for 30 seconds, accept the first point of the calibration by pressing “Enter.”
5. Rinse the sensor and calibration cup with pH 10 buffer. Discard the rinsate.
6. Pour enough pH 10 buffer into the calibration to immerse the pH sensor (approximately 125 mL). Thread the cup onto the probe. Allow one minute for temperature to equilibrate.
7. Use the table on the buffer bottle to determine the temperature-corrected pH of the buffer.
8. Follow the instructions on the screen to continue the calibration. Enter the temperature-correct pH of the buffer.
9. All of the enabled sensor readings will be displayed on the screen. Once the pH readings have been stable (defined by WRD as less than or equal to 0.1 pH units of variation) for 30 seconds, accept the calibration by pressing “Enter.”

6.5.4 Collecting Readings

After calibration, place the instrument in the water body, allowing it to equilibrate with the water for approximately 2 minutes. Select “Run” from the main menu, and record the readings once they have stabilized.

6.6 AMS+

As described in *SOP 15: Quality Assurance Project Plan*, Alternative Measurement Sensitivity Plus (AMS+) is a concept used to evaluate measurement sensitivity in an ambient condition such as a well-mixed flowing stream. AMS+ for each instrument should be calculated **once near the beginning of the field season and once near the end of the field season**. The procedure for making these measurements is described in *SOP 3: Field Season Preparations*.

6.7 Version Information

Table SOP 6.2. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 7. Sample Handling, Storage, and Shipping

7.1 Introduction

There are two types of samples collected under the Streams and lakes protocol: water samples from streams and lakes and BMI samples from streams. This SOP describes how these samples should be handled, stored, and shipped. Some of the information contained in these SOPs was taken from the websites of the water chemistry laboratory (CCAL) and the BMI laboratory (USU BugLab) used by the network.

7.2 Water Samples

The water samples collected from GRBA streams and lakes consist of three 500 mL bottles, two filtered and one unfiltered. Because chemical analyses of dilute waters can be affected by trace contamination, chemical preservation (e.g., acidification) is not used. Instead, two bottles (one filtered and one unfiltered) should be kept cool ($<4^{\circ}\text{C}$) in the field, then frozen immediately upon return to headquarters. These samples should be stored in a freezer until shipped. The third bottle (filtered) is for dissolved organic carbon analysis. This sample should be refrigerated and shipped to the lab within four weeks.

The samples must be shipped on a Monday to ensure that they reach CCAL (the analytical lab) by Thursday afternoon. Samples should be shipped on the first Monday after they have been collected, unless more water samples will be collected within the next week, in which case it is permissible to ship them the second Monday after their collection.

The samples should be shipped in coolers (generally provided by CCAL) with sufficient hard-sided “blue ice” to prevent the frozen samples from melting for four days. A hardcopy of the sample submittal form should be placed in a plastic bag inside the cooler. An electronic version of the sample submittal form should be uploaded to the CCAL website:

<http://wwwdata.forestry.oregonstate.edu/fs/ccal/default.aspx>

Ship samples to:

CCAL/ College of Forestry
Oregon State University
Peavy 048/056
Corvallis, OR 97331

Include “Water Samples: Refrigerate Immediately Upon Receipt” on the top of the cooler to alert receiving personnel. Upon shipping, the lab should be contacted by telephone at (541) 737-5122 to ensure that they are expecting the shipment.

7.3 BMI Samples

As described in *SOP 12: Stream Chemistry and BMI Sampling*, the BMI samples are preserved in ethanol, and labeled consecutively (e.g., 1, 2, 3 etc.). For samples requiring more than one jar, the jars should be numbered, 1a, 1b, 1c, etc. A duplicate label on waterproof paper should be put inside the jar. **The label inside the jar should be made with laser printer, photocopying or with pencil as the ink in inkjet printers and many ballpoint pens and permanent markers**

are soluble in ethanol. The jars should be stored in a climate-controlled environment away from direct sunlight until they are shipped.

Ethanol is considered a hazardous material. Therefore, unless special arrangements are made, samples cannot be shipped in alcohol. Instead, the samples should be shipped overnight while in water, which the BugLab can replace with alcohol the following day. Overnight shipments cannot be made from GRBA, so the samples should be brought to LAKE at the end of the field season for shipping. The following protocol should be followed:

1. Arrange for the disposal of the ethanol with LAKE's Environmental Manager. As of 2010, this position is filled by Michael Moran (702-293-8705). Currently, LAKE's hazardous waste is disposed of by H2O Environmental (Tracy Smith, 702-396-4148). However, this may change in the future.
2. The samples should be preserved in alcohol for at least two weeks prior to shipment.
3. Arrange with Fedex, UPS, or another courier service for the samples to be shipped overnight.
4. On the morning of the day that the samples will be picked up, pour the alcohol from each sample jar into a 2-gallon or 5-gallon pail with a watertight lid. The alcohol should be poured through a 500-micron sieve, and any invertebrates or organic material caught in the sieve should be washed back into the sample jar using a spray bottle. The sieve should be cleaned between samples. It is acceptable if a few milliliters of alcohol remain in the sample jar, as low concentrations of ethanol do not constitute a flammable or ignitable waste.
5. Fill the jars $\frac{3}{4}$ full with tap water so that the specimens are not damaged by jostling. The jars should be shipped in a box with sufficient packing material to prevent breakage. The BMI sample submittal sheet and the field sheets for the samples should be included in a plastic bag. Ship samples to:

The Buglab
Department of Watershed Sciences
Utah State University
Logan, UT 84322-5210

Upon shipping, the lab should be contacted by telephone at (435) 797-2612 to ensure that they are expecting the shipment. The Buglab provides notification of the receipt of shipments by postcard.

6. Place the watertight lid on the pail, and store or dispose of the waste as instructed by the Environmental Manager.

7.4 Chain of Custody Forms

[This section adapted from O’Ney, 2006]

The MOJN Streams and Lakes chain of custody form is included in the Supplementary Materials and in this section (Figure SOP 7.1). One chain of custody form must be filled out and submitted to laboratory for each shipment of samples.

The chain of custody documents the possession of the samples from the time they were collected until the sample analytical results are received. Lab technicians, field crew members, and the field crew leader are responsible for maintaining chain of custody conditions during the time that samples are in their possession. Submitting a completed and signed chain of custody form with samples is mandatory. The purpose of this procedure is to assure that an accurate written record is created by the field crew that will be accepted as valid evidence to trace a sample or samples from the moment of collection through laboratory testing and reporting of test results.

Because the samples will typically be collected over the course of several days of field work, there should be several chain of custody forms submitted to the labs with each sample shipment. The field crew must use a form to formally relinquish the samples to the GRBA Aquatic Ecologist at the end of each day, even though they work in the same office. At the time of shipping, the chain of custody forms must be completed and placed in a water-tight plastic bag inside the sample container (cooler). The bag can be taped to the inside of the lid. If a common carrier is used to deliver the samples to the analytical laboratory, the shipping receipts are retained as proof of transfer of custody. Laboratory personnel indicate date and time received and signs the form. The original forms are retained at the MOJN office and are filed in chronological order.

7.5 Version Information

Table SOP 7.1. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 7-4

Figure SOP 7.1. Chain of custody form.

SOP 8. Regulatory Status

8.1 303(d)-Listed Waters

Section 303(d) of the Clean Water Act (CWA) is meant to protect water bodies that are impaired by pollution that does not violate existing effluent standards. Under Section 303(d), states are required to further regulate such pollution by developing total maximum daily loads (TMDLs) for the applicable pollutants for each impaired water body.

The water quality standards used to determine if a water body has been impaired are a function of the beneficial uses of that water body. Beneficial uses are defined during an attainability analysis which determines actual use and potential future uses of a waterbody. Beneficial use status is reviewed every two years during 303(d) assessments as mandated under the Clean Water Act.

Designated or beneficial uses of surface waters evaluated for potential 303(d) listing include irrigation, watering of livestock, recreation involving or not involving contact with water, industrial supply, municipal or domestic supply, propagation of wildlife, propagation of aquatic life, aesthetic value, water quality enhancement, and maintenance of freshwater marshes. A table listing beneficial uses of each Nevada waterbody in or adjacent to LAKE and Nevada Class A waterbodies is included below as Table SOP 8.1. The beneficial uses determined by the state of Arizona are included in Table SOP 8.2.

LAKE contains the only water bodies located in the MOJN parks that are designated as 303(d) impaired. The waterbodies in or adjacent to LAKE that were listed as impaired by either Arizona or Nevada in 2004, 2006, or 2008 are given in the Table SOP 8.3. The list of impaired waterbodies is used for ranking of priority sites and Total Maximum Daily Load (TMDL) development in order to limit discharges of specific pollutants to the water bodies (Ledder 2003). The existing TMDLs for each impaired segment are also given in Table SOP 8.3.

8.1.1 Listed Waters Monitoring Procedure

There are three sources for information regarding the regulatory status of the waters in the MOJN parks: The EPA, the state of Arizona, and the state of Nevada. The EPA's water quality information portal is the Watershed Assessment, Tracking, and Environmental Results (WATERS) system. WATERS can be accessed at <http://www.epa.gov/waters/ir/index.html>. The current and historical 303(d) reports for Arizona and Nevada can be accessed from this site. However, this site only links to the final, EPA-approved reports, so it is necessary to review the reports on the state agencies' websites as well. The Arizona Department of Environmental Quality reports are available at <http://www.azdeq.gov/environ/water/assessment/assess.html>. The Nevada Division of Environmental Protection reports are available at <http://ndep.nv.gov/bwqp/standard.htm>. The three websites should be reviewed annually at the time of report preparation.

Table SOP 8.1. State of Nevada-determined beneficial uses of waterbodies in or adjacent to LAKE and Nevada Class A Waterbodies.

		<i>Beneficial Uses</i>											Aquatic Species of Concern
Water Body	Description	Irrigation	Stock Watering	Contact Recreation	Non-Contact Recreation	Industrial Use	Municipal or Domestic Use	Wildlife	Aquatic Life	Outstanding Aesthetic Value	Water Quality Enhancement	Freshwater Marsh	
Virgin River	Mesquite to Lake Mead	x	x		x	x		x	x				
Colorado River	Lake Mohave inlet to CA state line	x	x	x	x	x	x	x	x				
Colorado River	Hoover Dam to Lake Mohave inlet	x	x	x	x	x	x	x	x				
Lake Mead	Excluding Las Vegas Bay	x	x	x	x	x	x	x	x				Warm-water fishery
Lake Mead	Las Vegas Bay	x	x		x	x		x	x				Warm-water fishery
Las Vegas Wash	Telephone Line Road to Lake Mead	x	x		x			x	x			x	Excluding fish
Muddy River	Glendale to Lake Mead	x	x		x	x		x	x				
All Class A Waterbodies		x	x	x	x	x	x*	x	x				

* The beneficial use of Class A waterbodies for municipal or domestic use assumes the water will be treated by disinfection only.

Table SOP 8.2. State of Arizona-determined beneficial uses of waterbodies in or adjacent to LAKE.

Water Body	Description	Coldwater Fishery	Warmwater Fishery	Aquatics and Wildlife-Ephemeral	Aquatics and Wildlife-Effluent	Domestic Water Source	Fish Consumption	Full Body Contact	Partial Body Contact	Agricultural Irrigation	Agricultural Stock Watering
Colorado River	Hoover Dam to Lake Mohave	x				x	x	x		x	x
Lake Mohave	Lake Mohave	x				x	x	x		x	x

Table SOP 8.3. Water bodies within and adjacent to LAKE listed as impaired by the State of Nevada and the State of Arizona.

Arizona Listings					
Waterbody Name	Reach Description	Existing TMDLs	2004 List (EPA-Approved)	2006 List (EPA-Approved)	2008 List (EPA-Approved)
Colorado River	Hoover Dam to Lake Mohave	None	Selenium	Selenium	Selenium

Nevada Listings					
Waterbody Name	Reach Description	Existing TMDLs	2002 List (EPA-Approved)	2004 List (EPA-Approved)	2006 List (Submitted to EPA)
Las Vegas Wash	Telephone Line Rd to Lake Mead	Total ammonia, Phosphorus (total)	Iron (total) Total Suspended Solids	Iron (total) Selenium	Iron Molybdenum
Virgin River	Mesquite to Lake Mead	Draft TMDL for Boron	Boron (total) Iron (total) Temperature Phosphorus (total)	Boron (total) Iron (total) Temperature Phosphorus (total) Selenium	Manganese Iron Temperature Phosphorus (total)
Muddy River	Glendale to Lake Mead	None	Boron (total) Iron (total) Temperature	Boron (total) Iron (total) Temperature	Boron Iron Temperature Manganese Molybdenum
Colorado River	Lake Mohave Inlet to CA state line	None	pH	Temperature	Temperature
Colorado River	Hoover Dam to Lake Mohave Inlet	None	pH	Zinc (total)	Dissolved oxygen Temperature

8.2 Outstanding Natural Resource Waters

The EPA water quality standards authorized by the Clean Water Act include a provision for the identification of Outstanding National Resource Waters (ONRWs) to provide protection to the Nation's most treasured water bodies. Under anti-degradation rules (40 CFR §131.12), no lowering of water quality is allowed for ONRWs.

Each state has developed its own list of ONRW waters. For the parks in MOJN, only GBRA has water bodies that have received a designation that could be interpreted as ONRW. In the State of Nevada, the Nevada Administrative Code (NAC 445A.124) identifies waters defined as Class A waters. Class A waters include waters or portions of waters located in areas of little human habitation, no industrial development or intensive agriculture and where the watershed is relatively undisturbed by human activity. Four Class A waters are found in GRBA (Table SOP 8.4).

8.2.1 ONRW Monitoring Procedure

The NAC does not provide for regular monitoring or reporting of the status of Class A streams. However, water bodies can be reclassified by the State Environmental Commission, particularly in response to discharge permit requests. Therefore, the NAC should be checked each year during the preparation of the annual report for the possible presence of an updated Class A waters list. As of 2009, The NAC can be accessed at <http://www.leg.state.nv.us/nac/>.

NAC 445A.124 also gives the water quality standards for Class A waters (Table SOP 8.5). Water quality data collected for GRBA's Class A waters will be compared to these standards when applicable. However, it is important to recall that the CWA's anti-degradation rules do not allow any lowering of water quality in ONRWs, regardless of whether state standards are met.

Table SOP 8.4. Streams in GRBA classified as Class A by the state of Nevada.

Name	Description
Baker Creek	From its origin to the national forest boundary.
Lehman Creek	From its origin to the national forest* boundary.
Pine Creek	From its origin to the first point of diversion, near the west line of section 17, T. 13 N., R. 68 E., M.D.B. & M.
Ridge Creek	From its origin to the first point of diversion, near the west line of section 17, T. 13 N., R. 68 E., M.D.B. & M.

* Since the creation of Great Basin National Park, the park boundary is the appropriate limit for the Class A segment of Lehman Creek.

Table SOP 8.5. Water Quality Standards for Nevada Class A Waters.

Item	Standard
Floating solids, sludge deposits, or taste- or odor-producing substances.	None attributable to man's activities.
Sewage, industrial wastes or other wastes.	None.
Toxic materials, oils, or other wastes.	None.
Settleable solids.	Only amounts attributable to man's activities which will not make the waters unsafe or unsuitable as a drinking water source or which will not be detrimental to aquatic life or for any other beneficial use established for this class.
pH.	6.5 to 9.0 SU.
Dissolved oxygen.	≥6.0 mg/l.
Temperature:	
Maximum.	≤20°C.
Change from natural temperature	=0°C.
Fecal coliform (No./100 ml).	≤200/400. ^a
Total phosphorus (as P) in streams:	≤0.10 mg/l.
Total dissolved solids.	≤500 mg/l or one-third above that characteristic of natural conditions (whichever is less).

^a The fecal coliform concentration, based on a minimum of five samples during any 30-day period, must not exceed a geometric mean of 200/ 100 ml, and not more than 10 percent of total samples during any 30-day period may exceed 400/100 ml.

8.3 Version Information

Table SOP 8.6. Version information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 9. Stream Discharge

9.1 Overview

This SOP describes how stream discharge will be measured on the four second-order streams at GRBA. Currently, the USGS is operating a stream gage on Lehman Creek. The other three second-order streams in the park, Baker Creek, Snake Creek, and Strawberry Creek, were formerly monitored by the USGS. GRBA and MOJN will collect monthly discharge measurements on all four second-order streams at the active or abandoned stream gaging sites, and collect continuous stage data at the former stream gaging sites on Baker Creek, Snake Creek, and Strawberry Creek. If the USGS ceases to monitor Lehman Creek, MOJN and GRBA will take over continuous stage recording at that site. In addition, MOJN will collect discharge measurements and continuous stage data at a newly established stream gaging site on the perennial (upper) portion of Snake Creek.

All of the gaging sites in this protocol have been established by USGS-trained personnel. In the event that a gage is destroyed, it should be re-established by an experienced hydrologist, preferably one working for the USGS or NPS WRD.

This SOP describes the field monitoring activities involved in monitoring stream discharge. The development of rating curves and the analysis of the continuous stage data is described in *SOP 17: Data Analysis and Reporting*.

9.1.1 Site Access

All five gages are located short distances from the roads that run parallel to the creeks. They can be located using the GPS coordinates listed in Table SOP 9.1 and the navigation techniques described in *SOP 12: Stream Chemistry and BMI Sampling*. In practice, it may be most useful to visit the sites with a GRBA staff member who is familiar with their locations. A map of the stream gages is shown in Figure SOP 9.1.

Table SOP 9.1. Stream gage locations. Easting and northing coordinates are for UTM zone 11S, NAD 83.

Gaged Stream	Gage Easting (m)	Gage Northing (m)
Baker Creek	742,027	4,319,535
Lehman Creek	741,152	4,321,829
Lower Snake Creek	748,657	4,311,656
Upper Snake Creek		
Strawberry Creek	733,483	4,327,499

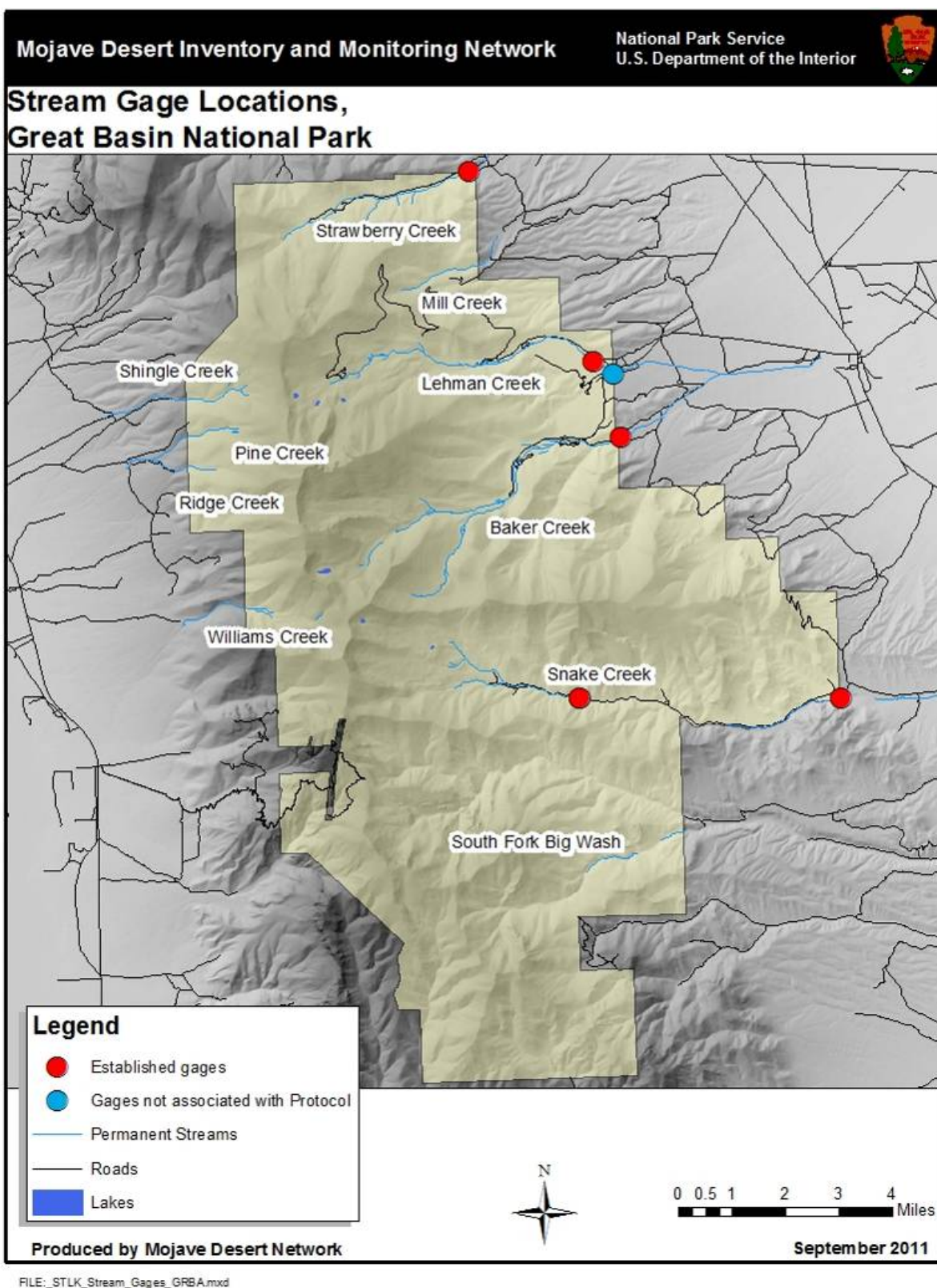


Figure SOP 9.1. Stream gage locations in GRBA.

9.2 Discharge Measurement

Discharge will be measured according to the standard methods described in the USGS publication “Discharge Measurements at Gaging Stations” (Turnipseed and Sauer 2010). Any of the techniques described in these USGS publications may be used to measure discharge for this project. However, it is anticipated that the conventional current meter used with the six-tenths depth method (page 21) will be used in most situations and the surface floats method (page 85) will be used for the largest streams at peak discharge.

Seasonal technicians will be trained using the USGS On-Demand Web-stationed Training for discharge estimates (<http://pubs.usgs.gov/fs/2007/3099/>). The seasonal crew will compare results with an experienced hydrologist or aquatic ecologist at least once after the training.

9.3 Continuous Stage Data

9.3.1 USGS Data

Lehman Creek is currently being gaged by the USGS and stored in their online database. MOJN personnel should access this data on an annual basis at the website:

<http://waterdata.usgs.gov/nv/nwis/current/?type=flow>

Once at the website, click on the gaging station number (10243260 for the Lehman Creek gage), then click on “summary of all available data for this site”, then click on “Daily Data”. Check the box for “Discharge” under “Available Parameters”, then enter the date range for the data you wish to download. Select “Tab Separated” as the output format, then click “Go”. The resulting data table can be copied in MS Excel.

9.3.2 Data Download and Logger Setup

Continuous stage data will be collected using Global Water Level loggers (models WL-15 and WL-16) owned by GRBA. Data from these loggers will be downloaded on an approximately monthly basis using the Global Logger II software. The manual for this software is included in the Supplementary Materials. The following steps should be taken for data download:

1. Connect the water level logger to the serial port of a computer with the software installed using the specially-provided cable.

Open the Global Logger II application. The main menu should appear (Figure SOP 9.2). **Check that the logger time is Pacific Daylight Time.**

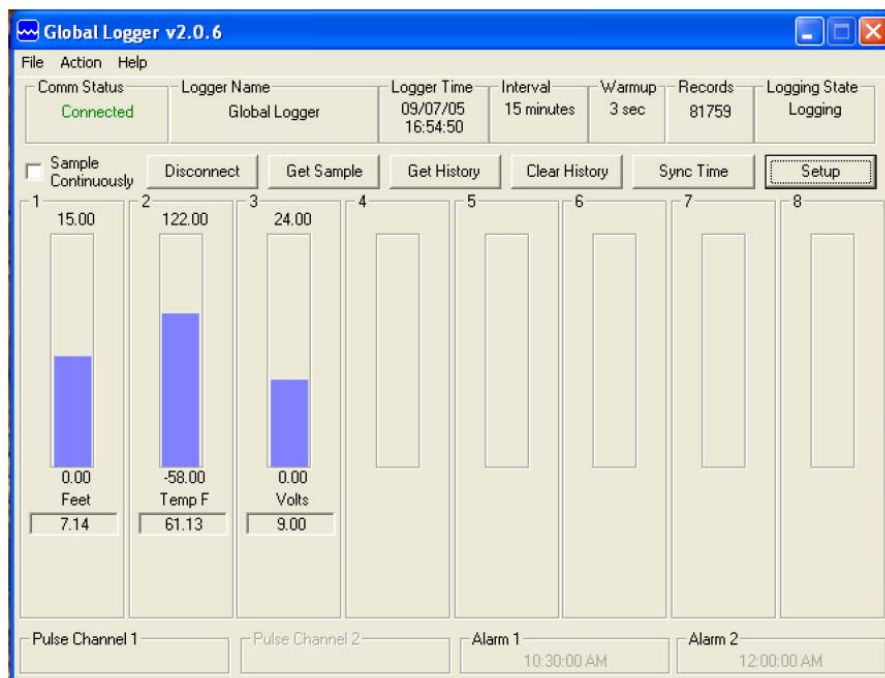


Figure SOP 9.2. Main screen of the Global Logger II software. Image taken from the manual.

- Click on “Get History.” This will download the data in the sonde to the computer. On the Historical Data Viewer screen (Figure SOP 9.3), select “Save to File.” Save the file with the name *locationID_NNNNN_WPRESLOG_YYYYMMDD.csv*. The digits *NNNNN* should be the last five digits of the logger’s serial number.

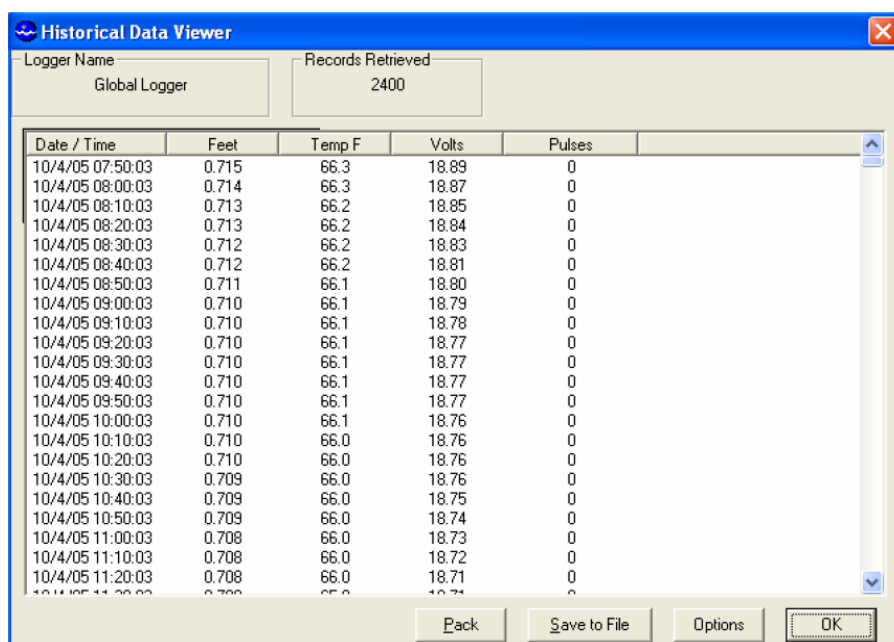


Figure SOP 9.3. Historical Data Viewer screen in Global Water II. Image taken from manual.

3. Click “OK” to return to the main screen, and “Clear History” to clear the logger’s memory.

Follow the steps below to set up the logger for data collection:

1. On the main screen (Figure SOP 9.2) click “Setup.” The Setup screen should appear (Figure SOP 9.4).

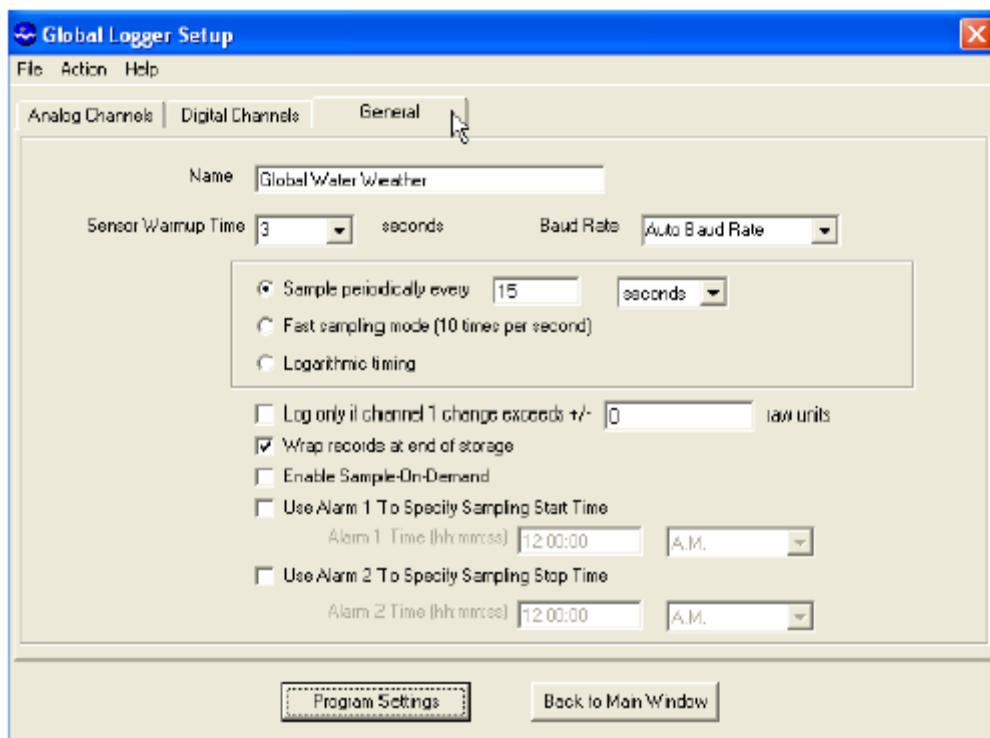


Figure SOP 9.4. Setup screen in Global Water II. Image taken from manual.

2. Enter the logger’s serial number and the name of the creek in the “Name” field. Set the sample interval to 15 minutes, and choose a start time (“Alarm 1”) so that data will be collected on the hour, and at 15, 30, and 45 minutes past the hour. Click “Back to Main Window.”
3. Click “Disconnect” and disconnect the logger. The logger can now be redeployed.

9.3.3 Conversion to Discharge

Continuous stage data are converted to discharge readings using rating curves. Rating curves are developed by plotting measured discharges against staff gage readings at a given site. The development and application of rating curves is discussed in *SOP 17: Data Analysis and Reporting*. A rating curve is only valid if no major changes occur in the channel that could alter the stage-discharge relationship. For example, if a flood regrades the streambed in the channel just below the stream gage, then a new rating curve must be constructed that does not use data collected before the flood. For this reason, it is important to collect photographic documentation of channel conditions every time the site is visited.

9.4 Version Information

Table SOP 9.2. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 10. Lakes Field Procedures

10.1 Overview

10.1.1 Lake Visit Activities

- Collect the MOJN core site data. The core water quality parameters will be collected as part of the depth profile.
- Measure Secchi disk depth.
- Collect a depth profile.
- Collect a water sample.
- Use line level to measure lake level relative to permanent benchmark.
- Retrieve data logger housing.
- Download data logger and redeploy (Section 5.1)
- Download barometer data and redeploy (if applicable).

All data should be recorded on a copy of the lakes field sheet (Figure SOP 10.1). An electronic copy of the field sheet is included in the *Supplementary Materials*.

10.1.2 Schedule

The three southern lakes (Baker, Dead, and Johnson) are accessed via hiking trails that can be dangerous when snow is present. Therefore, all six lakes will be monitored during a late summer index period (August to September). The three northern lakes (Brown, Stella, and Teresa) can be monitored in a single field day, while the southern lakes will likely require two field days due to the distances involved.

10.1.3 Site Access

The three northern lakes (Brown, Stella, and Teresa, shown in Figure SOP 10.2) are accessed via well-marked hiking trails (approximately 3 miles round trip) that begin at the Wheeler Peak campground parking area at the end of Wheeler Peak Scenic Drive.

Johnson Lake and Dead Lake are accessed via a hiking trail (approximately 7.5 miles round trip) that begins at the Shoshone campsite parking area at the end of Snake Creek Road. Baker Lake is accessed via a hiking trail (approximately 12 miles round trip) that begins at a trailhead at the end of Baker Creek Road. These hikes are strenuous, and the southern lakes (shown in Figure SOP 10.3) are far from any possible assistance, so they should only be undertaken by experienced hikers.

In all cases, GRBA backcountry travel procedures should be followed (see *SOP 1: Safety*).

MOJN I&M STREAMS AND LAKES PROTOCOL- LAKES FIELD SHEET								
DATE (mm/dd/yy):		TIME (PST):		LAKE NAME:				
				PARK: GRBA				
CREW:								
GPS COORD. SYSTEM (default UTM zone 11):			DATUM(def. NAD83):		UNITS (m or ft):			
P/T LOGGER			WATER QUALITY DEPTH PROFILE					
LOOK UP IN OFFICE:			<i>collect at least 4 readings no more than three feet apart</i>					
Prior Logger GPS Coordinates and Description:			Observer:					
Benchmark BM-1 GPS Coordinates and Description:			Air Temp:					
Benchmark BM-2 GPS Coordinates and Description:			Depth	pH	DO	SpCond	Raw Cond	Temp
Benchmark BM-3 GPS Coordinates and Description:			meters	units	mg/L	uS/cm	uS/cm	deg C
Prior Atmospheric Logger GPS Coordinates and Description: (if applicable)			x.xx	x.xx	x.xx	var.	var.	xx.xx
Lake data logger downloaded? (Y/N):			surface					
Atm. data logger downloaded? (Y/N):								
New Lake Logger GPS Coordinates: E								
Note: N								
last 5 digits of serial no.: +/-								
New Atm. Logger GPS Coordinates: E								
Note: N								
last 5 digits of serial no.: +/-								
LAKE LEVEL: use best precision possible			SECCHI DEPTH					
Benchmark Used (e.g., BM-1):			Is the disk visible at the lake bottom? (Y/N)					
Staff Reading units:			depth in feet (x.xx)					
Take 7 Readings			Observer: Time: Calm Surface?:					
1 4			Descending 1: Descending 2: Descending 3:					
2 5			Ascending 1: Ascending 2: Ascending 3:					
3 6								
7 7								
NOTES:			WATER SAMPLES					
			Sample Time:		Sample Method:		Depth:	
			Unfiltered sample? (Y/N):					
			Filtered sample? (Y/N):					

Figure SOP 10.1. Lakes field sheet.

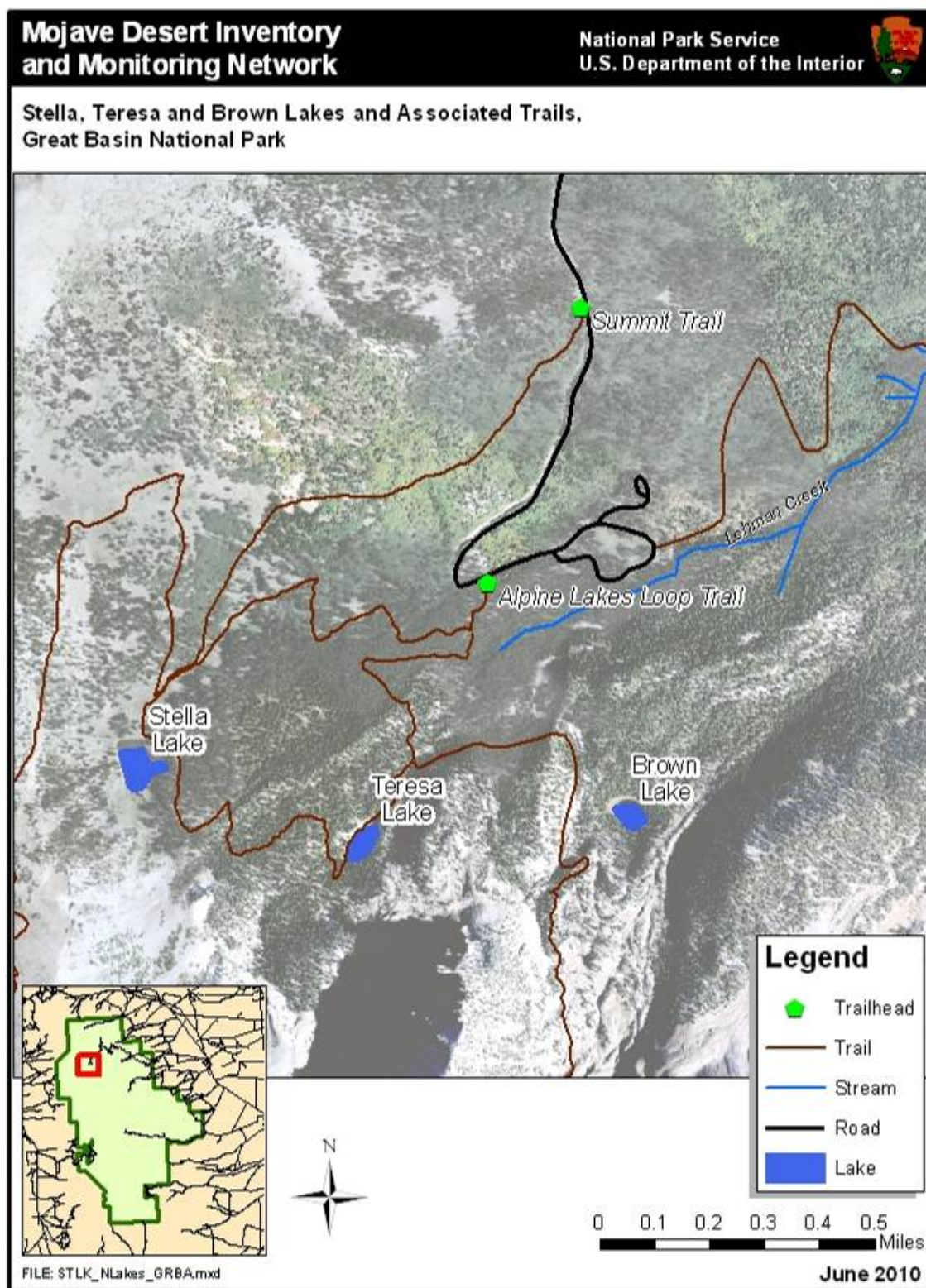


Figure SOP 10.2. Trails near GRBA's northern lakes.

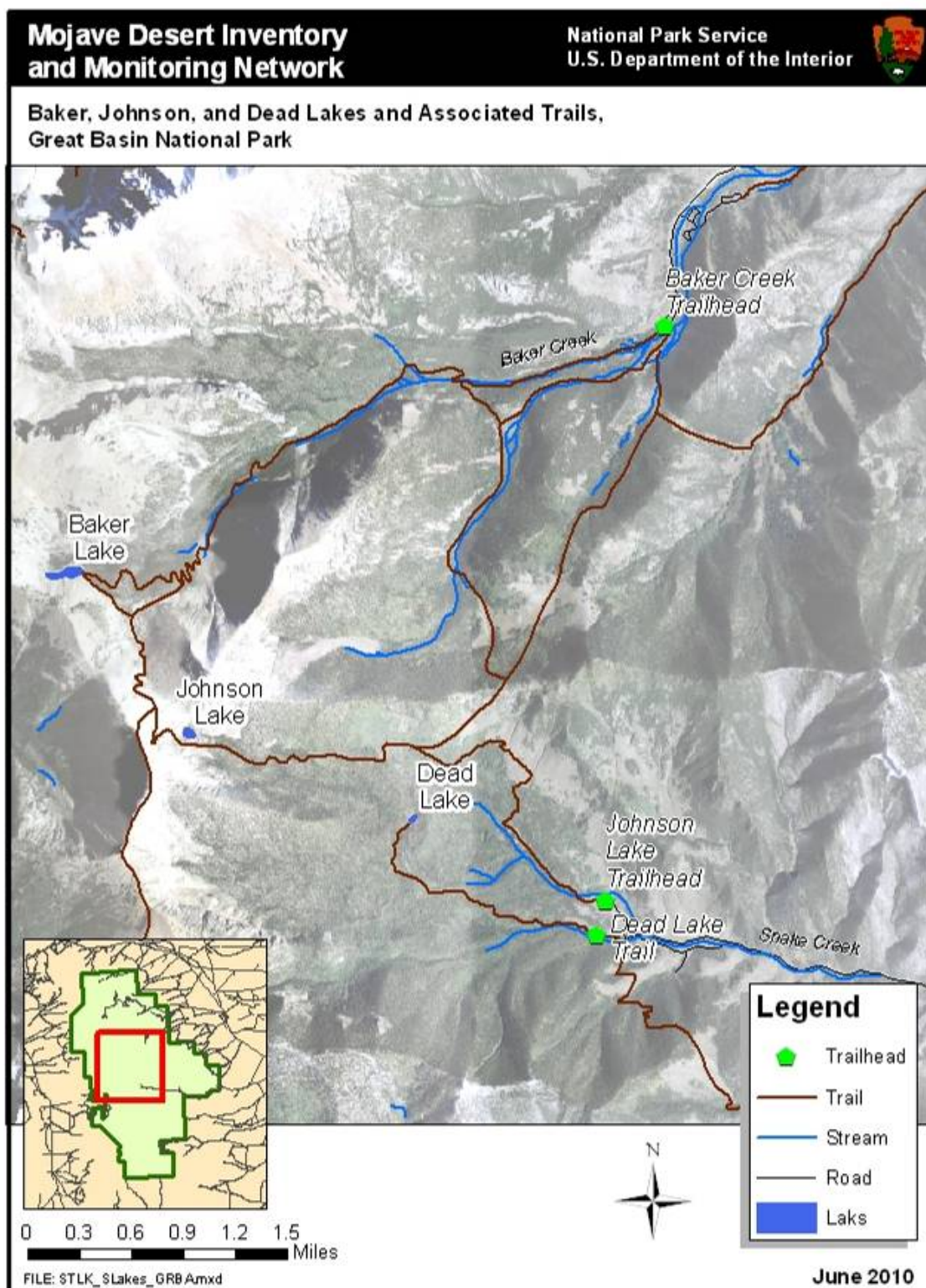


Figure SOP 10.3. Trails near GRBA's southern lakes.

10.2 Lake Level and Temperature

Lake level and temperature are monitored continuously using one HOBO U20 Logger in each lake. The apparent water levels measured by these probes are affected by atmospheric pressure variations, so three additional HOBO loggers are required to monitor atmospheric pressure: one near the three northern lakes, one near Johnson Lake and Dead Lake, and one near Baker Lake.

10.2.1 Logger Setup

Important: The information in this section is supplementary to the instructions in the HOBO equipment manuals. This section will need to be revised if the HOBO software is updated.

-Open the HOBO software (HOBOWare Pro). Use the USB cable to connect the optical shuttle to the computer.

-Remove the black plastic cap from the coupler. Insert the logger into the correct coupler (the one labeled “Coupler for U20 Water Level, Part No. COUPLER2-8”). Align the flat portion of the threaded end of the coupler with the arrow on the coupler labeled “flat”. Push the logger in until it cannot turn. If the logger can turn freely in the coupler, it is not correctly aligned. However, the coupler is made of a relatively soft plastic, so do not attempt to force the logger to turn.

-Press the lever on the coupler until it touches the plastic casing of the shuttle. If the logger, coupler, and shuttle are all functional and configured correctly, the amber LED on the shuttle should blink, followed by a steady green LED indicating that the logger is connected to the computer.

-Select the “Launch” option from the “Device” menu in HOBOWare Pro, and launch the logger. In the launch window, change the Description field to the name of the lake the logger will be deployed in, and set the logger to record pressure, temperature, and battery voltage (a valuable trouble-shooting parameter discussed in SOP 17: Data Analysis and Reporting). Set the time interval to either 15 minutes (in the initial stage of the monitoring) or 12 hours (the interval that it is assumed will be used once the 15-minute data has been analyzed). Delay the start time until the desired first reading. Click on the “Launch” button.

-Once HOBOWare Pro indicates that the launch was successful, remove the logger from the coupler and replace the black plastic cap. The logger can now be deployed.

10.2.2 Logger Deployment

The loggers should be deployed inside PVC stilling wells (Figure SOP 10.4). These stilling wells are mounted on steel U-bar fenceposts that can be pounded into the lake bottom. The exact details of the logger deployment may be changed by project personnel. The key elements are that the logger be protected from debris and be held in a fixed position (elevation).

The loggers should be deployed as close to the deepest part of the lake as is practical. In addition to GPS coordinates, careful note should be taken of the deployment location in order to ensure that the logger can be retrieved.

The loggers used to record atmospheric pressure variations should be tied to trees above the maximum snow level, far from areas of high foot-traffic. They should not be exposed to direct

sunlight. In addition to GPS coordinates, careful note should be taken of the deployment location in order to ensure that the logger can be retrieved.



Figure SOP 10.4. PVC stilling well used to house logger.

10.2.3 Data Download

Data from the loggers can be downloaded in the field using the HOBO optical shuttle. No laptop is required. The shuttles used by MOJN can hold up to 63 files.

Launching the Shuttle

- The shuttle must be launched using HOBOWare Pro before it is used for the first time, and every time that the software is changed.
- Make sure that the clock of the computer you are using is set to the correct time zone. **All data should be collected in Pacific Daylight Time.**
- Open the HOBO software (HOBOWare Pro). Use the USB cable to connect the optical shuttle to the computer. The Shuttle should not be connected to the coupler or logger.
- Select the “Launch” option from the “Device” menu in HOBOWare Pro, and launch the shuttle. The screen should indicate that the shuttle was launched successfully.

Uploading the Data onto the Shuttle

-Ensure the logger, coupler, and shuttle are clean.

-Remove the black plastic cap from the coupler. Insert the logger into the correct coupler (the one labeled “Coupler for U20 Water Level, Part No. COUPLER2-8”). Align the flat portion of the threaded end of the coupler with the arrow on the coupler labeled “flat”. Push the logger in until it cannot turn. If the logger can turn freely in the coupler, it is not correctly aligned.

-Press the lever on the coupler until it touches the plastic casing of the shuttle. If the logger, coupler, and shuttle are all functional and configured correctly, the amber LED on the shuttle should blink continuously, indicating that readout is occurring. Do not remove the logger while the amber LED is blinking.

-The shuttle automatically sets the logger to continue sampling with the same sample interval. If any changes are desired, the logger must be connected to a computer (section 2.1). When the logger is ready for redeployment, the green LED blinks for 15 minutes. If the red LED is blinking, the redeployment has failed, and the logger manual should be consulted.

Downloading Data onto a Computer

-Open the HOBOWare software (HOBOWare Pro). Use the USB cable to connect the optical shuttle to the computer.

-Select the “Readout” option from the “Device” menu in HOBOWare Pro, and select the shuttle as the device to be downloaded.

-Select a folder to save the data to, check the files you wish to save, then click on the “Save Checked” button.

-Check any files you wish to delete, then click on the “Delete Checked” button. It is a good idea not to perform this step until you have checked that the files are saved in the location you selected.

-Click on the “Close” button, and disconnect the shuttle.

10.2.4 Measuring Lake Level

[This section adapted from Hoffman et al., 2005]

Establishing Benchmarks

The water level in each lake relative to a permanent benchmark will be measured each year. Three permanent benchmarks will be established at each lake so that the data set will not be compromised by the destruction of a single benchmark. All of the benchmarks were established during the 2010 field season, but accurate measurements of relative elevation were only made at Baker Lake. The remaining benchmark elevations will be measured in the 2011 field season. The benchmark positions are given in table SOP 10.1 below. A document containing descriptions and photographs of each benchmark is included in the *Supplementary Materials*.

Table SOP 10.1. Permanent benchmark sites at GRBA lakes. Easting and northing coordinates are for UTM zone 11S, NAD 83.

Lake	No.	Easting (m)	Northing (m)	Nominal
Stella	1	0732195	4320600	100.00 m
	2	0732196	4320608	
	3	0732193	4320634	
Teresa	1	0732922	4320344	100.00 m
	2	0732926	4320343	
	3	0732935	4320355	
Brown	1	0733612	4320624	100.00 m
	2	0733604	4320621	
	3	0733620	4320622	
Baker	1	0733127	4315327	100.00 m
	2	0733134	4315324	100.17 m
	3	0733144	4315318	99.85 m
Johnson	1	0734133	4313987	100.00 m
	2	0734138	4313987	
	3	0734138	4313972	
Dead	1	0736325	4312969	100.00 m
	2	0736347	4312969	
	3	0736335	4312962	

At each visit, the water level will be measured relative to all three benchmarks.

Making the Measurement

The equipment required to make the measurement consists of a cord that can be stretched taut, a line level, a measuring staff at least 2 m long marked in gradations of cm or hundredths of a foot, and a bubble level that can be used to ensure that the measuring staff is vertical.

-Attach one end of the cord to the benchmark.

-Extend the cord from the benchmark to a point at least 1 m beyond the land-water interface where the lake level will be measured. It will be easiest to make the measurement at a point where the rod can be rested on a rock exactly at the water level.

-Attach the line-level to the cord and make certain that the cord is level.

-At the distal point of the extended cord, measure the distance from the cord to the surface of the water using the measuring staff. Use the bubble level to ensure that the staff is vertical.

-Allow the line to go slack, and then repeat the measurement six additional times.

Calculating Lake Level

The lake level should be reported in meters. If the staff readings are in feet, then convert the measurements to meters before further calculations are made.

-Calculate the mean of the three repeated water level measurements (z_{WL}).

-Assign benchmark 1 an arbitrary elevation of 100 m. The lake level (z_{lake}) is given by:

$$z_{lake} = z_{benchmark} - z_{WL}$$

Replacing a Destroyed Benchmark

Lake level should be measured relative to all three benchmarks (z_{surf1} , z_{surf2} , and z_{surf3}), but the reported levels are based on the measurements made at benchmark 1. The nominal elevation of benchmark 1 is set to 100.00 m. The other two elevations are calculated using:

$$z_{benchmark2} = 100.00 - z_{WL1} + z_{WL2}$$

$$z_{benchmark3} = 100.00 - z_{WL1} + z_{WL3}$$

If benchmark 1 is destroyed, then water levels should be reported relative to benchmark 2, and a new benchmark (benchmark 4) should be established as soon as possible.

10.3 Depth Profiles

Depth profiles of the four core parameters (temperature, pH, specific conductivity, and dissolved oxygen) will be collected with a handheld YSI meter. The calibration of this meter and the method of data collection are described in *SOP 6: Handheld Water Quality Instruments*.

The parameters should be measured at equally-spaced depth intervals from the surface to near the lake bottom. If the total depth of the lake is less than 2 m, then a 0.3 m depth interval should be used. Otherwise, a 0.5 m or 0.6 m depth interval is appropriate. If the lake appears to be stratified (that is, the parameters change abruptly with depth), then additional readings should be taken in the vicinity of the abrupt change.

10.4 Water Sample Collection

A water sample will be collected from each lake for the chemical analyses described in *SOP 14: Laboratory Analysis of Water Chemistry*. The first two years of lake data suggest that the lakes in GRBA are frequently mixed, and no stratification has been observed in any of the lakes. Therefore, a single hand-dipped sample should be collected.

[Adapted from Section 5 of the EMAP Protocols (Peck et al., 2006)]

1. Collect water by hand-dipping a clean 1000 mL bottle in the lake. Return to the shore.
2. Uncap the unfiltered sample bottle, and fill it 3/4 full from the 1000 mL bottle. Place the sample bottle into the sample cooler.
3. Using clean forceps, place a glass fiber filter on the filter holder. Attach the vacuum pump to the filter assembly.

5. If necessary, return to the deepest point of the lake and refill the 1000 mL bottle. Return to the shore. Pour lake water from the sampling beaker into the filter funnel. Pump the water through the filter until 750 mL of water has been filtered.
6. Decant the filtered sample from the filter chamber to the two filtered sample bottles.
7. Place waterproof labels with the following information on each bottle:
 - Sample name
 - Date and time of collection
 - Filtered or unfiltered
 - Collectors initials
 - Name of lake
8. Temporarily place the bottles in the sample container with solid-sided “blue ice”. Sample handling and shipping is discussed in *SOP 7: Sample Handling, Storage, and Shipping*.

10.5 Water Clarity Measurement

This section adapted from Hoffman et al. (2005).

Water clarity will be measured using a weighted 20 cm black and white Secchi disk that is lowered through the water column at the deepest point of each lake. The Secchi disk is attached to the end of a nylon or cotton rope marked at 0.5-m intervals. Just below the Secchi disk and also attached to the rope is a weight or small stuff sack filled with rocks that provides weight to the rope as the Secchi disk is lowered through the water column.

Secchi disk depth measurements should be taken when the surface of the site is calm and as close to noon (standard time) as possible. However, if this is not possible, Secchi disk depth measurement can be completed before or after noon under less than calm surface conditions. The time and surface condition at the time of measurement should be clearly and accurately recorded. The measurement should be taken on the sunny side of the observer to avoid interference from the underwater shadow.

Secchi disk depth is the average of the recorded descending reading at the point where the disk disappears from the view of an observer and the ascending reading at the point when the disk reappears to the view of the observer. Three of these average measurements should be determined for a site during each visit and recorded on the appropriate data sheet. Data to be recorded for each of the three measurement trials include descending depth, ascending depth, and average depth [i.e., $(\text{descending depth} + \text{ascending depth})/2 = \text{average depth}$].

If the Secchi disk can be seen when resting on the bottom of the lake, then the depth of the lake is recorded as the Secchi disk depth. **The fact that the bottom of the lake was reached while the disk was visible must be noted.** In this case, it is not necessary to collect three measurements or record ascending and descending depths.

10.6 Version Information

Table SOP 10.2. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 11. Continuous Water Quality Sonde

11.1 Overview

The NPS Water Resources Division (WRD) has designated four water quality parameters (temperature, dissolved oxygen, specific conductivity, and pH) as core parameters that should be measured at every sampling event. MOJN's YSI 6920 multiprobe (henceforth referred to as the probe, the multiprobe, or the sonde) is capable of measuring these parameters continuously. By collecting continuous records of these parameters, diel and other variations can be readily accounted for, permitting the detection of long-term trends. Hourly readings of the four core parameters will be collected continuously over the field season each second-order stream in GRBA.

11.1.1 Rationale for not Collecting ORP Data

MOJN's multiprobe has the ability to collect oxidation-reduction potential (ORP) data. However, according to the USGS National Field Manual (NFM) (Nordstrom and Wilde, 2005):

“In contrast to other field measurements, the determination of the reduction-oxidation potential of water (referred to as redox) should not be considered a routine determination. Measurement of redox potential, described here as Eh measurement, is not recommended in general because of the difficulties inherent in its theoretical concept and its practical measurement”.

In Part C of the WRD Guidance for Designing and Conducting Water Quality Monitoring (Penoyer 2003), similar reservations regarding the value of ORP data are expressed:

“Field probe-measured REDOX is often difficult to interpret because the controlling REDOX reaction is rarely known or understood. Without knowing which REDOX reaction controls the potential, the measurement is “nonspecific” and of limited use.”

Based on these recommendations, MOJN will not collect ORP data as part of this protocol.

11.2 Sampling Plan

11.2.1 Site Selection

Stream discharge measurements are extremely valuable in interpreting core parameter records. Therefore, the continuous core parameter measurements will be collected near the stream gages on GRBA's four second-order streams (Baker, Lehman, Snake, and Strawberry). These streams were selected because they have the highest discharges, they harbor fishes, and they have been identified as the highest priority monitoring targets by park staff.

A map of the stream gages is shown in Figure SOP 11.1.

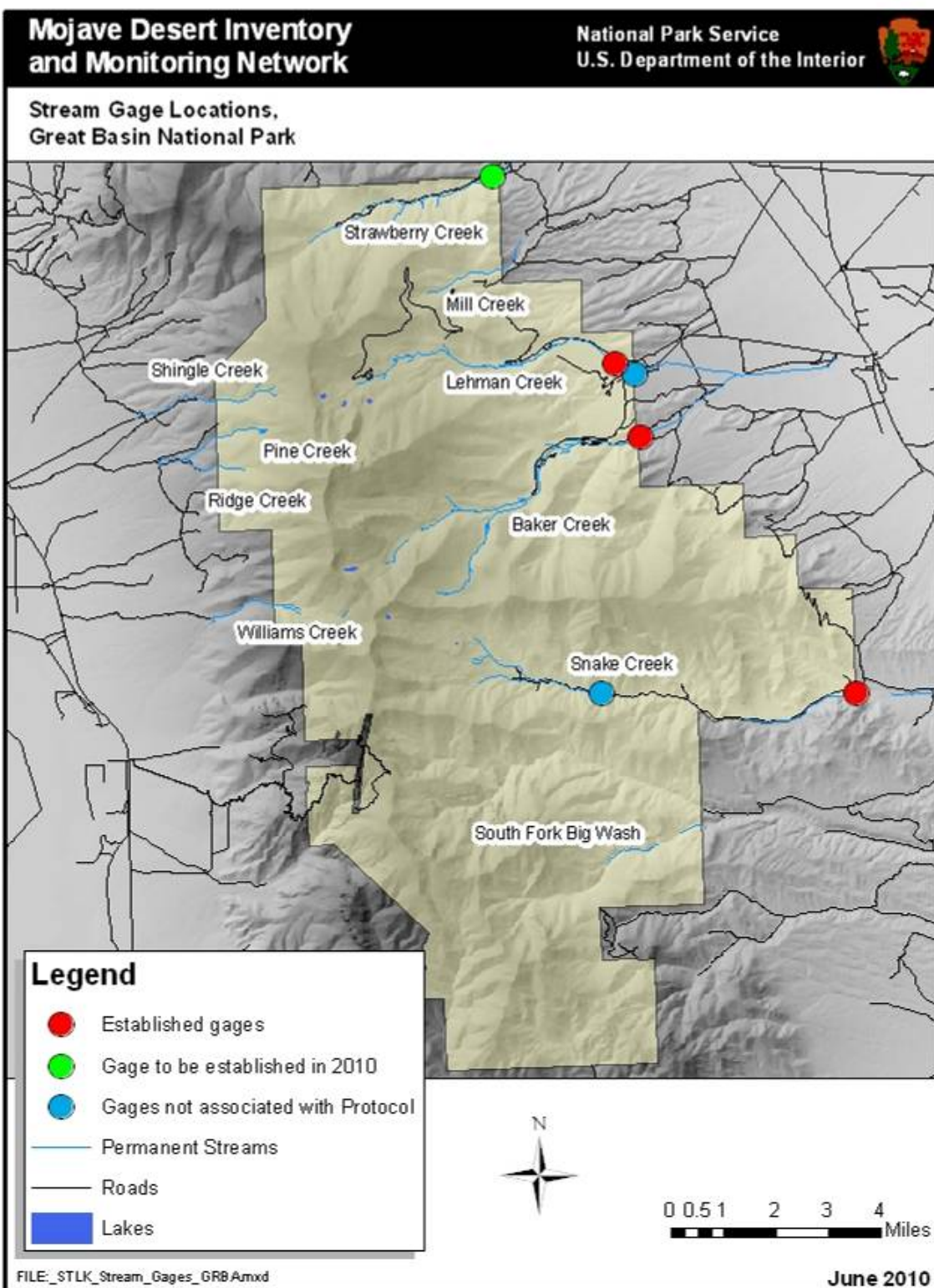


Figure SOP 11.1. Stream gage locations in GRBA.

11.2.2 Sampling Schedule

A multiprobe will be deployed in each of the second-order streams after peak runoff has occurred (mid-June) and retrieved in the fall before ice forms (mid-October). Eliminating the winter sampling period will reduce the possibility of damage to a multiprobe and reduce staff time during a period of low natural variability and biological activity. Eliminating the early-summer sampling period will reduce the possibility of the loss of a multiprobe during peak runoff.

Core parameter values will be recorded hourly, a frequency that will characterize diel variation in parameter values while minimizing data storage and processing requirements.

An overview of the steps taken at the time of deployment, the time of retrieval, and at each calibration visit are given in Table SOP 11.1, below.

Table SOP 11.1. Multiprobe operation overview. Adapted from Wagner et al. (2006)

Multiprobe Deployment (after peak-runoff)	Calibration Visits (every 2-3 weeks)	Multiprobe Retrieval (before streams freeze)
-In-lab T sensor comparison (SOP 3)	-Data download	-Data download
-Collect 7 readings for AMS+ (SOP 3)	-Record sonde readings	-Record sonde readings
-Field calibration	-Record handheld multiprobe readings	-Record handheld multiprobe readings
-Cross-section survey	-Clean sonde and record new sonde readings	-Clean sonde and record new sonde readings
-Data acquisition set-up	-check calibration of sonde	-check calibration of sonde
-Deploy sonde in stream using fenceposts	-record sonde calibration check readings	-record sonde calibration check readings
	-Recalibrate, if necessary	-remove fenceposts
	-return sonde to stream and record readings	-Collect 7 readings for AMS+ (SOP 3)
	-Data acquisition set-up	
	- Re-deploy sonde in stream	

All data should be recorded on a field sheet, either the first deployment field sheet (Figure SOP 11.2) or the biweekly visit field sheet (Figure SOP 11.3). Electronic copies of these field sheets are included in the *Supplementary Materials*.

MOJN I&M STREAMS AND LAKES PROTOCOL- WQ SONDE FIRST DEPLOYMENT OF SEASON FIELD SHEET													
DATE (mm/dd/yy):				TIME (PST):		STREAM:				SONDE ID (e.g., "A"):			
CREW:					LOCATION ID:				HANDHELD ID (e.g., "5"):				
ANNUAL CROSS-SECTION SURVEY OF STREAM SITE													
Sonde/handheld?:		Instructions: Measure T and SpCond at 3-6 stations (3 for streams ~1 m wide). At each station, measure at mid-water column depth. If stream is deeper than ~0.3 m, take readings at top and bottom.											
		position 1 (required)		position 2 (required)		position 3 (required)		position 4 (if >1 m wide)		position 5 (if >2 m wide)		position 6 (if >3 m wide)	
dist. from left bank (looking upstream)													
---		Temp.	SpCond	Temp.	SpCond	Temp.	SpCond	Temp.	SpCond	Temp.	SpCond	Temp.	SpCond
Near Surface (if depth>0.3 m)													
Mid-Column (all surveys)													
Near Streambed (if depth>0.3 m)													
ANNUAL AMS+ DATA COLLECTION					SONDE DEPLOYMENT								
<i>If sonde was not included in pre-season AMS+ test, collect seven data points less than 2 minutes apart.</i>													
Data pt.	pH	DO	SpCond	Temp	ACTION	pH	DO	SpCond	Raw Cond	Temp.			
1					1. Calibrate. Record sonde reading in stream.								
2					2. Collect a reading with a HANDHELD probe								
3					3. Check diff. between readings is less than these tolerances	0.2 units	0.3 mg/L	3%	---	0.2 deg C			
4					4. Set-up the sonde for data acquisition, and deploy it.	---	---	---	---	---			
5					NOTES:								
6													
7													

Figure SOP 11.2. Water quality sonde first deployment field sheet.

MOJN I&M STREAMS AND LAKES PROTOCOL- WQ SONDE BIWEEKLY VISIT FIELD SHEET																																														
DATE (mm/dd/yy):		TIME:		STREAM:																																										
CREW:		LOCATION ("at gage" or UTM's, including zone, datum, accuracy):																																												
SONDE ID (e.g., "A"):																																														
HANDHELD ID (e.g., "5"):																																														
Actions	Name of Reading	pH	DO	SpCond	Raw Cond	Temp																																								
1. , Attach control unit, download data, record reading in stream	end-of deployment reading																																													
2. Clean sensors, record reading in stream	post-cleaning reading																																													
3. BEFORE recalibration, record readings in standards (pH 7 buffer for pH)	calibration check reading				---	---																																								
4. Record values for calibration standards (pH 7 buffer for pH)	---				---	---																																								
5. Recalibrate, if necessary. Return sonde to stream and record reading.	pre-deployment reading																																													
6. Collect a reading with a HANDHELD probe side-by-side with the sonde.	handheld QA/QC reading																																													
7. Check difference between readings in steps 5 and 6 is less than these tolerances	Maximum difference- check in field!	0.2 units	0.3 mg/L	3%	---	0.2 deg C																																								
8. Set-up the sonde for data acquisition, and re-deploy it.	---	---	---	---	---	---																																								
AMS+: Collect seven data points less than 2 minutes apart on the sonde retrieval visit. <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <thead> <tr> <th>Data</th> <th>pH</th> <th>DO</th> <th>SpCond</th> <th>Temp</th> </tr> </thead> <tbody> <tr><td>1</td><td></td><td></td><td></td><td></td></tr> <tr><td>2</td><td></td><td></td><td></td><td></td></tr> <tr><td>3</td><td></td><td></td><td></td><td></td></tr> <tr><td>4</td><td></td><td></td><td></td><td></td></tr> <tr><td>5</td><td></td><td></td><td></td><td></td></tr> <tr><td>6</td><td></td><td></td><td></td><td></td></tr> <tr><td>7</td><td></td><td></td><td></td><td></td></tr> </tbody> </table>							Data	pH	DO	SpCond	Temp	1					2					3					4					5					6					7				
Data	pH	DO	SpCond	Temp																																										
1																																														
2																																														
3																																														
4																																														
5																																														
6																																														
7																																														
FILENAME USED FOR NEW DEPLOYMENT:																																														
NOTES:																																														

Figure SOP 11.3. Water quality sonde biweekly visit field sheet.

11.3 Field Calibration of Specific Conductance DO, and pH

A common practice is to calibrate the multiprobe sensors in the office or laboratory prior to deployment. However, the instruments on the multiprobe can be affected by jostling and pressure changes, so it is strongly recommended that the sensors be calibrated at the sampling site just prior to deployment. WRD requires that, at a minimum, the pH and DO sensors be calibrated in the field. Field personnel may wish to prepare laminated instruction sheets summarizing the steps described below.

Most calibrations will be performed in the field using the control unit. However, in the event that the control unit is unavailable, the sondes may be calibrated in the lab using a PC with the EcoWatch software loaded. This software package has the same set of menus as the software on the control unit, so the instructions below can be used with either the control unit or a PC.

Setup

-From the main menu, select the “Sensor” option. A list of the sensors that can be enabled should appear. Enable “Time,” “Temperature,” “Conductivity,” “Optic O,” and “ISE1 pH.” Do not enable “Dissolved Oxy,” as that option refers to a membrane-based DO sensor that is not included on MOJN’s multiprobe. Return to the main menu.

-Select “Report” from the main menu. A list of the parameters to be recorded should appear. Select “Date,” “Time,” “Temp C,” “SpCond mS/cm,” “Cond,” “DO mg/L,” “DOsat%,” and “pH.” **Note that NPS WRD requires that uncorrected conductivity values (“Cond”) be recorded along with the temperature-corrected specific conductance values (“SpCond mS/cm”).** Return to the main menu.

-Conduct the following calibrations with the probe connected to the control unit. Dry the sensors and calibration cups between calibrations.

DO Calibration

Note: As of 2009, MOJN’s multiprobe has an optical DO sensor. References in the YSI manual to the Rapid-Pulse Polarographic DO sensor do **not** apply to MOJN’s instrument.

Errors in DO calibration are common, so care should be taken to follow these instructions carefully. The objective of the procedure is to use water-saturated air as a calibration standard. However, the saturation point changes as a function of temperature and pressure. The multiprobe automatically corrects for temperature, and pressure is measured by a barometer built into the control unit. If the control unit is not available, pressure can be read from a handheld barometer.

-Place the sensor in a calibration cup containing 3 mm (1/8 inch) of water. The intent of the procedure is to perform the measurement in water-saturated air, so the sensor should not be underwater. Loosely thread the calibration cup onto the probe housing, ensuring that the air pressure inside the cup is the same as the atmospheric pressure. Wait 10 minutes to allow the water and air in the cup to reach the ambient temperature and equilibrate. This time may be used to begin installing the fenceposts in the stream bed.

-From the main menu, select “Calibrate”. From the Calibrate Menu, select “ODOsat %,” then “1-point.” Accept the barometric pressure in mm of Hg displayed as the default option on the control unit (or enter a value read from a handheld barometer).

-All of the enabled sensor readings will be displayed on the screen. Once the DO readings have been stable (defined by WRD as less than or equal to 0.3 mg/L of variation) for 30 seconds, accept the calibration by pressing “Enter.” It may take as long as 15 minutes for the readings to stabilize.

Specific Conductance Calibration

The NPS WRD recommends the use of a 1,413 $\mu\text{S}/\text{cm}$ conductivity calibration solution for all fresh water measurements (P. Penoyer, Hydrologist, NPS WRD). Therefore, MOJN uses a NIST-traceable calibration standard with a conductivity of 1,413 $\mu\text{S}/\text{cm}$.

Note: As of 2011, MOJN’s multiprobe uses conductivity/temperature sensor 6560. References in the manual to the 600 OMS V2-1 Conductivity sensor do **not** apply to MOJN’s instrument.

-Rinse the conductivity sensor and calibration cup with a small amount of the calibration solution. Discard the rinsate.

-Fill the calibration cup with approximately 200 mL of the calibration solution. Enough solution should be used to cover the vent hole on the side of the sensor. Allow one minute for the temperature to equilibrate.

-From the main menu, select “Calibrate”. From the Calibrate Menu, select “Conductivity,” then “SpCond.” Enter the specific conductivity of the calibration solution (1.413 mS/cm).

-All of the enabled sensor readings will be displayed on the screen. Once the specific conductivity readings have been stable (defined by WRD as less than 3% variation) for 30 seconds, accept the calibration by pressing “Enter.”

pH Calibration

Preliminary measurements of the pH of the streams and lakes at GRBA have generally been between 7 and 9. Therefore, a two-point pH calibration with pH 7 and pH 10 buffers is appropriate. The USGS NFM recommends that specialized buffers and pH electrodes be used for waters with specific conductivities below 0.1 mS/cm (Ritz and Collins, 2008). However, YSI has demonstrated that the pH sensor on the multiprobe performs well in low-conductivity water when calibrated with standard buffers (YSI, 2005). Therefore, no specialized pH electrodes or buffers will be used.

Note: If the response of the pH sensor appears to be slower than normal, then the sensor should be cleaned according to the instructions given in the manual.

-Pour enough pH 7 buffers into the calibration to immerse the pH sensor (approximately 125 mL). Do not thread the cup onto the probe. Allow one minute for temperature to equilibrate.

-Measure the temperature of the buffer in the cup using a digital thermometer. Use the table on the buffer bottle to determine the temperature-corrected pH of the buffer.

-Thread the cup onto the probe. From the main menu, select “Calibrate”. From the Calibrate Menu, select “ISE1 pH,” then “2-point.” Enter the temperature-corrected pH.

-All of the enabled sensor readings will be displayed on the screen. Once the pH readings have been stable (defined by WRD as less than or equal to 0.1 pH units of variation) for 30 seconds, accept the first point of the calibration by pressing “Enter.”

-Rinse the sensor and calibration cup with pH 10 buffer. Discard the rinsate.

-Pour enough pH 10 buffer into the calibration to immerse the pH sensor (approximately 125 mL). Thread the cup onto the probe. Allow one minute for temperature to equilibrate.

-Use the table on the buffer bottle to determine the temperature-corrected pH of the buffer.

-Follow the instructions on the screen to continue the calibration. Enter the temperature-correct pH of the buffer.

-All of the enabled sensor readings will be displayed on the screen. Once the pH readings have been stable (defined by WRD as less than or equal to 0.1 pH units of variation) for 30 seconds, accept the calibration by pressing “Enter.”

11.4 Cross-Section Surveys

The USGS National Field Manual for the Collection of Water quality Data (NFM) indicates that:

“In a small (usually less than 5 feet (ft) in width) and well-mixed stream, a single point at the centroid of flow may be used to represent the cross section.”

The small, fast-moving streams of GRBA are generally less than five feet wide, and are likely to be well-mixed. However, cross-section surveys will be conducted to ensure that the spatial variation of core water quality parameters is minimal. Given the size of the GRBA streams, **one cross-section survey per monitoring site per sampling year** will be sufficient to verify that the streams are well mixed. If cross-section variability is observed, or the variability appears to change with time, then more frequent surveys will be undertaken. The surveys should be conducted at the time of sonde deployment (late runoff).

The cross-section surveys can be completed using the multiprobe in “Discrete sample” mode while attached to the YSI 650 control unit. However, a handheld water quality instrument such as the YSI 556 or YSI 85 is better suited to the task because of its instantaneous readout and the relative ease with which the sensors can be held in different positions. The instructions below assume the handheld unit will be used:

-Calibrate the unit according to the instructions in *SOP 6: Handheld Water Quality Instruments*.

-Stretch a measuring tape across the stream at the site where the multiprobe will be installed and select monitoring locations. The NFM recommends a minimum of four evenly-spaced monitoring locations per stream, but the WRD considers three locations appropriate for streams less than 1 m wide (P. Penoyer, Personal Communication).

-Measure the water quality parameters at mid-water column depth at the monitoring locations. Record the values on the field form for cross-section surveys.

-At measurement stations where the water is deeper than approximately 0.3 m, measure the water quality parameters a few cm below the water surface and a few cm above the streambed. Record the values on the field form for cross-section surveys.

-Determine the median readings for temperature and specific conductivity. If the temperature readings vary from the median value by less than 0.2°C and the specific conductivity readings vary from the median value by less than 5%, then the stream can be considered well-mixed. According to the NFM, these tolerances for temperature and specific conductivity variation can be adjusted based on NPS personnel’s “best professional judgment of what is reasonable for the field site.”

In the event that one or more of the GRBA streams are not well-mixed, the sonde should be deployed in such a way that the measurements are taken in the most representative part of the cross-section (i.e., the location with values closest to the median values for all of the measured

parameters). Cross-section surveys should be collected each time these streams are visited to ensure that the monitoring location is still representative.

If a stream is not well mixed and there is no location that has parameter values that are representative of the stream as a whole, then the data can be corrected using the Equal Discharge Increments method described in the NFM. However, this correction should only be applied by an experienced hydrologist after several detailed cross-section surveys.

11.5 Data Acquisition Setup

Once the sensors have been calibrated, the sonde can be prepared to collect continuous readings.

- Select “Run” from the main menu, then “Unattended Sample.” This will take you to the “Unattended Setup” menu.

- Set the interval to 01:00:00, the start date to the current date, and the start time to the next hour (i.e., if it is 12:25, set the start time to 13:00). The duration can be left at 365 days. The file name should consist of the first four letter of the creek’s name, the two-digit month, and the two-digit year (e.g., LEHM0709, for data collected in Lehman Creek in July 2009). Enter the Creek name for the site name. The memory in the control unit is “flash” memory, so files are not truly overwritten until the entire memory is erased. Therefore, IT IS IMPORTANT NOT TO USE DUPLICATE FILE NAMES.

- The “Unattended Setup” menu also displays the estimated battery life and the number of days of data that can be stored. If either of these numbers is less than the anticipated length of the deployment (two weeks), then the batteries should be changed or the memory should be cleared.

- If the “View Params to Log” option is selected, it will list the raw parameters logged by the sonde. Some parameters, such as specific conductivity and DO in mg/L, are calculated based on these parameters, and do not appear on this list.

- Select the “Start Logging” option, and select “Yes” on the next screen. The menu should now show “Stop Logging” as an option, which confirms that the probe is in logging mode. The sonde can now be deployed in the stream.

11.6 Stream Deployment

The multiprobe should be deployed inside a deployment housing constructed from PVC or ABS pipe (Figure SOP 11.4). These deployment housings should be tied to two steel U-bar fenceposts that can be pounded into the streambed. The probe should also be directly secured to a tree or rock on the stream bank. The probe should be deployed near the center of the channel, where most of the flow is concentrated.

The exact details of the probe deployment may be changed by project personnel. The key elements are that the probe be protected from debris and prevented from being washed away in flood events.



Figure SOP 11.4. MOJN's multiprobe deployed in Strawberry Creek.

11.7 Data Download

-Connect the multiprobe to the control unit. Select “Run” from the main menu, then “Unattended Sample”, then “Stop Logging”.

-Return to the main menu, and select the “File” option. Select “Directory” to view the files saved in the sonde’s memory and the number of samples in each.

-Return to the “File” menu, and select “Upload.” Upload the data file (.dat extension) that has just been collected to the control unit’s memory.

11.8 Sonde Cleaning

As observed by Wagner et al. (2006), data errors due to sensor fouling have become less common since the introduction of wipers and optical DO probes. However, to ensure that fouling is not a problem, field personnel will clean the sensors and record the readings before and after cleaning each time the sonde is visited (every 2-3 weeks). For all sensors, the body of the sensor will be cleaned removing any accumulations of sediment with a soft-bristled toothbrush and the rinsing of the probes in stream water. The manufacturer’s recommendations for further cleaning are given below:

Optical DO sensor: The wiper pad on the DO sensor should be inspected for wear and replaced if necessary. The probe may be cleaned with water, but the use of alcohol or other solvents will destroy the membrane.

-Conductivity and temperature sensor: The small brush provided by the manufacturer should be used to remove accumulations from the openings in the sensor. In the event that accumulations cannot be moved by brushing with water, a mild detergent may be used.

-pH sensor: If the pH response of the probe slows, then use tap water and a clean cloth to remove accumulations from the glass bulb and platinum button. If performance does not improve, consult the manual for further procedures that may be undertaken.

11.9 Calibration Check

The calibration of the DO, specific conductivity, and pH sensors must be checked immediately after data are downloaded to check for drift. A certain amount of instrument drift is inevitable in long-term sensor deployments. Quantifying this drift is important for quality assurance, and it allows for the drift corrections discussed in *SOP 17: Data Analysis and Reporting*. Calibration check measurements should be made **after** the data file has been downloaded, but **before** the files in the probe's memory (which include the calibration file) have been cleared. The calibration file names have the format [sonde name] C [DO/PH/SC] [mmdd], where sonde name is a one-letter name, DO/PH/SC are the two letter codes for DO, pH, and specific conductivity, respectively, and mmdd is the month and day of the calibration check.

-Rinse and dry the probe sensors.

-Place the probe in a calibration cup containing 3 mm (1/8 inch) of water. The intent of the procedure is to perform the measurement in water-saturated air, so the sensor should not be underwater. Loosely thread the calibration cup onto the probe housing, ensuring that the air pressure inside the cup is the same as the atmospheric pressure. Wait 10 minutes to allow the water and air in the cup to reach the ambient temperature and equilibrate.

-Select the "Run" option from the sonde's main menu, then select the "Discrete Sample" option from the Run menu.

-From the Discrete Sample menu, enter a sample interval of 10 seconds, a file name of "[sonde name]cDO[mmdd]", and a site name consisting of the name of the stream.

-Select the "Open File" option to open the file you have created, then select the "Start Sampling" option.

-The parameter values measured by the probe should begin to appear on the screen, with a new sample added every ten seconds. Once the probe has stabilized, select the "Log Last Sample" option (Option 1) to log a single reading.

-Hit the **Esc** key to return to the Discrete Sampling menu. Select the "Close File" option.

-Repeat the above steps using conductivity calibration solution (filename: "[sonde name]cSC[mmdd]") and pH 7 buffer (filename: "[sonde name]cPH[mmdd]") instead of water-saturated air. Be sure to clean and dry the sonde sensors and calibration cup when switching solutions.

-Once the three calibration check files have been collected, upload them to the laptop and copy them to a flash drive as described in section 12.9.

-From the main menu, and select the “File” option. Select the “Delete all files” option, and confirm your choice by answering “yes” on the next screen.

-The instrument drift can be assessed quantitatively during the data analysis stage. However, field personnel should take note if any of the calibration check values are so far from the true values that they represent a problem with the instrument.

11.10 Multiprobe Retrieval

At the end of the field season (early fall) the multiprobe should be removed from the stream. For aesthetic reasons, the fenceposts should also be removed.

For logistical reasons, the multiprobe may need to be stored for periods of up to one week between deployments. The pH electrode has a special storage jar that slips over the sensor. This jar should be filled with pH 4 buffer for short-term storage. The multiprobe should be stored with the calibration cup threaded on, and with a damp sponge in the bottom of the calibration cup. In the event that the probe is stored dry for a period of greater than 2 hours, consult the manual for instructions on repairing the damage to the ODO sensor and the pH electrode.

For long-term storage procedures, consult the manual or *SOP 4: Post-Season Activities*.

11.11 Version Information

Table SOP 11.2. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 12. Stream Chemistry and BMI Sampling

12.1 Overview

The target population for benthic macroinvertebrate (BMI) and water chemistry sampling consists of the perennial streams in the park. However, Williams Creek is extremely inaccessible, making annual sampling logistically difficult. Therefore, it will not be sampled, allowing network resources to be focused on a sample population of the other nine streams.

One permanent site on each of the nine streams will be visited annually. During the site visit water quality data will be collected, a water chemistry sample will be collected, and a BMI sample will be collected. The sequence of events for a site visit is given below:

- navigate to site
- record GPS coordinates to confirm location
- collect core site data
- calibrate handheld water quality instrument
- collect water quality cross-section data
- collect unfiltered water sample
- collect filtered water sample
- collect BMI sample and characterize transect reaches

All data should be recorded on a copy of the streams annual visit field sheet (Figure SOP 12.1). An electronic copy of the field sheet is included in the *Supplementary Materials*.

MOJN I&M STREAMS AND LAKES PROTOCOL- STREAMS ANNUAL SAMPLING FIELD SHEET																													
DATE (mm/dd/yy):				TIME (PST):				STREAM NAME:				LOCATION ID:																	
CREW:										PARK: GRBA																			
GPS COORD. SYSTEM (default UTM zone 11):										GPS DATUM(def. NAD83):				GPS UNITS (m or ft):															
Water Quality Cross-Section										Location																			
		pH		DO		SpCond		Raw Cond		Temp				Target Location		GPS Reading													
center												easting																	
left (looking upstream)												northing																	
right (looking upstream)																													
Water Quality Instrument ID No:										Permanent Marker Located? (Y/N):																			
										GPS Accuracy:																			
TRANSECT CHARACTERISTICS: <i>Circle one substrate type and one channel type for each transect</i>																													
Downstream										X-site										Upstream									
A		B		C		D		E		F		G		H		I		J		K									
Substrate	Channel	Sub	Chan	Sub	Chan	Sub	Chan	Sub	Chan	Sub	Chan	Sub	Chan	Sub	Chan	Sub	Chan	Sub	Chan	Sub	Chan								
F-Fine/Sand	P-Pool	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P								
G-Gravel	GL-Glide	G	GL	G	GL	G	GL	G	GL	G	GL	G	GL	G	GL	G	GL	G	GL	G	GL								
C-Coarse	RI-Riffle	C	RI	C	RI	C	RI	C	RI	C	RI	C	RI	C	RI	C	RI	C	RI	C	RI								
O-Other	RA-Rapid	O	RA	O	RA	O	RA	O	RA	O	RA	O	RA	O	RA	O	RA	O	RA	O	RA								
Fine/sand: up to ladybug sized (2 mm)										Gravel: ladybug to tennis ball sized; 2 mm to 64 mm diam.																			
Coarse: tennis ball to car sized; 64 mm to 4000 mm										Other: bedrock, wood, vegetation, etc. Note in "Notes"																			
Pool: Still water, low velocity, smooth										Glide: Water moving slowly with smooth unbroken surface; low turbulence																			
Riffle: small ripples waves, and eddies and "babbling"										Rapid: turbulent, intermittent "white water", continuous rushing sound																			
WATER SAMPLES										BMI SAMPLE																			
Sample Time:										Sample Collected? (Y/N):																			
Unfiltered sample? (Y/N):										Sample Time:																			
Filtered sample? (Y/N):										No. of Bottles:																			

Figure SOP 12.1. Streams annual sampling field sheet.

12.2 Sampling Sites

In order to eliminate the sample bias that can be caused by judgment-based site selection, sample sites have been selected randomly for the nine accessible perennial streams. A list of 50 random sites was generated for each perennial stream in the park (included in the Supplementary Materials). For several streams, the first randomly selected sites were rejected based on insufficient discharge or inaccessible locations. These rejected sites are noted in the Supplementary Materials. The accepted sites are listed in Table SOP 12.1. Maps showing the roads and trails in the vicinity of the sites are shown in Figures SOP 12.2, SOP 12.3, and SOP 12.4.

Table SOP 12.1. Sample sites for water chemistry and BMI sample collection. Easting and northing coordinates are for UTM zone 11S, NAD 83.

Stream	Sample Site Easting (m)	Sample Site Northing (m)	Rejected Sites
Strawberry	735651	4326941	1 ^b
Mill	736689	4324562	0
Lehman ^a	734703	4322017	1 ^c
Baker ^a	736781	4315879	2 ^d
Snake	737569	4312594	0
S. Fk. Big Wash	743243	4307414	3 ^e
Shingle	729424	4320644	0
Pine	729600	4319780 ^f	0
Ridge	729383	4318560	2 ^g

a. The sites listed for Baker and Lehman have not been visited, and may not be suitable.

b. Site rejected because it was in a stream segment known to be intermittent (dry in the summer).

c. Site rejected because it was in a campground.

d. Sites rejected for being in a tributary spring and in an intermittent segment.

e. Sites rejected due to location in an inaccessible canyon.

f. Northing value corrected based on field verification and satellite imagery.

g. Sites rejected because they were located above the stream's source

The lists of randomly-selected sites in the Supplementary Materials can be used to select additional or replacement sampling sites, should the need arise.

12.2.1 Navigation

[This section adapted from a 2009 draft of the North Coast Cascades Network Forest Vegetation Protocol (John Boetsch, Personal Communication)]

Locating the sites listed in Table SOP 12.1 will require GPS navigation. Regardless of GPS receiver type, certain aspects of data collection apply.

- Satellite availability:

Acquiring at least 4 satellites will give you a 3-D position. Satellites that are spread out have better geometry and will give a more accurate reading than when they are clustered together.

- Multipath error, or signal interference

While mostly beyond a user's control, some adjustments can be made to minimize multipath error. These include positioning the GPS in the most unobstructed view of the sky as possible, using offsets from better satellite reception areas to the target location, or using an external antenna.

- Signal to noise ratio (SNR)

This is out of a user's control, although Trimble units allow a minimum ratio value to be set in the configuration such that positions with SNR below that value are not logged. A value of 4 is recommended for SNR values in Trimble units.

The GPS should not be exclusively relied upon for navigation. It gives straight-line azimuth and distance to targets and will not show the safest navigation routes, for example, following ridge lines, safely crossing rivers or circumnavigating cliffs. At times the GPS receiver may not function due to location (i.e. in a canyon), low satellite coverage, or battery power loss. Always use a map, and compass (and altimeter if available), with GPS as an adjunct navigation method.

Selected sampling coordinates can be incorporated into the GPS background map if background maps are available in the GPS model. In the absence of a background map, hardcopies of target coordinates can be compared to GPS unit coordinate calculations shown on the GPS unit's coordinate display screen.

See instruction sheets or users' manuals for specific GPS models for navigation functions that give distance and bearing to selected target locations from a current location.

The coordinates displayed on GPS unit display screens will often rapidly change or jump around. Use the coordinate averaging capability, if available, of GPS units to better calculate a current location.

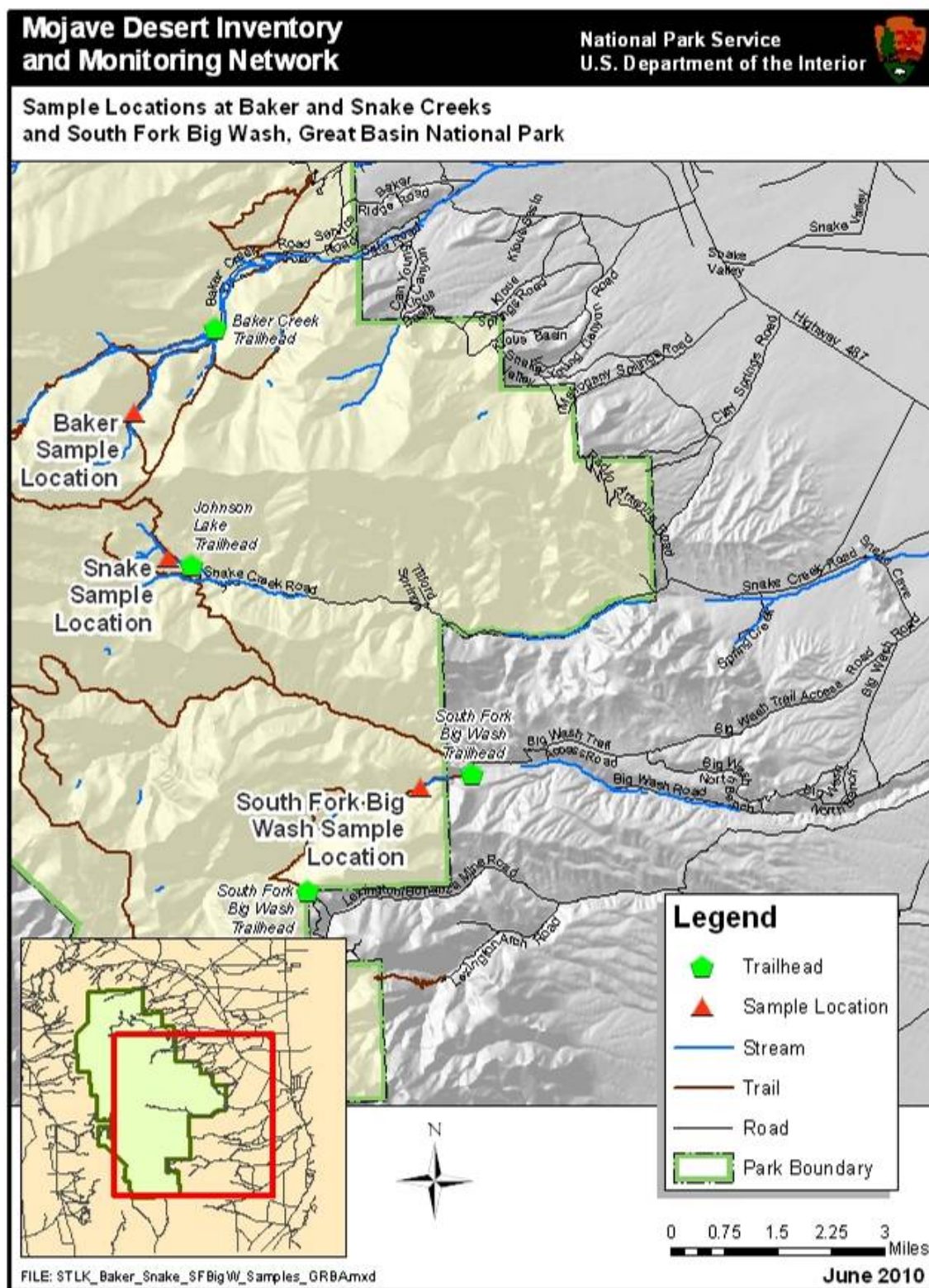


Figure SOP 12.2. Sample locations for Baker Creek, Snake Creek, and South Fork Big Wash.

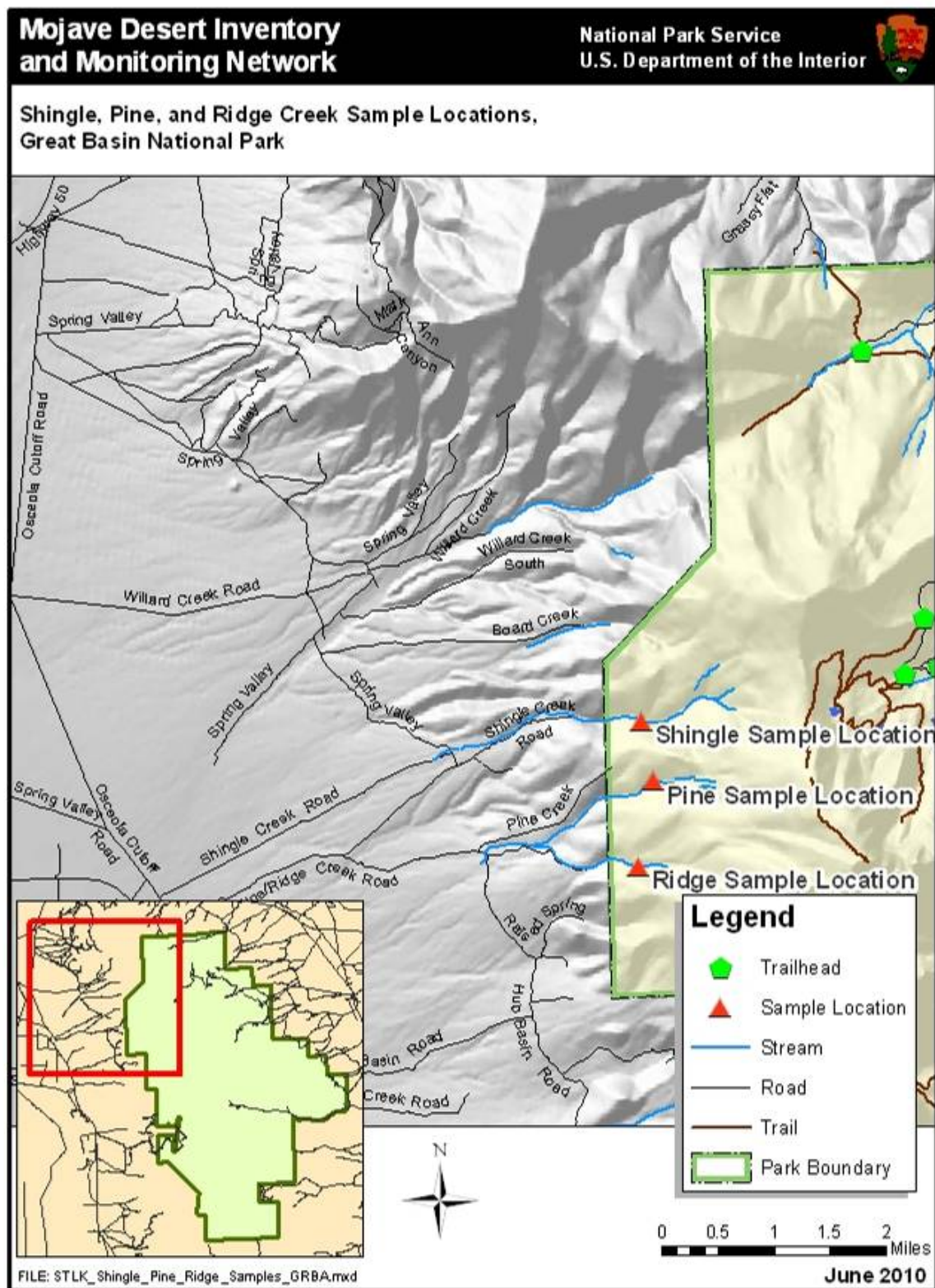


Figure SOP 12.3. Sample locations for Shingle, Pine, and Ridge Creeks.

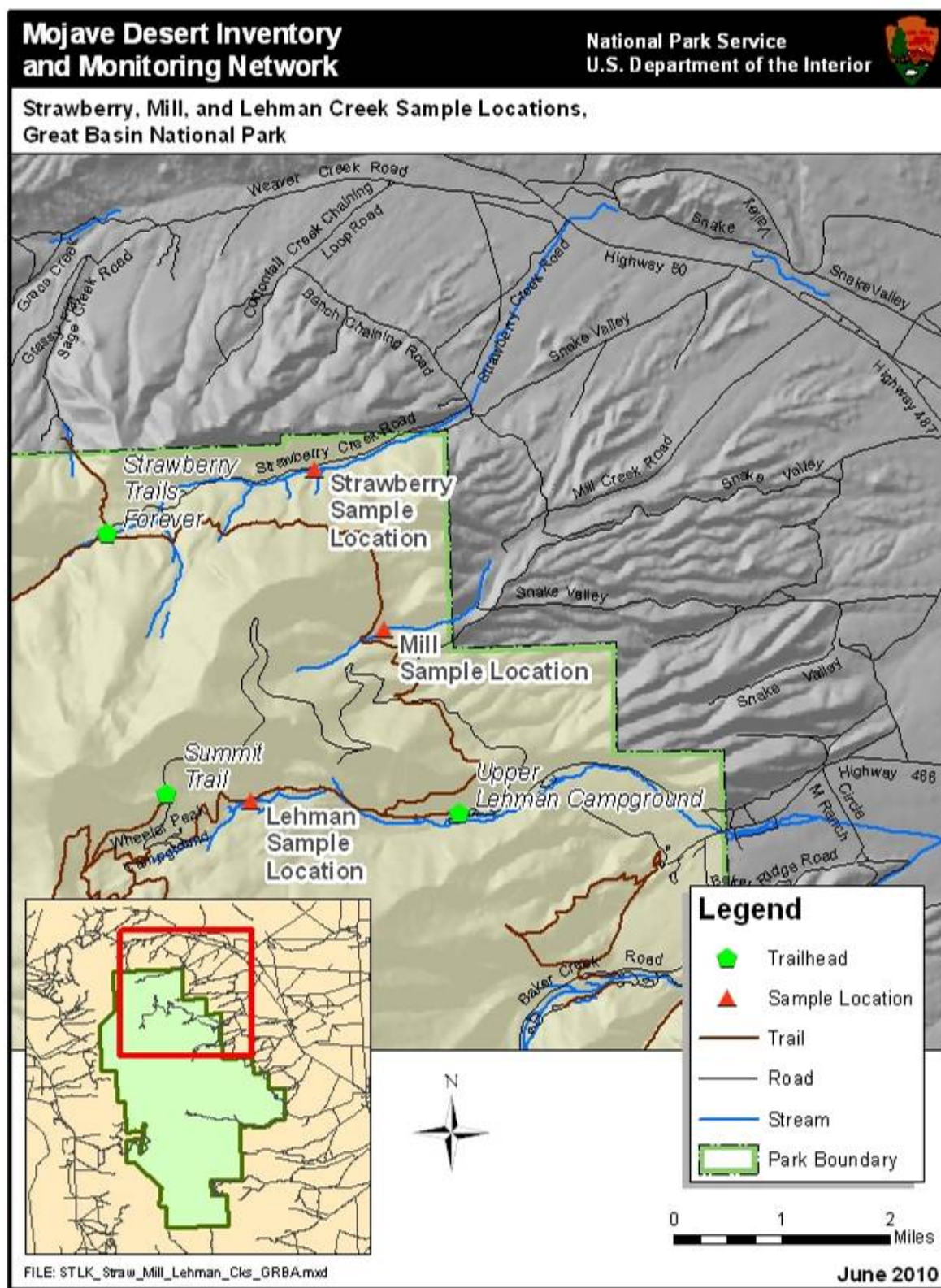


Figure SOP 12.4. Sample locations for Strawberry, Mill, and Lehman Creeks.

Strategy for Locating a Sampling Site

1. First look at a hardcopy map marked with the plot location and determine your route.
2. When leaving the trailhead, turn on the GPS receiver to verify your location and the target location.
3. Navigate to within the vicinity of the site using map and compass.
4. Turn on the GPS if you need to check your location.
5. Turn on the GPS as you near the plot. Continue to move toward the site, getting as close as you can. Established sites should have a permanent marker on the streambank.
6. Within a few meters of the point you may find that the UTM coordinates, as displayed by the GPS unit, are continually changing. This is because satellite signals are often blocked or bounced around by terrain and trees.
7. If a permanent marker has not yet been established for the site, then you may place the marker at a location where the current UTM coordinates are closest to the target coordinates as long as the difference is within 10 meters.
8. MOJN personnel have observed that streams in GRBA may be several meters from their mapped positions. In the event that the site is not located on a stream channel, choose the point on the stream that has the same easting coordinate as the sampling site.

12.3 Water Quality Cross-Section

Water quality measurements should be made in accordance with *SOP 6: Handheld Water Quality Instrument*. In order to ensure that the measurement is representative of the entire stream, measurements should be made across a cross-section of the stream. For streams on the order of 1 meter wide, three measurements are sufficient (P. Penoyer Personal Communication). The measurements should be made at mid-water column in the center of the stream and near each bank. All parameters should be recorded for each measurement.

12.4 Water Chemistry Sample Collection

The volume of water sample and the type of field preservation (e.g., acidification, filtration) needed by the laboratory depends on the analyses that are to be performed. For the analyte list used in 2011, CCAL requires one 500 mL bottle of unfiltered sample and two 500 mL bottles of filtered sample. If the analyte list is changed, then the testing laboratory must be contacted before field samples are collected.

Many commonly used filters are known to contaminate filtered water with several µg/L of nitrate. This level of contamination is not a concern for typical water samples. However, it is anticipated that nutrient concentrations in the water samples collected from GRBA streams and lakes will be extremely low. Therefore, MOJN will use 0.7 µm pore size glass fiber filters (Whatman Grade GF/F) that have been ashed in a muffle furnace by CCAL. The drawback to using these filters is that the EPA defines dissolved constituents as those that pass a 0.45 µm pore-size filter. In the unlikely event that analyte concentrations approach regulatory standards, it will be necessary to collect a third bottle of sample that has been filtered with a standard 0.45 µm pore-size filter. The decision to collect 0.45 µm-filtered samples in addition to the 0.7 µm-filtered samples will be made by network staff between field seasons.

[Adapted from Section 5 of the EMAP Protocols (Peck et al., 2006)]

1. Collect from the center of transect A (the furthest downstream transect).
2. Uncap the unfiltered sample bottle, and fill it by dipping it in the stream. Place the sample bottle into the sample cooler.
NOTE: this procedure cannot be used on acidified samples if the acid is already measured into the bottle.
3. Using clean forceps, place a glass fiber filter on the filter holder. Use a small amount of deionized water to settle the filter properly onto the holder. Attach the vacuum pump to the filter assembly.
4. Rinse the sampling beaker (any clean container with a volume of approximately 500 to 1000 mL) in stream water three times. Discard the rinse water downstream.
5. Pour stream water from the sampling beaker into the filter funnel. Pump the water through the filter until 500 mL of water has been filtered.
6. Decant the filtered sample from the filter chamber to the filtered sample bottle.
7. Place waterproof labels with the following information on each bottle:
 - Sample name
 - Date and time of collection
 - Filtered or unfiltered
 - Collectors initials
 - Name of stream
8. Temporarily place the bottles in the sample container with solid-sided “blue ice”. Sample handling and shipping is discussed in *SOP 7: Sample Handling, Storage, and Shipping*.

12.5 BMI Sampling

BMI samples should be collected in accordance with the protocol described in Section 10 of the EPA EMAP manual (Peck et al. 2006). After collection, the samples should be stored at GRBA until all BMI samples have been collected. BMI samples should be shipped as described in *SOP 7: Sample Handling, Storage, and Shipping*.

12.6 Version Information

Table SOP 12.2. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 13. Laboratory Analysis of BMI

13.1 Overview

The composition of benthic macroinvertebrate (BMI) communities can be a key indicator of stream health. As discussed in *SOP 17: Data Analysis and Reporting*, many metrics are used to assess these communities. In order to calculate these metrics, however, BMI samples have to be processed in a way that is quantitative and repeatable. The procedures described in this SOP are similar to those described by the USGS NAWQA program (Cuffney et al. 1993; Moulton et al. 2000), and were described by Vinson and Hawkins (1996).

13.2 Procedures

The laboratory procedures used by the BLM/USU National Aquatic Monitoring Center (also known as the USU BugLab) are included in the *Supplementary Materials*. Their web page was accessed on July 7, 2009, at the following address:

<http://www1.usu.edu/buglab/process/lab%20procedures.htm>

13.3 Taxonomic Level

The USU BugLab's standard taxonomic identification levels are listed below. The only variation from the standard is for Chironomidae, which will be identified to the genus level at the request of MOJN.

Table SOP 13.1. USU BugLab's standard taxonomic identification levels.

Phylogenetic Level	Taxonomic Resolution
Annelida	
Hirudinea	Order\Family\Genus\Species
Oligochaeta	Subclass
Arthropoda	
Trombidiformes	Order
Crustacea	
Cladocera	Order\Family\Genus\Species
Copepoda	Order\Family\Genus\Species
Decapoda	Order\Family\Genus\Species
Ostracoda	Order\Family\Genus\Species
Amphipoda	Genus\species
Isopoda	Order\Family\Genus
Entognatha	
Collembola	Order
Insecta	
Coleoptera	Genus
Except Curculionidae & Heteroceridae	Family
Diptera	
Atherceridae	Genus\Species
Blephariceridae	Genus
Ceratopogonidae	Family/Genus
Chaoboridae	Genus
Chironomidae	Genus
Culicidae	Genus
Deuterophlebiidae	Genus
Dixidae	Genus
Empididae	Genus
Ephydriidae	Family
Muscidae	Family
Pelecorhynchidae	Genus
Psychodidae	Genus
Ptychopteridae	Genus
Sciomyzidae	Family
Simuliidae	Genus
Stratiomyidae	Genus
Tabanidae	Genus
Tanyderidae	Family

Table SOP 13.1. USU BugLab's standard taxonomic identification levels (continued).

Phylogenetic Level	Taxonomic Resolution
Thaumaleidae	Genus
Tipulidae	Genus
Ephemeroptera	Genus/Species
Hemiptera	Genus
Lepidoptera	Genus
Megaloptera	Genus
Odonata	Genus\Species
Plecoptera	Genus\Species
Trichoptera	Genus\Species
Coelenterata	Class\Order
Mollusca	Order\Family\Genus
Nematoda	Phylum
Nematophora	Phylum
Turbellaria	Class

13.4 QA/QC Procedures

A description of the USU BugLab's QA/QC procedures is included in the *Supplementary Materials*. The description was taken from the BugLab website, accessed on July 7, 2009 at the following address:

<http://www1.usu.edu/buglab/process/QAQC.html>

13.5 Version Information

Table SOP 13.2. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 14. Laboratory Analysis of Water Chemistry

14.1 Overview

Water samples collected from the streams and lakes of GRBA will be analyzed by Oregon State University Cooperative Chemical Analysis Laboratory (CCAL). Their web page was accessed on July 10, 2009, at the following address:

<http://ccal.oregonstate.edu/>

CCAL has a QA/QC procedure that conforms to EPA surface water criteria, and participates in the USGS Standard Reference Water Survey Program. CCAL's Quality Assurance Plan is included in the Supplementary Materials.

14.2 Analytes

The water samples will be analyzed for basic parameters, nutrients, and major ions.

Basic Parameters:

pH
Specific Conductance
Alkalinity

Nutrients:

Dissolved nitrogen
Total nitrogen
Nitrate plus nitrite (dissolved)
Dissolved phosphorus
Total phosphorus
Dissolved organic carbon

Major Ions:

Sodium (dissolved)
Potassium (dissolved)
Calcium (dissolved)
Magnesium (dissolved)
Sulfate (dissolved)
Chloride (dissolved)

The rationale for analyzing the samples for major ions is that they may be useful in determining the relative proportions of spring flow and runoff in a given sample. Major ions may be removed from the analyte list if it is shown that the same inferences can be drawn from the specific conductivity and alkalinity data.

The pH and Specific Conductance measurements are included as analytes because they are measured by the laboratory at the same time that alkalinity is measured. The laboratory measurements of these values will be archived, but they will not be reported, as they are less accurate than the in situ measurements made at the time of collection.

14.3 Analytical Methods

CCAL procedures were developed from American Public Health Association (APHA) standard methods (APHA, 2005). The methods are listed below, along with comparable EPA methods and the modifications made to those methods:

Table SOP 14.1. Methods used by CCAL to analyze MOJN samples.

Analysis	* Method # with Specifications and Modifications
Alkalinity	APHA 2320, titrate to pH 4.5. Modifications: Use 0.02N Na ₂ CO ₃ and 0.02N H ₂ SO ₄
Bromide	APHA 4110 B; EPA 9056A
Calcium	APHA 3111 D; flame atomic absorption spectroscopy. Modifications: nitrous oxide/ acetylene flame. Addition of 1 ml 50,000 mg/l lanthanum oxide to 10 ml sample to control ionization.
Chloride	APHA 4110 B; EPA 9056A
Specific Conductance	APHA 2510; Wheatstone bridge.
Magnesium	APHA 3111 B; flame atomic absorption spectroscopy.
Nitrate + Nitrite	APHA 4500-NO ₃ F; EPA 353.3. Cadmium reduction method.
Nitrogen-Total and Dissolved	APHA 4500-NO ₃ F; APHA 4500-P J. Persulfate digest
Dissolved Organic Carbon	APHA 5310 B
pH	APHA 4500 H; Calomel reference electrode, glass pH electrode, temperature compensator.
Phosphorous- Total and Dissolved	APHA 4500-P J; APHA 4500-P F; EPA365.2. Persulfate digest.
Potassium	APHA 3111 B; flame atomic absorption spectroscopy.
Sodium	APHA 3111 B; flame atomic absorption spectroscopy.
Sulfate	APHA 4110 B; EPA 9056A

note: All information in this table is taken from the CCAL website, accessed August 30, 2011.

CCAL's laboratory analysis SOPs are included in the Supplementary Materials.

14.4 QA/QC Procedures

CCAL's Quality Assurance Plan is available on their website, accessed on July 10, 2009 at the following address:

<http://ccal.oregonstate.edu/qaqc.htm>

The plan is included in the *Supplementary Materials*. MOJN personnel have reviewed this plan, and are confident that the procedures it outlines are sufficient to meet the data quality objectives for this protocol. CCAL's quality assurance procedures include participation in the USGS Standard Reference Water Survey Program, an external interlaboratory QA Program, to monitor accuracy of analytical procedures.

14.5 Version Information

Table SOP 14.2. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 15. Quality Assurance Project Plan

15.1 Introduction

The Quality Assurance Project Plan (QAPP) is the written record of the QA/QC program.

Quality assurance (QA) refers to the overall *management system* which includes the organization, planning, data collection, quality control, documentation, evaluation, and reporting activities of the group. QA provides the information needed to ascertain the quality of data and whether it meets the requirements of the program. QA ensures that data will meet defined standards of quality with a stated level of confidence.

Quality control (QC) refers to the routine *technical activities* whose purpose is, essentially, error control. Since errors can occur in either the field, the laboratory or in the office, QC must be part of each of these functions. QC should include both internal and external measures.

[This QAPP was modified and expanded from an SOP prepared by Thoma et al. (2009): The format of this QAPP is from EPA (2001).]

15.2 Distribution list and contact information

Table SOP 15.1. People who will be aware of the project goals, tasks, and products. These people will be aware of the project goals, tasks, and products

Name/Title/Agency	Contact
Nita Tallent/Program Manager/MOJN	702-293-8911, nita_tallent-halsell@nps.gov
Unfilled/Hydrologist/MOJN (temporarily Geoff Moret, U. of Idaho)	702-293-8843, geoffrey_moret@partner.nps.gov
Gretchen Baker/Ecologist/GRBA	775-234-7331 x251, gretchen_baker@nps.gov

15.3 Project Management

This project is intended to be a long-term (30+ years) monitoring plan. As such, consideration in this QAPP is given to potential change in equipment, laboratory method, and staff. Generally speaking, the plan will be managed by network (MOJN) personnel and implemented by park (GRBA) personnel. Some sites will be monitored in cooperation with USGS and technical assistance will be provided by USGS and NPS Water Resources Division (WRD). Decisions regarding the I&M Water Quality Program development and long term monitoring plan have been and will continue to be made by consensus of the MOJN aquatic professionals team consisting of key network staff including the aquatic ecologist, network coordinator, and GRBA staff. The I&M Water Quality Program will remain adaptive to changing park and network needs. Broader-based, long-term decisions are approved by the NPS-WRD with additional technical guidance from USGS and the MOJN technical committee. These include approval of the overall monitoring plan.

Table SOP 15.2. Project tasks and responsibilities.

Name (Affiliation)	Title/Responsibility
Unfilled (MOJN)	Hydrologist Technical Lead - coordinate collection of monitoring data and data management, coordinate report writing and protocol revision. This position is temporarily filled by CESU Cooperators (Geoff Moret, University of Idaho).
Gretchen Baker (GRBA)	Oversee the collection of monitoring data, manage the temporary staff.
Nita Tallent (MOJN)	MOJN I&M Coordinator - Coordinate with water quality technical lead on reporting requirements, assist with peer review process, program oversight
Robert Truitt (MOJN)	MOJN Data Manager- assist with water quality database management, archive, and uploading to NPS and national data bases
Pete Penoyer / Roy Irwin/ Gary Rosenlieb (WRD)	WRD Hydrologists - technical oversight, peer review, and formal program approval

15.4 Problem Definition/Background

The overarching programmatic goal of the MOJN I&M Program is to obtain information that will aid in the assessment, conservation, and restoration of surface water resources. The *management questions* given below are the overarching questions faced by park managers. The *measurable objectives* are the information that the monitoring program can provide. In some cases, additional data from other sources will need to be combined with the protocol data to address the management questions. The purpose of the Streams and lakes protocol monitoring is not to answer the management questions, but to provide some of the information required to address them.

15.4.1 Monitoring Questions

The Streams and Lakes Protocol outlines a monitoring program that will address five primary management questions faced by park managers. These questions fall into two categories, the **regulatory status** of surface waters at LAKE and GRBA and **assessment of ecosystem condition and trend** in streams and lakes at GRBA. Regulatory status is defined as the listing status of each waterbody as 1) impaired or unimpaired, as assessed under section 303(d) of the CWA, and 2) an Outstanding National Resource Water (ONRW) or not, as defined in 40 CFR §131.12(3). ONRW status is determined by the state of Nevada. Determinations of 303(d) status are made by the State of Nevada and the State of Arizona and approved by US EPA.

Management Questions Related to Regulatory Status:

1. What is the regulatory status of the LAKE reservoirs under section 303(d) of the Clean Water Act? Which of the GRBA streams are classified as ONRWs? Do changes in listing status indicate improving or declining water quality?

Management Questions Related to GRBA Stream and Lake Ecosystems:

1. What is the status of and what are the trends in the overall health of the ecosystems in GRBA streams?
2. Is stream water quantity changing in GRBA streams? In particular, is stream discharge being affected by groundwater withdrawals and/or climate change?
3. Is climate change affecting the physical limnology of GRBA lakes?
4. Are atmospheric deposition and/or nutrient loading affecting the chemistry of GRBA streams and lakes?

15.4.2 Measurable Objectives

In light of these questions and the broader goals outlined above, this protocol will address the following specific measurable objectives:

Regulatory Issues:

1. What is the regulatory status of 303(d)-assessed waters within LAKE? Is the number of listed water bodies or listed water quality parameters changing over time?
2. What is the regulatory status of Nevada Class A streams (the classification used by Nevada to designate ONRWs) within GRBA? What is the condition and trend in water quality of GRBA Class A streams? Specifically, is there any evidence of declining water quality that would warrant a change in regulatory status?

The measurable objectives for regulatory issues will be achieved by monitoring the listing status of all 303(d)-assessed waters and Class A streams in Nevada and reporting the status of all listed water bodies located within LAKE and GRBA.

Condition and Trends in Streams at GRBA:

1. What are long term trends in the quantity and seasonal patterns of stream discharge?
2. What is the status of and what are the trends in stream water chemistry?
3. What is the status of and what are the trends in stream macroinvertebrate assemblages in streams? Do macroinvertebrate assemblages indicate “reference” or “stressed or impaired” water quality using regional bioassessment criteria?

Condition and Trends in Lakes at GRBA:

1. In subalpine lakes, are water levels or lake ice-free season changing over time?
2. What is the status of and what are the trends in lake water chemistry?

15.5 Project/Task Description Synopsis

15.5.1 Regulatory Status

303(d) Listed Waters (SOP 8)

Under Section 303(d) of the Clean Water Act (CWA), states are required to provide biennial lists of water bodies that are impaired by pollution. Currently, LAKE contains the only water bodies located in MOJN that are designated as 303(d) impaired. The 303(d) lists provided by the state of Nevada and the state of Arizona will be monitored for any changes in the status of LAKE waters.

Outstanding Natural Resource Waters (SOP 8)

In the State of Nevada, the Nevada Administrative Code (NAC 445A.124) identifies certain waters as Class A waters, the equivalent of the Outstanding Natural Resource Waters (ONRWs) defined in the CWA. The only Class A waters located in MOJN are four streams in GRBA. The list of Class A waters provided by the state of Nevada will be monitored for any changes in the status of GRBA waters.

Exclusion of Regulatory Status Monitoring from QAPP

As the regulatory status monitoring portion of the monitoring program does not involve the generation of data by MOJN or other NPS personnel, it is not discussed further in this QAPP. Details of the regulatory status monitoring plan are discussed in *SOP 8: Regulatory Status*.

15.5.2 Streams

Stream Discharge (SOP 9)

Stream flow will be monitored using a combination of continual-recording stage devices and discrete discharge measurements using standard USGS techniques. Stream gages are located at sites previously established by USGS and NPS staff. Stage will be continuously recorded at the four second-order streams in GRBA (Lehman, Baker, Strawberry, and two gages on Snake). Monthly discharge measurements will be made at these four streams to permit the development of rating curves.

Stream Core Water Quality Parameters (SOP 11)

Core parameters will be measured continuously using multiprobes deployed near existing stream gages in the four second-order streams in GRBA. Each stream will be monitored for two two-week periods each field season.

Stream Benthic Macroinvertebrates (SOP 12)

Benthic macroinvertebrate (BMI) samples will be collected annually from each of the ten streams in GRBA. Samples will be collected from randomly selected sites along each stream, with the same site revisited each year. As described in *SOP 12: Stream Chemistry and BMI Sampling*, the BMI samples will be collected using EPA EMAP protocols (Peck et al. 2006), and analyzed by a contract laboratory.

Stream Water Chemistry (SOP 12)

A water sample will be collected prior to the annual BMI sampling event for each of the ten streams in GRBA. These samples will be analyzed by a contract laboratory for acid neutralizing

capacity, major ions, sulfate, dissolved organic carbon (DOC), total nitrogen (TN), total dissolved nitrogen (TDN), nitrate, total phosphorus (TP), and total dissolved phosphorus (TDP).

15.5.3 Lakes

Lake Level and Temperature (SOP 10)

Lake level and temperature will be recorded semi-daily in all six GRBA lakes using pressure-temperature loggers. In order to estimate lake level from pressure readings, the logger positions will be surveyed, and atmospheric pressure will be recorded separately. The loggers will record continuously, and be retrieved and downloaded annually.

Lake Core Parameters and Clarity (SOP 10)

A vertical profile of core parameters at the deepest point in each GRBA lake will be collected annually using a multiprobe. At the same time that these vertical profiles are collected, the water clarity of each lake will be measured using a Secchi disk.

Lake Water Chemistry (SOP 10)

A water sample will be collected annually from each GRBA lake. These samples will be collected from mid-water column depth near the deepest point in each lake. The samples will be analyzed by a contract laboratory for the same analyte list used for the stream water chemistry samples: acid neutralizing capacity, major ions, sulfate, dissolved organic carbon (DOC), total nitrogen (TN), total dissolved nitrogen (TDN), nitrate, total phosphorus (TP), and total dissolved phosphorus (TDP).

15.6 Data Quality Objectives (DQOs)

This section is intended to demonstrate how this project generates data of known and documented quality, resulting in complete, accurate and transferable information. Data credibility necessary for the intended uses will be achieved when it is:

1. consistent over time and consistent between staff members
2. collected and analyzed using standardized and acceptable techniques
3. comparable to data collected in other assessments using the same methods
4. used appropriately to make decisions based on sound statistics

Specific, quantitative objectives for the quality of measured data are referred to as Measurement Quality Objectives (MQOs). The MQOs for this protocol are discussed in Section 15.7.

15.6.1 Spatial Representativeness

Stream Discharge

As discharge data is being collected in cooperation with the USGS, stream discharge measurements will be collected at previously-established stream gage locations on Baker, Lehman, Snake, and Strawberry Creeks. These gages are generally located near park boundaries in order to measure the total discharge generated in the park, a consideration that is a higher priority than the enhanced representativeness that results from randomized location selection.

Stream Core Water Quality Parameters

The continuous core parameter measurements will be collected near the stream gages because of the critical importance of discharge in interpreting core parameter records. Cross-section surveys

will be conducted to help determine the most representative location for multiprobe placement. The USGS National Field Manual for the Collection of Water quality Data (NFM) indicates that:

“In a small (usually less than 5 feet (ft) in width) and well-mixed stream, a single point at the centroid of flow may be used to represent the cross section.”

The streams of GRBA are less than five feet wide in many locations, and are well-mixed by turbulent flow in rapids. However, field personnel will take readings at several locations in each stream to assess the degree of spatial variation in core water quality parameters. If the variation is insignificant (as evaluated in relation to the MQOs given in Table SOP 15.4), only the readings from the centroid will be recorded. If cross-section variability is observed, then a formal cross-section survey (described in *SOP 11: Continuous Water Quality Sonde*) will be undertaken.

Stream Water Chemistry and BMI

As described in *SOP 12: Stream Chemistry and BMI Sampling*, one site for each stream will be randomly chosen for BMI and water chemistry sampling and revisited annually. Using a fixed site for each stream decreases the power of the data set to determine stream status, but enhances the power of the data set to detect trends. In accordance with EMAP protocols and as described in *SOP 12: Stream Chemistry and BMI Sampling*, 11 transects will be established at each site to ensure the spatial representativeness of the BMI sample on the scale of the reach. The water sample for the site will be collected from the central point of the transects. GRBA streams are small, fast-moving, and well-mixed, so no compositing of water samples is required.

Lake Level and Temperature

In small lakes, lake level in one location is representative of the level of the entire lake. Lake temperature is less homogeneous. However, the temperature record is being collected to infer the presence or absence of ice cover, a parameter which should not vary greatly over a small lake (data is being collected over the 2009-2010 winter that will test this hypothesis). Therefore, logistics (specifically the need for the logger to remain submerged year round) will be allowed to dictate the positioning of the pressure-temperature data loggers in the lakes.

Lake Core Water Quality Parameters, Clarity, and Water Chemistry

The depth profile of core parameters will be collected at or near the deepest point in each lake to ensure that the greatest possible variations in water quality are observed.

Currently, the Secchi depths of the lakes are greater than the depth of the lakes (i.e., the disk is visible on the bottom of all of the lakes). Therefore, the Secchi depth will also be measured at or near the deepest point so that small decreases in lake clarity can be observed.

The core water quality parameter depth profiles collected during the pilot data acquisition phase of the monitoring indicate that the lakes are reasonably well-mixed, so a single water sample will be representative of each lake. The water chemistry sample will be co-collected with the depth profile and Secchi depth at or near the deepest point in each lake. If the depth profile suggests that the lake may be stratified, then two samples, one from near the surface and one from 1 m above the lake bottom should be collected and mixed together. Otherwise, a single sample should be collected.

15.6.2 Temporal Representativeness*Stream Discharge*

The continuous measurements of stream stage will be made every 15 minutes. This measurement frequency is standard for stream gages, and the long experience of the USGS and other agencies has shown that it is sufficient to characterize the discharge variations of interest to hydrologists.

Stream Core Water Quality Parameters

The continuous measurements of core parameters (two two-week periods for each stream in each field season) could be impacted by annual variation. To minimize this effect, each stream will be revisited during the same two two-week periods each year. Core parameters are greatly impacted by discharge, so the simultaneous collection of stage measurements in the second-order streams will help to clarify the impact of annual variation. The water quality parameters will be measured hourly. Pilot data collected in GRBA streams indicate that this frequency is sufficient to characterize diel variations.

Stream Water Chemistry and BMI

The impact of diel and annual variations on BMI communities will be minimized by collecting the samples between 10:00 AM and 2:00 PM during a mid-summer (July-August) index period. The same strategy will minimize the impact of diel and annual variations on water chemistry.

Lake Level and Temperature

It is anticipated that semi-daily sampling will be sufficient to characterize lake level and temperature variations. However, the first temperature-pressure loggers deployed will collect data every 15 minutes for at least several months to confirm that semi-daily sampling produces a temporally-representative record.

Lake Core Water Quality Parameters, Clarity, and Water Chemistry

The depth profile of core parameters, clarity measurement, and water chemistry sample will be collected annually in each lake. These measurements will be collected between 10:00 AM and 2:00 PM in late summer or early fall. By collecting data at a fixed time of day during a fixed index period, the impact of diel and annual variations will be minimized. In addition, the continuous lake level and temperature records can be examined to determine if cyclical variations in hydrologic processes are occurring that could impact the value of the annual samples.

15.6.3 Completeness

Given the goals of assessing long range trends in surface water dynamics and water quality, it is important that the monitoring and sampling events occur as planned. However, many of the streams and lakes in GRBA are not easily accessible. It is likely that not all sites will be sampled every year given these access issues. In addition, some of the streams may be dry in some years.

Every effort will be made to achieve 100% completion of data collection and analysis for all of the lakes and for the largest and most easily accessible streams. The target percentage of completeness for the smaller, more isolated streams will be refined after several years of sampling, but an initial estimate of 90% completeness (which would correspond to one of the 5 small remote stream missed every other year) seems both feasible and acceptable if complete records are available for the most accessible streams.

15.6.4 Internal Data Comparability

Data comparability through time across network parks even when sensors, instruments, and staff change occur is ensured by following guidelines laid out in the SOPs for staff training, sample handling, field methods and laboratory methods. When methods or equipment change, a record will be made in the appropriate SOP and in *SOP 20: Protocol Revision and Review*. The avoidance of cumulative measurement biases is described in detail in *SOP 16: Cumulative Measurement Bias*.

15.6.5 External Data Comparability*Stream Discharge*

Stream discharge measurements and stage data will be collected in accordance with widely used USGS standard operating procedures (USGS Water Supply Paper 2175, *SOP 9: Stream Discharge*).

BMI Sampling and Analysis

To ensure data comparability with other studies, BMI sampling will be undertaken in accordance with EMAP protocols (Peck et al., 2006, *SOP 12: Stream Chemistry and BMI Sampling*), and the analysis of the samples will be contracted to a qualified macroinvertebrate taxonomy laboratory with expertise in western BMI communities.

Core Water Quality Parameters in Streams and Lakes

Data comparability in core parameters is maximized by employing USGS standard operating procedures for measurement and NPS WRD guidelines for calibration frequency and methodology (*SOP 6: Handheld Water Quality Instrument*). Additionally, careful attention is paid to equipment manufacturer guidelines to maintain equipment in optimum working condition. Further assurance of data comparability in core parameter data is achieved by using National Institutes of Standards and Technology (NIST) traceable standards for calibration.

Stream and Lake Water Chemistry

The water chemistry samples will be analyzed by the Cooperative Chemical Analysis Laboratory (CCAL), a laboratory operated by the College of Forestry at Oregon State University and the U.S. Department of Agriculture (USDA) Forest Service. CCAL specializes in high quality, trace level analysis of nutrients, ions, and physical properties of lake, stream, precipitation, and groundwater research samples. CCAL conforms to EPA surface water chemistry criteria, and participates in the USGS Standard Reference Water Survey Program, an external interlaboratory QA Program. CCAL's Quality Assurance Plan is available online at <http://www.ccal.oregonstate.edu/pdf/QAP%20Final.pdf>

Lake Level and Temperature

Pressure data will be collected, converted to lake level, and corrected for atmospheric pressure variation in accordance with the standard practices used to collect and process water level data (*SOP 10: Lake Field Procedures* and *SOP 17: Data Analysis and Reporting*). The temperature sensors used in the pressure-temperature data loggers are calibrated to NIST standards in the factory, and in theory no user calibration is required. In practice, the temperature readings can be compared to the calibrated temperature measurements collected as part of the depth profile. If needed, the sensors can be recalibrated by the manufacturer.

Water Clarity

The Secchi depth of each lake will be measured using standard practices (*SOP 10: Lake Field Procedures*) that have been developed to ensure data comparability between studies and with historical data.

15.7 Measurement Quality Objectives

The measurement quality objectives (MQOs) discussed in this section apply to the analytical water chemistry data and the core water quality parameter data only. Quantitative QA/QC goals for the analysis of the BMI samples are discussed in *SOP 13: Laboratory Analysis of BMI*.

15.7.1 Measurement Sensitivity

Water Chemistry

The method detection limit (MDL) and minimum level of quantitation (ML) are the terms used to describe the minimum concentration of an analyte that can be observed and measured accurately, respectively. They are important concepts in water quality data reporting and analysis for many reasons, especially when considering chronic low level pollution that is near the detection limits of analysis methods (Irwin 2008). These values will be updated / reported at least once per year or when methods change and become part of the permanent data record.

The MDL for an analytical method or sample is the lowest value that can be distinguished from zero. The MDLs determined by CCAL for all water chemistry analytes are listed in Table SOP 15.5. Given the assumptions of constant standard deviation at low concentration, normal distribution, and minimal matrix interferences, the MDL is the concentration at which no more than 1 percent of the blank measurements result in a false positive detection. Therefore, detections at concentrations greater than or equal to the MDL concentration should be true detections 99 percent of the time.

The MDL is calculated as:

$$\text{MDL} = s * t_{(n-1, 1-\alpha = 0.99)},$$

where:

- n = number of replicate spike determinations at 1 to 5 times the estimated MDL,
- s = standard deviation of measured concentrations of n spike determinations,
- α = level of significance, and
- t = Student's t value at $n-1$ degrees of freedom and $1-\alpha$ (99%) confidence level.

The ML is the lowest value that can be reliably measured. It is generally the MDL multiplied by 3.18. When dealing with STORET, the phrase “lower quantitation limit” (LQL) can be considered a synonym for a ML.

Results cannot be reported for values less than the Method Detection Limit (MDL). Most MDLs are much lower than water quality standards and provide the rationale for confidence in the data. However some parameters, particularly nutrients, often have extremely low values in pristine waters. It is these water bodies that NPS hopes to keep clean and monitoring these requires an effective method for dealing with parameter values near detection limits of analytical procedures (Irwin 2004). Data values below an MDL will not be presented numerically. Data falling

between the MDL and minimum level of quantitation (ML) are considered “semi-quantitative” and can be presented as greater than zero. These semi-quantitative values will be handled according to Helsel (2005) consistent with the modernized STORET recommendation. Modernized STORET suggests not uploading into a database any value higher than the MDL but lower than the ML. Instead, the detection condition field is set to "Present, below Quantification Limit (PQL)". With that detection condition, STORET automatically enters "*Present <QL" in the result field. A major advantage of this approach is that no "estimates" are treated as quantitative when in fact they are not quantitative. In later statistical analyses these data between the two limits are best interpreted using either an interval-censored method (parametric), or a rank-based method (nonparametric) where all in-between values are represented as the same tied rank. Values above the PQL are classified in EPA's modernized STORET database with the detection condition of “Detected and Quantified” This is ideal, and according to EPA STORET Staff, this is optimally the only choice which permits reporting a single number (Irwin 2004).

Core Water Quality Parameters

The manufacturer specified measurement sensitivities (resolutions) for the YSI multi parameter sonde are given below:

Table SOP 15.3. Manufacturer-specified sensitivities for the YSI multiprobe.

Parameter	Accuracy	Resolution
Temperature	+/- 0.15 °C	0.01 °C
pH	+/- 0.2	0.01
Conductivity	+/- 0.5% of reading + 1 µs/cm	Range-dependent- 1 to 100 µs/cm
DO	+/- 1% of reading or 0.1 mg/L, whichever is greater	0.01 mg/L

However, manufacturer's claims for resolution specifications are not consistent and not necessarily good representations of instrument measurement sensitivity in harsh outdoor environments. Instead a measure known as Alternative Measurement Sensitivity Plus (AMS+) will be documented for each parameter as measured by each field instrument no less than twice a season (usually at the beginning and end of the field seasons).

AMS+ is a concept used to evaluate measurement sensitivity in an ambient condition such as a well mixed flowing stream. It is affected by instrument noise and natural heterogeneity, and is useful in the range of quantitative values where low level detection limits are not an issue. Seven repeated measurements are made in rapid succession in situ. AMS+ is then calculated as:

$$AMS+ = t \times s ,$$

where:

s = sample standard deviation of the 7 in-situ measurement values, and

t = 3.708, the 99% confidence middle (two-sided) t-value for a sample size of 7.

The result is functionally analogous to a ML but uses the two-sided (middle) t-value because we are not only interested in one side (distinguishing a value from zero) but in the two-sided issue of

how large of a difference between two individual values we can justify as actually being a true difference (from one another) rather than being due to measurement noise.

Like MDLs, AMS+ should be re-calculated when something significant in the measurement process changes or every sampling season at a minimum. For example, if the measuring instrument or the methods or SOPs change, recalculate AMS+ to see if measurement sensitivity has changed (Irwin 2008).

15.7.2 Measurement Precision

Water Chemistry

The precision of laboratory analysis is monitored by the laboratory performing the analysis. The most important measure of precision at low concentrations is the MDL, which is a measure of sensitivity and precision. The details of laboratory performance are presented in *SOP 14: Laboratory Analysis of Water Chemistry*.

MOJN staff will monitor laboratory precision by submitting field duplicate samples once each year. CCAL will analyze one field duplicate for each ten submitted samples free of charge, provided that they are informed beforehand that the sample is a duplicate, and afterwards which sample it was a duplicate of. The analytical results for the duplicate samples are compared using Relative Percent Difference (RPD). RPD is a less rigorous measure of repeatability than AMS or AMS+ (sample size 2 rather than 7), but it is used more frequently in assessing analytical laboratories, where the analysis of 7 duplicates is not economical. The RPD for each analyte is calculated as:

$$RPD = \left[\frac{S_1 - S_2}{(S_1 + S_2)/2} \right] \times 100 ,$$

where:

S_1 = the larger test result value, and
 S_2 = the smaller test result value.

Core Water Quality Parameters

As described above, AMS+ will be used to measure the sensitivity of core parameters. AMS+ is a measure of the precision of the measurements as well as their sensitivity, so the AMS+ MQO will be used to evaluate both the sensitivity and the precision of the core parameter measurements.

The precision of core water quality parameter measurements can also be evaluated by conducting a field stabilization check. When the probe is placed in the stream or lake, the fluctuations in measured parameter values are observed, and the ranges of the fluctuations are compared to the field stabilization criteria (Table SOP 15.4).

15.7.3 Bias

Systematic error/bias is the systematic or persistent distortion of a measurement process that causes errors in only one direction (either high or low). The bias of a measurement technique is evaluated by measuring a sample where the true value of the measured parameter is known. The avoidance of cumulative measurement bias is described in *SOP 16: Cumulative Measurement Bias*.

Water Chemistry

The analytical laboratory (CCAL) has an extensive set of QA/QC procedures to minimize measurement bias. These procedures include analyzing blanks, analyzing standards, and participating in the USGS Standard Reference Water Survey Program, an external interlaboratory QA Program. CCAL's Quality Assurance Plan is available online at <http://www.ccal.oregonstate.edu/pdf/QAP%20Final.pdf>.

If it is suspected that bias is being introduced into the samples through field procedures (e.g., contamination from filters, etc.), then a field blank can be submitted to the analytical laboratory. The laboratory should be consulted regarding the purity of the water required for the blank sample. The blank water should then be filtered, placed in a bottle, stored, and shipped using the same procedures and equipment used for sample water.

Core Water Quality Parameters

Bias in core water quality parameters is avoided by frequent calibration. Bias can be evaluated in pH, DO, and specific conductivity by measuring these parameters in the appropriate calibration standards immediately after calibration. The difference between the standard value and the measured value should be less than the field calibration check tolerance, or the instrument should be recalibrated. This process is described in *SOP 6: Handheld Water Quality Instruments* and *SOP 11: Continuous Water Quality Sonde*.

Bias in temperature readings can be assessed by comparing two or more NIST-certified thermometers across a range of temperature conditions. This test should be undertaken at least once a field season.

Table SOP 15.4. MQOs for field measurements.

Parameter	Instrument	PRECISION MQO	BIAS MQO	SENSITIVITY MQO
		Field Stabilization Criteria	Field Calibration Check Tolerance	Alternative measurement sensitivity (AMS+) ¹
Field pH	Sonde or handheld multiprobe	0.1	0.1	0.3
Field Dissolved Oxygen (mg/L)	Sonde or handheld multiprobe	0.3	0.3	0.4
Field Temperature (°C)	Sonde or handheld multiprobe	0.2	0.2 ²	0.3
Field Specific Conductance (µs/cm)	Sonde or handheld multiprobe	5 µs/cm or 3%, whichever is greater	5 µs/cm or 3%, whichever is greater	5 µs/cm or 3%, whichever is greater
Discharge by flowmeter				

1. AMS+ a measure of uncertainty (99% confidence interval) based on 7 in-situ measurements.

2. The "field calibration check" for temperature is actually performed in the laboratory once a field season.

Table SOP 15.5. MQOs for laboratory analyses.

Parameter	Method	PRECISION MQO	BIAS MQO	SENSITIVITY MQOs	
		Relative percent difference (RPD of duplicates) ¹	Blanks (field)	Method detection limit (MDL) ²	Minimum level of quantitation (ML) ³
Laboratory pH	APHA 4500 H	+/- 30%	N/A	N/A	N/A
Laboratory Specific Conductance (µS/cm)	APHA 2510	+/- 30%	N/A	0.4	1.3
Alkalinity (mg/L)	APHA 2320 with modifications ⁴	+/- 30%	< MDL	0.2	0.6
Chloride (mg/L)	APHA 4110 B	+/- 30%	< MDL	0.01	0.03
Sulfate (mg/L)	APHA 4110 B	+/- 30%	< MDL	0.02	0.06
Calcium (mg/L)	APHA 3111 D with modifications ⁴	+/- 30%	< MDL	0.06	0.019
Sodium (mg/L)	APHA 3111 B	+/- 30%	< MDL	0.01	0.03
Potassium (mg/L)	APHA 3111 B	+/- 30%	< MDL	0.03	0.10
Magnesium (mg/L)	APHA 3111 B	+/- 30%	< MDL	0.02	0.06
Nitrate+Nitrite (mg/L)	APHA 4500-NO3 F	+/- 30%	< MDL	0.001	0.003
Total nitrogen (mg/L)	APHA 4500-NO3 F	+/- 30%	< MDL	0.010	0.032
Total dissolved nitrogen (mg/L)	APHA 4500-NO3 F	+/- 30%	< MDL	0.010	0.032
Total phosphorus (mg/L)	APHA 4500-P F	+/- 30%	< MDL	0.002	0.006
Total dissolved phosphorus (mg/L)	APHA 4500-P F	+/- 30%	< MDL	0.002	0.006
Dissolved Organic Carbon (mg/L)	APHA 5310 B	+/- 30%	< MDL	0.05	0.16

1. RPD is the relative percent difference between two or more measurements calculated as a percentage. If specific RPD criteria are not provided by the laboratory, then an MQO of RPD < 30% will be used

2. Defined by National Environmental Methods Index (NEMI) as the lowest "measurable" concentration for an analyte by the specified method (http://web1.er.usgs.gov/nemi/field_def.jsp?method_field_name=DL_VALUE).

3. The ML is generally the MDL multiplied by 3.18.

4. Method modifications are described in SOP 14: Laboratory Analysis of Water Chemistry.

15.7.4 Measurement Quality Objectives for Discharge Measurements

The primary MQO for discharge measurements is the USGS measurement quality rating, which can be excellent (2 percent uncertainty), good (5 percent), fair (8 percent), or poor (more than 8 percent). These ratings are determined in the field based on a number of factors, such as hydraulic conditions, weather, the number of sections measured, or any other relevant conditions. Turnipseed and Sauer (2010), write:

“For instance, a measurement might be rated as excellent (2 percent) if (1) the cross section is smooth, firm, and uniform; (2) the velocity is smooth and evenly distributed; (3) the equipment is in good condition; (4) the two-point velocity measurement method was used; and (5) weather conditions are good (no wind or ice). On the other hand, if several of these factors make it difficult to accurately measure depth and (or) velocity, the measurement might be rated fair (8 percent), or even poor (more than 8 percent).”

The MQO for this protocol is a “good” measurement, implying a 5% uncertainty.

As described in Section 9.2, the floats method will be used for discharge measurements at high flows when the streams cannot be waded. Turnipseed and Sauer (2010) state that discharges measured by the floats method have a “best case” uncertainty of approximately 10%, with uncertainties of 25% or more for less ideal measurements. The MQO for this protocol is 15% uncertainty in floats measurements: that is, non-ideal conditions are acceptable, but very poor measurements are not.

One issue that can introduce bias into discharge records is the difference between crews. To minimize this bias, all technicians will be trained using the USGS On-Demand Web-stationed Training for discharge estimates (<http://pubs.usgs.gov/fs/2007/3099/>). Each crew will compare results with an experienced hydrologist or aquatic ecologist at least once after the training. In the event that measurements rated “good” are collected by both the experienced and inexperienced crew, the results should differ by 5% or less.

15.7.5 Measurement Quality Objectives for Secchi Depth

At this time, the Secchi disk is clearly visible on the bottom of all of the lakes. In the event that lake clarity is significantly degraded in the future, bias MQOs should be developed by comparing the Secchi depths between observers and precision MQOs should be developed by collecting AMS+ measurements.

15.7.6 Violation of Measurement Quality Objectives

The MQOs are designed to allow data comparability through space and time keeping in mind limitations of the sampling design when drawing conclusions. It is likely at times that some of the MQOs cannot be met. In these cases data must either be discarded or considered in isolation to avoid drawing misleading or erroneous conclusions. This is especially true near the detection limits for laboratory analyses and when evaluating data from different laboratory techniques that attempt to quantify the same parameter.

If measurements do not meet or exceed these criteria they will be discarded and re-runs for laboratory samples will be requested if possible. Appropriate measures will be taken to

determine the source of error so that future measurements will comply with these minimum requirements.

15.8 Training Requirements / Certification

Staff training is covered in *SOP 2: Staff Training*.

15.9 Documentation and Records

15.9.1 Field Data

Field sheets will be completed for all monitoring activities. At this time, paper copies of the forms are taken to the field for recording data, and pencil is used to record observations.

The data from the form or forms will be entered into electronic copies in the office. Quality control for completeness is determined by a visually scanning the entered data. At this point hard copy output is printed for archival purposes. Both the original paper forms used in the field and the completed forms printed after completing all data entry are stored indefinitely with the MOJN network.

A series of three rotating backups are made for all field data. Short term backups are made on the PC hard drive as data entry progresses. Daily backups are made on CD or flash drive when significant data entry occurs on any day, and an archival backup is made on CD after complete QC checks are made. Additionally, data are uploaded to the M-drive in LAKE periodically to serve as an off-site backup.

15.9.2 Laboratory Data

Both CCAL and the BMI laboratory (USU BugLab) used by MOJN submit electronic reports of their results. These files will be uploaded to the M-drive in the MOJN office as soon as they are received. In addition, a hard copy of each report will be printed out and kept on file in the MOJN office.

15.9.3 Data management

Data evaluation in the field is the responsibility of NPS personnel collecting data in the field. Likewise, hardcopy archive and interim digital backup are the responsibility of the individual scientists in charge of data collection for different cooperating groups within the MOJN. The MOJN aquatic ecologist and the MOJN data manager are jointly responsible for organizing and uploading data to MOJN and national databases.

15.9.4 Evaluation

Data evaluation for internal consistency, erroneous and quality control checks are the responsibility of the MOJN aquatic ecologist. After these quality control checks the MOJN aquatic ecologist will upload data to the MOJN-water database. Having one person responsible for this step will ensure consistency in a final quality control check before data is uploaded to WRD STORET and eventually EPA STORET. Additionally, this will provide consistency in reporting values near detection and quantitation limits.

15.9.5 Reporting

The MOJN aquatic ecologist with the help of park personnel and the MOJN data manager is responsible for annual reports, multi-year comprehensive analysis and reporting, and

coordination with laboratories and MOJN data manager to ensure data integrity and archive. These reports are described in *SOP 17: Data Analysis and Reporting*.

15.10 Sampling Process Design

15.10.1 Program design

The MOJN monitoring program is designed to monitor surface water quality and dynamics in the streams and lakes of GRBA. Section 2 of the monitoring protocol narrative has more information about the process of monitoring program development.

15.10.2 Type, frequency and timing of sample collection

As described in section 2 of the monitoring protocol narrative, the type of data collected was determined based on the objectives of the program. The frequency of data collection was determined by balancing the data needed to answer the monitoring questions with the resources available. The timing of data collection was restricted to the summer months for all parameters but discharge and lake level by the lack of winter access to many sites and the possibility of losing water quality sondes during spring runoff.

15.10.3 Sample site selection

Stream Discharge and Stream Core Parameters

For scientific reasons as well as legal reasons, it is desirable to know the stream discharge at the point that the streams leave the park. Therefore, discharge will be measured at or near the park boundary, at sites previously established by the USGS for this purpose.

Stream core parameters will be collected continuously near the discharge-measurement sites because variations in flow must be considered in interpreting records of water quality parameters.

Stream Benthic Macroinvertebrates and Water Chemistry

The BMI-sampling site for each stream was selected randomly, although some sites were rejected as unsuitable because of extremely low summer flows or access concerns. The water chemistry samples will be co-collected with the BMI samples so that both data sets can be considered simultaneously in assessing any potential water quality degradation.

Lake Level and Temperature

The pressure and temperature data loggers will be installed in each lake at locations that are sufficiently deep that the loggers remain submerged when the lakes are at their lowest levels.

Lake Core Parameters and Clarity

The depth profiles of core parameters will be collected near the deepest point of each lake so that the greatest possible variations in water quality are observed. The Secchi depth measurements will also be collected near the deepest point of each lake to provide the maximum sensitivity to any decrease in water clarity. The water chemistry samples will be co-collected with these data.

15.10.4 Sampling constraints

Many of the sampling sites in GRBA are reached by hikes of more than 2 hours, and many of the sites are more than 3,000 meters above sea level. Weather and unanticipated problems including unsafe travel and sampling conditions may preclude the completion of the data collection

activities outlined in the protocol. Therefore, completeness goals have been set for a minimum of 75% for remote sites. It is anticipated that the completeness for easily accessible sites will approach 100%, providing continuous long term records for some sites.

Williams Creek will not be sampled due to access difficulties. A section of Snake Creek that runs through a steep-walled canyon was also removed from consideration in selecting random sample locations.

Safety considerations and emergency contacts are listed in *SOP 1: Safety*.

15.11 Sampling Methods Requirements

Sampling and measurement techniques are discussed in *SOP 9: Stream Discharge*, *SOP 10: Lakes Field Procedures*, *SOP 11: Continuous Water Quality Sonde*, and *SOP 12: Stream Chemistry and BMI Sampling*.

15.12 Sample Handling and Custody Requirements

Details of sample handling, storage, shipping, and custody requirements are described in *SOP 7: Sample Handling, Storage, and Shipping*.

15.13 Analytical Methods Requirements

The laboratory methods used to analyze the benthic macroinvertebrate samples are described in *SOP 13: Laboratory Analysis of BMI*. The laboratory methods used to analyze water samples are described in *SOP 14: Laboratory Analysis of Water Chemistry*.

15.14 Quality Control Requirements

Quality control for precision and accuracy of both field and laboratory measurement has been addressed in section 15.7 of this document.

15.15 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Preparation of equipment for field work and its care and handling are discussed in *SOP 3: Field Season Preparations* and *SOP 4: Post-Season Activities*, as well as in the user manuals.

15.16 Instrument Calibration and Frequency

As described in *SOP 6: Handheld Water Quality Instruments* and *SOP 11: Continuous Water Quality Sonde*, field instruments are checked for integrity and calibrated at each site prior to collecting data.

15.17 Inspection/Acceptance Requirements for Supplies

All reagents and standards are National Institutes of Standards and Technology (NIST) traceable and measurement instrumentation meets NPS WRD and USGS specifications. It is the responsibility of each field crew leader to order new supplies of consumables and replacement parts as necessary at the end of each sampling run so that adequate supplies within their expiration date are on hand for the next monthly sampling run.

15.18 Data Acquisition Requirements

A field sheet is completed each time field data are collected. These field sheets are shown in *SOP 9: Stream Discharge*, *SOP 10: Lakes Field Procedures*, *SOP 11: Continuous Water Quality*

Sonde, and *SOP 12: Stream Chemistry and BMI Sampling*. Electronic versions of the field sheets are included in the *Supplementary Materials*.

15.19 Data Management

Data management is addressed in *SOP 18: Database Design* and *SOP 19: Information Workflow and Tasks*, and the MOJN Data Management SOPs included in the *Supplementary Materials*.

15.20 Assessment and Response Actions

Evaluation of field, lab and data management activities of cooperating groups within the MOJN will be a routine and on-going responsibility of the MOJN aquatic ecologist as data “round-up” progresses.

The MOJN aquatic ecologist will be responsible for checking completeness and internal consistency of the collected data. It will be up to the MOJN aquatic ecologist to follow-up and determine if errors can be corrected, or if data should be discarded.

Analytical data from the Class A streams in GRBA must be compared to Nevada standards (given in *SOP 8: Regulatory Status*). In addition, the MOJN aquatic ecologist must determine whether trends in stream chemistry meet the anti-degradation requirements of the Clean Water Act.

15.21 Reports

Reporting is discussed in *SOP 17: Data Analysis and Reporting*.

15.22 Data Validation and Verification Requirements

MOJN will verify and validate all data as detailed in the protocol (Section 4), NPS National Data Management Plan (2008), and MOJN Data and Information Management Plan (Chung-MacCoubrey et al. 2008).

15.22.1 Verification

Data verification is the process of ensuring that the values measured in the field or lab are correctly transcribed onto the field sheet and into the database.

In the field, care should be taken to ensure that all numbers are transcribed accurately. Typically, one crew member takes measurements and calls out the values to another crew member, who writes them on the field sheet. The crew member writing down the number should ensure that the measurements are not being made too quickly for accurate transcription, and should have the measuring crew member repeat herself if necessary.

The next possible source of recording error is in entering lab and field data into the database. Care should be taken during this step to avoid transcription errors, and all entered data should be reviewed by a staff member who did not enter the data.

Once the data has been reviewed for data entry errors, a member of the MOJN data management team performs checks on bounds and internal consistency. Other checks that occur at this stage include ensuring that data,

- a. contain all required fields,

- b. have encoded valid values from constrained look-up lists where specified, and
- c. are in the correct format (text in text fields and values in numeric fields, etc.).

15.22.2 Validation

Data validation is the process of ensuring that the measurements made and entered in the database are true measurements of the parameters in question rather than the product of mistakes in the field, instrument malfunctions, or other spurious occurrences.

Review of data as it is collected in the field is paramount to successfully collecting representative field data. The test for “representativeness” is based on the reported range of previously-measured values for the site and professional judgment. All field data must meet the MQOs listed in Table SOP 15.4. Corrective measures to ensure un-biased and precise measurement of core parameters can only be made while the operator is in the field.

The testing laboratories screen their results for spurious values before sending data to the MOJN. Prompt review (< 7 days after receipt of data) of laboratory data by the protocol lead is critical to ensure re-runs are possible before samples are discarded or mature beyond their holding times. The MOJN hydrologist will conduct an internal review of laboratory results as they are received from the laboratory that includes the following:

- Comparison of duplicate samples using a 10% threshold for further investigation.
- Screen all the blanks and audit standards, and require lab to respond to every inconsistent result.
- Compare dissolved P and N to total P and N (dissolved should be less than or equal to total).

Data validation is most difficult for remotely-collected data such as continuous water quality data, because there are no field personnel present to determine whether unusual values result from unusual conditions or problems with the instrument. The instrument performance checks at the end of each two week deployment (Table SOP 11.1) can be used to detect poor-quality records, but they will not record if, for example, the instrument was above water for two hours. Data validation decisions should be made by the protocol lead based on their knowledge of the natural variability of GRBA streams and their professional judgment. Some examples of data that should be discarded are given in Section 17.2.4.

Numerous checks on data quality will be made as data are analyzed in the analysis and reporting phase. Often subtle trends or occasional erroneous data are not detected until examined in context with other data collected from a site in the form of graphs, and tables. At this stage it is the collective responsibility of all cooperating personnel to track down potential sources of error and make corrections where appropriate and flag the data to document the changes. However, no data will be removed from the database unless a compelling and rational reason exists to explain why it should be removed.

At any point in the data collection and review process the MOJN Hydrologist can make decisions to discard or flag data that they know is not representative.

15.22.3 Reconciliation with Data Quality Objectives

To ensure data collection, compilation, and review meet the project objectives, the annual report preparation will include an evaluation of the data with respect to the DQOs and MQOs discussed in Sections 15.6 and 15.7. In addition, the effectiveness and completeness of the monitoring activities will be evaluated.

Effectiveness, E will be calculated as

$$E = (U / N) \times 100 ,$$

where:

U = number of usable parameter values, and

N = number of parameter values collected, including low-quality data that cannot be used in future analyses.

Completeness C, will be calculated as

$$C = (U / P) \times 100 ,$$

where:

U = number of usable parameter values, and

P = number of potential parameter values that would have been collected had the field season proceeded as envisioned in the sampling plan.

These results will be used to make corrective actions that will improve the quality and efficiency of data collection where necessary.

15.23 Version Information

Table SOP 15.6. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 16. Cumulative Measurement Bias

16.1 Introduction

[*This SOP was adapted and expanded from Thoma et al. 2009.*]

This is a long term monitoring program and as such it is expected that field personnel, instruments, field methods, and laboratory analytical methods. It is extremely important to quantify the effect that change in these factors may have on data so to ensure that data comparability proceeds through the life of the monitoring program and beyond. This SOP outlines the major types of change, and how changes can be mitigated to ensure change detection is due to environmental conditions rather than observer, sensor or methodology.

16.2 Changes in Personnel

Observer variability needs to be controlled because although most of the water quality measurements are made with electronic instruments, the exact location of a monitoring and sampling site is somewhat subjective. Therefore, there is the potential for bias in selecting where measurements are made.

The seasonal field crews used by the network will change from season to season, and possibly from sampling event to sampling event, with no opportunity to compare the measurements between crews at the same site at the same time. Therefore, the GRBA aquatic ecologist and the protocol lead must closely supervise the training of these crews (*SOP 2: Staff Training*) to minimize the differences in field technique between crews.

Cumulative bias could also be created by turnover in the MOJN and GRBA aquatic ecologist positions. Ideally, this bias would be evaluated by having the outgoing and incoming ecologists make duplicate measurements and collect duplicate samples. The number of duplicates for each data type should be determined by the magnitude of the effect of differences between observers, the ease with which measurements can be collected, and the cost of sample analysis. However, there may not be a period of overlapping employment for the outgoing and incoming ecologists. For this reason, it is important that the SOPs describe the field procedures in detail, and that the MOJN and GRBA ecologists update the SOPs to reflect any changes in procedure.

When the only change is in personnel, a minimum of seven paired measurements should be made on the same object or sample by each observer. To ensure the highest possible degree of repeatability, readings should be taken close together in both space and time.

16.3 Replacement of Instruments

Changing instruments and sensors over time introduces the potential for bias, even when they are calibrated using the same standards. For instance, pH probes may have different algorithms for temperature compensation.

When the only change is in instrument or sensor a minimum of 30 measurements will be made on the same object or sample with each instrument. Sonde measurements should be made in containerized samples to avoid natural variation. DO measurements should be made in an

agitated sample to avoid oxygen consumption at the sensor tip if using a polarographic-type sensor.

16.4 Changes in Field Methods

Changes in field methods may be necessary as new techniques are developed that prove to be superior to older techniques. Rather than use inferior techniques for the sake of continuity, this monitoring program will adopt new methods while taking the appropriate precautions to avoid cumulative bias.

It should always be possible to collect paired measurements using the old and new methods. The number of duplicates should be determined by the magnitude of the effect of the change in methods (as determined from the first few paired measurements), the ease with which measurements can be collected, and the cost of sample analysis. If possible, at least 50 paired measurements will be made. More measurements are necessary when indicators (as opposed to measured parameters) change because very few indicators respond in exactly the same way to environmental stimuli. The more complex the relationship between the measured value and what it is intended to represent the more measurements need to be made to ensure data from the two indicators or methods can be compared through time.

16.5 Changes in Laboratory Methods

The MOJN Streams and lakes protocol uses outside labs for chemical analyses and benthic macroinvertebrate enumeration.

16.5.1 Chemical Analysis

Analytical laboratories have procedures in place to avoid the introduction of long term bias, including interlaboratory comparisons, comparisons between technicians, and frequent calibration of instruments. In the event that the testing laboratory replaces its instruments or changes its SOPs, the laboratory is responsible for avoiding cumulative bias. The protocol lead should discuss whether any changes have occurred at the laboratory at the beginning of the field season.

Over the course of the sampling program, it may be necessary to switch laboratories. In the event of a change, MOJN will attempt to have both laboratories analyze split samples, preferably for an entire field season. If the same procedures are used by both laboratories, and both laboratories participate in rigorous external QA/QC programs, then the differences may be minimal. If different analytical methods are used, the literature should be reviewed for any comparisons of the two methods. In any case, all current and historical laboratory procedures used to analyze MOJN samples should be included in the Supplementary Materials.

16.5.2 Taxonomic Identification

BMI data are generated by laboratory staff identifying and counting insect specimens. Experience has shown that the way these specimens are identified can drift over time, as personnel change and the science moves forward. The laboratory used by MOJN (the USU BugLab) follows internal QA/QC procedures to attempt to minimize this drift. However, over the long term, the key to avoiding bias in BMI samples is archiving. MOJN's BMI specimens are on long-term loan to the USU BugLab, who will properly archive the samples so that they are preserved indefinitely. As a result, any questions of cumulative bias in taxonomic identification

can be resolved by having future laboratory staff “re-identify” the sample. The protocol lead may wish to have the BugLab re-run samples if significant trends in BMI indices are observed over a period of decades.

A change in BMI laboratories should be avoided because of the convenience of having all past samples archived in the same location. However, if a change becomes necessary, then MOJN should arrange to have both laboratories analyze split samples, preferably for an entire field season.

16.6 Statistical Analysis of Paired Measurements

As noted above, paired measurements will be made whenever possible to avoid cumulative bias.

These measurements may involve changes in instruments, observers, methods, or indicators. In this section, “methods” will be used as shorthand for all of these possible changes.

16.6.1 Detecting Changes in Precision

Precision refers to how closely individual measurements agree with one another. Ideally, repeated measures made using the same method on the same sample will be very similar.

Precision will be assessed using the standard deviation of repeated measures of a normal environmental sample. Standard deviation is a measure of the amount by which estimates in a distribution differ from the mean of measured values. It can be calculated using any statistical software package or Microsoft Excel.

When a set of paired measurements is made in such a way that seven or more measurements are taken on a single sample, the standard deviations for each method should be reported in section 16.8 of this SOP. For laboratory analyses, laboratory-provided estimates of measurement precision may be used in lieu of having the same sample analyzed seven times by two labs.

16.6.2 Detecting Changes in Sensitivity

We measure sensitivity via an estimate of measurement precision expanded uncertainty (MPEU). Measurement sensitivity will be evaluated by analysis of repeated measures of a normal environmental sample. This is essentially an estimate of precision but in a more rigorous sense based on a confidence interval. It differs from AMS+ (section 7.4) in that MPEU samples are made in a bucket, while AMS+ measurements are made in situ.

MPEU is calculated as:

$$\text{MPEU} = t * \text{sd}_n ,$$

where t = the 99% confidence middle t value for sample size n , and

sd_n = standard deviation of n replicate samples on a normal environmental sample.

When a set of paired measurements is made in such a way that seven or more measurements are taken on a single sample, the MPEU for each method should be reported in section 16.8 of this SOP.

16.6.3 Detecting Measurement Bias

Measurement bias is a systematic difference between measurements made using different methods. Several methods may be used to detect measurement bias.

Significance Test

A significance test can be used if multiple measurements (7 or more) are made using both methods on a single sample. A t-test is performed to determine if the two sets of measurements came from the same population with the same mean. The t-test may be performed using any statistical software package or Microsoft Excel. While this test may be used to detect bias, it cannot be used to adjust data, as the level of bias at different parameter values is not explored.

Percent Difference

Percent difference is a measure of how different two measurements are expressed relative to the first measurement:

$$PD = ((q_2 - q_1) / q_1) * 100 \text{ ,}$$

where q_1 = method 1 measurement value, and

q_2 = method 2 measurement value.

If only a small number of data pairs are available, then PD can be used to qualitatively assess bias. In particular, if the PD values are predominantly positive or negative then a large bias may be present.

If a large number of data pairs are available, then the standard deviation and 95% confidence interval of the PD values should be calculated. If the 95% confidence interval does not include 0, then the bias is statistically significant. However, the sign of the bias may change in different parameter ranges (e.g., sensor 1 may record higher pH values than sensor 2 in acidic environments but lower pH values than sensor 2 in basic environments). In this case, the distribution of PD values would include zero, so 95% confidence interval test described above would not detect the bias, and slope determination should be used.

Slope Determination

A full evaluation of bias requires the collection of paired measurements collected on different samples with a wide range of parameter values. These measurements will be plotted against each other, and a best-fit line will be calculated using any statistical software package or Microsoft Excel. Ideally, this best fit line would have a slope of one and an intercept of zero. Any statistically-significant deviation from these values is an indication of measurement bias that must be corrected for the analysis of long-term trends (Section 16.7).

16.7 Adjusting Data to Correct for Cumulative Bias

When bias is detected, the preferred response is to adjust the laboratory method, instrument settings, or observer behavior to eliminate the bias. However, if these adjustments cannot be made, then the data must be adjusted prior to trend analysis. These adjustments are for the purposes of detecting long term trends only. Corrected data should never be recorded on a field sheet or uploaded to a database.

In general, data adjustments should be made at the time of trend analysis so that the authors of the trend analysis report have a complete understanding of all of the corrections that have been performed.

16.7.1 Before making adjustments

Before making adjustments to raw data a careful evaluation of the statistical results needs to be made in light of how the test was conducted. The offset, bias, slope, t-test, bias, percent difference and sample size calculations are more meaningful when the test includes multiple streams. This type of test is more meaningful because it provides information about how the two observers, instruments or techniques compare across the expected range in field conditions. Without paired observations collected in multiple streams or lakes (or perhaps multiple calibration standards) the data should not be adjusted.

Insufficient sample sizes result in data that are difficult to interpret. A way to ensure sufficient sample size is to conduct paired evaluations until the 95% confidence value (expressed as a percent difference) drops below 20% of either the old or new mean. In other words, if the 95% confidence value (1/2 the CI range) is greater than 20% of either the old or new mean then the number of paired measurements should be increased after all other sources of variation have been controlled.

16.7.2 Making adjustments

After determining that the means are not equal it is possible to adjust results collected with one method or instrument to correspond to results collected with another method or instrument by subtracting the measurement effects. In general, older data will be adjusted so that they are comparable to newer data. In some situations (e.g., if many years of data have been collected with the older method) it may be appropriate to adjust the newer data so that they are comparable to the older data. After adjustment temporal differences should only result from natural effects.

- a) In Excel plot new method results on X-axis and old method results on Y-axis.
- b) Determine the equation for the regression line.
- c) Right click on a data point and click add trend line.
- d) Make type be linear and under options select display equation and R-square value on chart.
- e) Adjust data using the equation displayed on the chart.

16.7.3 Documentation

If adjustments are made they need to be carefully documented. It is exceedingly important that the original raw data and paired data be retained so that in the future evaluations can be made using other techniques. All adjustments made, along with any paired data used to evaluate cumulative bias, should be added to section 16.8, below. Additionally, if data in any database are

adjusted a permanent record of the adjustment should be kept with the data in the comments field explaining why and how the adjustment was made.

16.8 Record of Paired Measurements Made to Control Bias

All paired measurements made for the purposes of bias control will be recorded in this section, along with any statistical analyses performed on them. In the event that paired sets of large continuous data sets are collected, it is appropriate to record only the summary statistics in this section.

16.8.1 Change in Laboratory Phosphorus Measurements

In 2010, CCAL began the transition to a new method of phosphorus analysis. CCAL used manual spectrophotometry (Method 4500-P E) for TP and TDP analyses of MOJN's 2009 samples. Going forward, automated spectrophotometry (Method 4500-P F) will be used. In 2010, MOJN had the lab perform both types of analyses on Streams and lakes protocol samples. The paired measurements are shown in Table SOP 16.1. In general, the concentrations measured with the new method are slightly lower than the concentrations produced by the old method with an average difference (new – old) of -0.0054 mg/L and a standard deviation of 0.004 mg/L. However, the data appear to indicate that the offset varies linearly as a function of P concentration (Figure SOP 16.1), with separate linear trends for the streams and the lakes. If future workers wish to include the 2009 P concentrations in trend analyses, then a correction will be required.

Table SOP 16.1. CCAL measurements of phosphorus made using the old method (manual) and the new method (AutoAnalyzer).

	TP- New (mg/L)	TP- Old (mg/L)	TDP- New (mg/L)	TDP- Old (mg/L)
Baker Creek	0.008	0.017	0.009	0.019
Baker Lake	0.033	0.036	0.026	0.029
Brown Lake	0.015	0.016	0.009	0.011
Dead Lake	0.051	0.057	0.039	0.044
Johnson Lake	0.009	0.008	0.008	0.008
Lehman Creek	0.010	0.013	0.007	0.011
Mill Creek	0.024	0.039	0.019	0.030
Pine Creek	0.015	0.020	0.012	0.018
Ridge Creek	0.020	0.031	0.016	0.023
Shingle Creek	0.010	0.018	0.009	0.015
Snake Creek	0.007	0.017	0.005	0.012
South Fork Big Wash	0.002	0.007	0.003	0.007
Stella Lake	0.011	0.009	0.007	0.008
Strawberry Creek	0.020	0.029	0.013	0.020
Teresa Lake	0.054	0.058	0.035	0.037

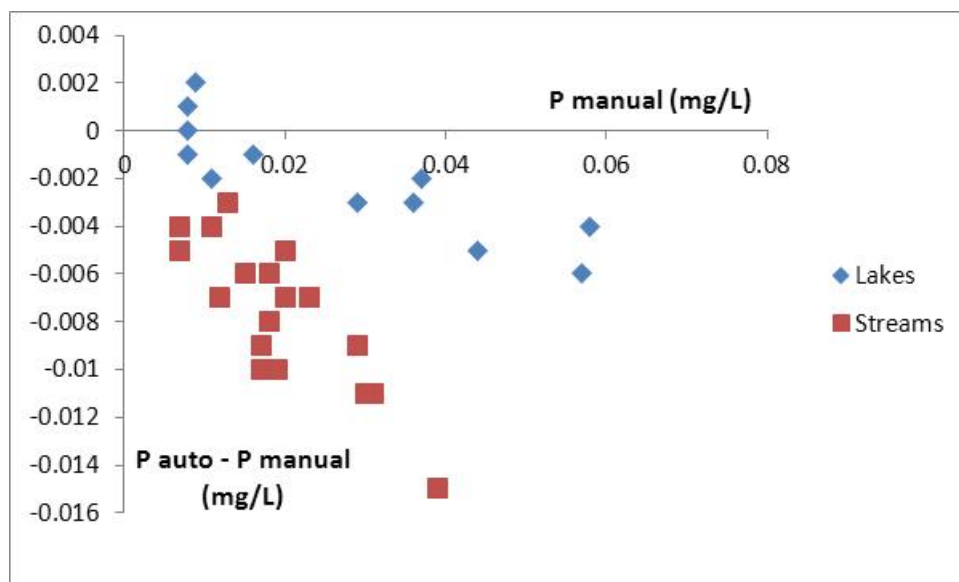


Figure SOP 16.1. Difference between P concentrations measured with the new method (P auto) and the old method (P manual) as a function of P concentrations for streams and lakes in 2010.

16.9 Version Information

Table SOP 16.2. Version Information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 17. Data Analysis and Reporting

17.1 Overview

This SOP describes the analytical procedures necessary to process and interpret water quality and quantity data collected in the field and reported by laboratories. In addition to the analyses for each type of data, this SOP also presents how the data should be reported and how long term trends will be detected in the data following five years of data collection.

At the conclusion of each field season, the Protocol Lead has the following data analysis and reporting responsibilities:

- Process the continuous water quality data using the Aquarius software package and generate summary statistics and figures
- Process the stream discharge data using the Aquarius software package and generate summary statistics and figures (currently, these data are currently handled by an outside scientist, but MOJN will take over responsibility when requested to by GRBA and WRD)
- Process the lake level records using the HOBOWare software package, and estimate ice-over and ice-out dates for each lake based on the lake level and temperature records. Generate figures and summary tables based on the results
- Review the discrete water quality measurements, water chemistry laboratory results, and BMI laboratory results and prepare summary tables
- Prepare the annual report

In addition, the protocol lead is responsible for performing trend analyses and preparing a trend analysis report every four years. The first report will be prepared after the 2013 field season.

17.2 Continuous Records of Core Water Quality Parameters

[The procedures outlined in this section are adapted from Starkey et al. 2009]

The core water quality parameters identified by the NPS WRD are dissolved oxygen (DO), specific conductance (SpCond), temperature (T), and pH. In addition to specific conductance, the WRD requires that raw conductivity be collected because field instruments use different internal algorithms to calculate SpCond from raw conductivity. Continuous records of these parameters will be collected in the four second-order streams and analyzed using the Aquarius software package.

17.2.1 Introduction to Aquarius Software

The MOJN will be using the Aquarius Workstation version of the software, with the Data QA value pack and the Rating Curve value pack. Aquarius uses a graphical user interface in which a series of toolboxes can be dragged onto the workspace (whiteboard) and connected to each other or wired together in a variety of ways. The basic data processing steps needed to take the water quality data from raw files to reporting products are briefly described in this section. For an in-depth discussion of all of the options in each toolbox, please consult the Aquarius user manual.

17.2.2 General Whiteboard/Workflow Setup

The MOJN will develop a standardized whiteboard or workflow to process continuous water quality records. Separate copies of the whiteboard will be needed for each parameter in each monitored stream, for a total of 20 whiteboards. Each whiteboard should have the following components:

- One copy of the “Import from File” toolbox, the “Data Correction” toolbox, and the “Data Grading” toolbox for each data file downloaded during the field season. The whiteboard should be able to accommodate up to 12 input files.

- A copy of the “Signal Joining” toolbox to join the separate data files into a single, season-long record.

- A copy of the “Threshold Flagging” toolbox to compare the data to regulatory standards. This toolbox is not required for specific conductivity or raw conductivity.

- Copies of the “Quick View” toolbox and “Descriptive Statistics” toolbox for visualization and reporting.

The raw data from each 2-3 week deployment period should be imported, corrected (if necessary), and graded immediately after the files are downloaded so that any problems are detected as soon as possible. The signals can be joined, compared to regulatory thresholds, graphed, and statistically summarized at the time of processes and analyses.

17.2.3 Importing from a File

When the sonde is re-deployed it is important that the log file be configured in a consistent format. Consistent formatting will greatly reduce the time and effort required to successfully import data to Aquarius. The format used by MOJN is described in the *SOP 11: Continuous Water Quality Sonde*. Note that the same configuration file will be used to import each parameter.

1. If you have an existing input configuration file, skip to Step 7. Double click the top most “Import from file” toolbox. An Import from File Toolbox window will appear. Click “Load,” then select the log file (.txt) for the deployment period you wish to process.

2. The “Import from File Wizard” should appear. Make sure the “Time Series” radio button is selected. Click “Next.”

3. The “Import from File Wizard” step 2 window should appear. In this step you will need to specify what Aquarius should import and what should be ignored. First, change the “Start import at row” field to 14 this will eliminate the miscellaneous header rows. Note that the number of headers may vary with different multiprobe manufactures. Next, add 2 quotation marks (“”) to the “Character(s) to discard” field. Make sure the delimiter is set as Comma. Click “Next.”

4. The “Import from File Wizard” step 3 window should appear. In this step you define what each column of data means, and eliminate columns without data. Select Column 1-Date. The Date/Time field should now be active, click the radio button next to “Date/Time”. Enter or select the correct format for the date (mm/dd/yyyy). Next, select Column 2–Time. Again, the

Date/Time field should be active. Enter or select the correct time format (HH:MM:SS). Notice that time designations use capital letters while the date uses lower case. Select columns with missing data or data that will never be used for analysis or QA/QC. After selecting a column you do not wish to import, select the “Do not import column (skip)” radio button. If you are unsure if a column will be useful, it is better to go ahead and import it. You can discard extra columns later. If you have skipped a column and wish to undo your selection, highlight the skipped column and select “Data.” Notice that this window also allows you to edit the name and the units of each column. It is especially important to delete characters that may have been added to your units (e.g., if the temperature units are displayed as “ $^{\circ}\text{C}$ ”, delete “ $^{\circ}$ ”). ***The configuration done in this step is very important since it will simplify future data importing.*** Click “Next.”

5. The “Import from File Wizard” step 4 window should appear. In this window you will be given the option to save your configuration for future use. If you save your configuration you won’t need to complete the setup procedure each time you import data. Check the “Save Configuration” box. Name the configuration YSI_MMDDYY_Config.cfg, where MMDDYY is the date the file was created. As long as the sonde is programmed to create data files with same format at each deployment, this log file can be used to quickly import data. Click “Finish.”

6. You will now see the original “Import from File Toolbox” except the “Output ports” field has been populated. These are the parameters you selected to import. Given that we are processing our data parameter by parameter you should delete any ports that are not of interest. To delete ports select the port and press <Delete> on the keyboard. You can also re-arrange these ports to make wiring the toolboxes less cluttered. It is recommended to keep the parameter of interest, and either the % Internal Battery or Internal Battery Volts output ports. Battery measures will help you determine when a sensor stopped working due to low battery power. If you accidentally delete the parameter port you needed you must completely re-load the data. This should not be a problem if you saved the configuration file. See the next section to re-load your data with a configuration file. Click “Done.”

7. *Import from File Using an Existing Configuration (Skip if you have just created a new file).* Double click on the “Import from File” toolbox. In the “Import from File Toolbox,” under the “Use batch import configuration file” heading click “Browse”. Navigate to the configuration file that corresponds to the data you are importing (see previous section). Note that there should be a unique configuration file for each multiprobe/stream. Click “Open,” then “Load.” Then select the log file (.txt) for the deployment period you wish to process. You will now see the original “Import from File Toolbox” except the “Output ports” field has been populated. These are the parameters you selected to import. Given that we are processing our data parameter by parameter you should delete any ports that are not of interest. To delete ports select the port and press <Delete> on the keyboard. You can also re-arrange these ports to make wiring the toolboxes less cluttered. It is recommended to keep the parameter of interest, and either the % Internal Battery or Internal Battery Volts output ports. Battery measures will help you determine when a sensor stopped working due to low battery power. If you accidentally delete the parameter port you needed you must completely re-load the data.

17.2.4 Data Corrections

The “Data Corrections” toolbox will be used to delete erroneous data and data affected by declining battery voltage and to apply linear corrections to data affected by calibration drift or

fouling. To complete data corrections you should have prior knowledge about the deployment location (i.e., discharge, weather, basin geology, etc.). This knowledge will allow you to interpret the data and look for false spikes/outliners versus real spikes. Some parameters may be interpreted more easily by looking at several parameters simultaneously (i.e., dissolved oxygen, water temperature).

Removal of spikes and corrections relies heavily on professional judgment, and should only be carried out by the protocol lead. The need for corrections can be determined by the various checks performed in the field. Spikes or other sections of unusual data should not be removed unless there is strong evidence that they are erroneous. Some examples of clearly erroneous data are:

- data collected when there is a record of very low battery levels,
- a large increase in specific conductivity suggesting that the instrument is above water,
- large-reading-to-reading swings for an extended period that indicate instrument malfunction, or
- physically impossible or extremely unlikely values, such as stream pH values below 4 or temperatures above 40 °C.

If there is any doubt about the validity of the data, it is best to leave it in the dataset, as the most interesting data points recorded may be those outside of the typical range.

1. After successfully loading one parameter and % battery, the graphical representation of the “Import from File” toolbox should have two triangular output ports. Click on the first output port (►) and drag a wire to the Input Port on the “Data Correction” toolbox. Next, connect the second output port (should be % battery) to the Surrogate Signal Input Port labeled with an “O.” You can tell which output port is which by placing the mouse cursor over the port and waiting for several seconds to see a dialog box that describes the data. The imported data is now connected to the Correction Toolbox.

2. Double click on the “Data Correction” Toolbox. You will see the Data Correction Toolbox window and a graph of the loaded parameter, along with the surrogate signal. Next, you should look at your data and determine if there are any erroneous data (described above) . Typically as % battery approaches zero the sensor stops reading correctly and/or gives values of zero. Any erroneous data should be removed using the “Data Correction” toolbox. The “Signal Trimming Toolbox” (not described in this SOP) can also be used.

3. *To remove erroneous data (if not necessary, skip to step 5):* Use the “Mark Region” (green highlighter) icon from the toolbar to highlight the section of data you wish to remove. Double check you have selected the correct region. It is useful to zoom in on the specific segment you want to remove. Click the “Delete Region” icon (green highlighter and eraser) on the toolbar.

4. Fill out the “Delete Marked Region” window. Make sure to add a comment describing the reason you have removed the data. This comment can be added to the list for future use. If you

have already added comments to the list they can be selected from the pull down menu. All deletions/corrections are logged in the correction history manager and will remain with the data in the Master Database. If you have made an error these deletions can be un-done from the correction history manager. Reasons for deletion might include a low battery, sensor spikes, etc.

5. The “fouling error for a data set is the difference between the parameter values measured in the stream before and after the sensors are cleaned. The calibration drift is the difference between the parameter values measured after cleaning and the parameter values measured after calibration. The total error is the sum of the magnitudes of the fouling error and the calibration drift. If the total error is greater than the relevant criterion in Table SOP 17.1, then drift and fouling corrections must be applied. Click the “Mark Region” icon (green highlighter) from the toolbar and select the entire time period. Next, type the correction values into the “Drift Correction” fields in the corrections control panel on the left side of the screen. Notice that there are separate fields for drift and fouling corrections. Make sure to include a negative sign if necessary. Click “Apply.” The “Apply Correction” window will appear. Click “OK.” You will now see a second signal within the graph, this is the corrected data.

6. After double checking that all corrections have been made, click the “Save data to output ports and exit” icon (disk and red power symbol) from the toolbar.

Table SOP 17.1. Data correction criteria. Taken from Wagner et al. (2006).

Measured Parameter	Data Correction Criterion (sum of the magnitude of the calibration drift and the fouling error)
Temperature	± 0.2 °C
Specific Conductivity	± 5 mS/cm or 3% of measured value, whichever is greater
Dissolved Oxygen	± 0.3 mg/L or $\leq \pm 5\%$, whichever is greater
pH	± 0.2 units

17.2.5. Data Grading

The USGS has established standards for data grades for continuous water quality data. Data are graded as “Excellent,” “Good,” “Fair,” or “Poor” based on the amount of instrument drift and fouling error experienced during the deployment period. These grades are assigned to the data using the “Data Grading” toolbox.

1. Wire the “Data Correction” toolbox output port to the “Data Grading” toolbox time series input port (top). Double click the “Data Grading Toolbox.”
2. Select the “USGS data grading option” from the pull down menu on the toolbar.
3. Click the “Add Grading Visually” icon (an A+ and a mouse pointer on top of green, yellow, orange, and red bars) on the toolbar, then highlight the entire period of record (entire deployment).

4. The “Add/Edit Data Grades” window will appear. Add any necessary comments in the field, and select the appropriate data grade from the drop down menu. These data grades are listed on the Site Inspection Summary worksheet and are based on the USGS rating criteria found in Wagner et al. 2006 and in Table SOP 17.2. Click “Add.”

5. After double checking the data grade click the “Save data to output ports and exit” icon (disk and red power symbol) from the toolbar. You should now have one active output port on the Data Grading Toolbox.

Table SOP 17.2. Data grading criteria. Taken from Wagner et al. (2006).

Measured Parameter	Data Grading Criteria (Based on Drift Correction Applied to Record)			
	Excellent	Good	Fair	Poor
Temperature	$\leq \pm 0.2$ °C	± 0.2 - 0.5 °C	± 0.5 - 0.8 °C	$> \pm 0.8$ °C
Specific Conductivity	$\leq \pm 3\%$	± 3 - 10%	± 10 - 15%	$> \pm 15\%$
Dissolved Oxygen	$\leq \pm 0.3$ mg/L or $\leq \pm 5\%$, whichever is greater	± 0.3 - 0.5 mg/L or ± 5 - 10% , whichever is greater	± 0.5 - 0.8 mg/L or ± 10 - 15% , whichever is greater	$> \pm 0.8$ mg/L or $> \pm 15\%$, whichever is greater
pH	$\leq \pm 0.2$ units	± 0.2 - 0.5 units	± 0.5 - 0.8 units	$> \pm 0.8$ units

17.2.6 Signal Joining

The “Signal Joining” toolbox allows you to join the signals from multiple deployment periods. Joining signals allows the user to perform descriptive statistic functions on the entire season’s dataset or on a monthly basis. Note that signal joining requires multiple signals. If you have only one signal you will need to bypass this step and go directly to Threshold Flagging. Do not include the “Signal Joining” toolbox on the white board if you have only one signal.

1. Connect multiple deployment signals to the signal joining input ports. If you need additional input ports, right click on the “Signal Joining Toolbox” and select “Properties Pane.” Change the number of input ports. If you have more input ports than signals the toolbox will not function.

2. Double click the “Signal Joining Toolbox.” The “Signal Joining” window will appear. Each signal (deployment period) will appear as a different color on the graph. Make sure the “Corrected” signal type is selected under the “Signal Type to be Joined” section of the Time Series Manager control.

3. Click the “Save data to output ports and exit” icon (disk and red power symbol) from the toolbar. You should now have one active output port on the “Signal Joining Toolbox.”

17.2.7 Threshold Flagging

Threshold flagging allows the user to input values that should be flagged for review or that exceed a specified criteria. This function will be used to indicate values that fall above regulatory thresholds. The regulatory standards for Nevada Class A Waters apply only to Baker, Lehman.

Pine, and Ridge Creeks, but all water quality data will be compared to these standards for informational purposes. The standards are given in *SOP 8: Regulatory Status*.

1. Connect the Signal Joining output port to the Threshold Flagging input port. Double click the “Threshold Flagging” toolbox.
2. Select “Threshold Based Flagging” from the pull down. Click “Add Rule.” Enter the appropriate rule for the parameter of interest. Click “OK.”
5. Click “Run” and then click “OK.” The actual flags will remain hidden until you graph the data and display the flags.

17.2.8 Graphing

This section describes the use of the “Quick View” toolbox to create graphs suitable for publication. More options for chart creation are given in the “Charting” toolbox (not described in this SOP). It is important to note that a user can either graph the entire set of raw or corrected data, or can analyze the data with the “Descriptive Statistics” toolbox (described in the next section first and subsequently graph summarized data (i.e., daily max, min, mean). The order of operations depends on the user’s specific needs.

1. Connect the “Threshold Flagging Toolbox” to the “Quick View Toolbox.”
2. Double click the “Quick View” toolbox. The “Quick View” graphing window should open. You can zoom to specific dates or graph the entire time period. Graph options can be edited by going to the Charting menu, then by clicking “Property.”
3. To improve the appearance of the graph in printed reports, change the grid lines to black and the frame to white.
4. To view the threshold flags click the “Select Active Flag” icon (red flag) from the toolbar. Choose the threshold rule you established in the “Threshold Flagging Toolbox.” If the threshold rule was not named, it can be displayed by clicking “Overlapped.”
5. When you have set up the graph go to the File menu and select “Save Chart Image.”

17.2.9 Export

The corrected, graded, and flagged data should be exported and archived at the end of the season.

1. Connect each parameter’s final, joined signal to the “Export To File”.
2. Export the corrected data, data grades, and correction history as text files (.txt). Name these files using the format [location ID]_WQ_[Parameter]_Corrected_WY[two digit year].txt, e.g. “GRBA_S_BAKR1_WQ_SpCond_Corrected_WY10.txt”.
3. Notify the Data Manager that the files are available for archiving.

17.2.10 Descriptive Statistics

The primary tool used for generating descriptive statistics of the water quality data is the MS Excel Descriptive Statistics tool available in the free in the Analysis ToolPak. Summary statistics will be generated for each parameter in each stream for five half-month periods that will be compared across years (July 1-15, July 16-31, August 1-15, August 16-31, and September 1-15), and the entire length of the record.

1. Copy the contents of the .txt file of corrected data for one parameter in one stream (Section 17.2.9) into a blank Excel workbook, and use the “text to columns” tool under the “Data” tab to separate the time, date, and data into separate columns.
2. Select all of the data in the first half-month period (July 1-15). Click “Data Analysis” on the “Analysis” tab, and select “Descriptive Statistics”. Select a cell in the workbook for the output data, and click “OK”.
3. Repeat this procedure for the other two week periods and the entire record, and put the statistical outputs in a single table. The outputs are mean, standard error, median, mode, standard deviation, sample variance, kurtosis, skewness, range, minimum, maximum, and 95% confidence level. Save the resulting table in the current year in the data analysis file on the MOJN server.

Two crucial statistics not calculated by the Descriptive statics tool are mean daily minimum and mean daily maximum over the half-month periods. These statistics are calculated using Aquarius and Excel

1. In the Aquarius whiteboard for a specific parameter and stream, connect the “Quick View” toolbox to the “Descriptive Statistics Toolbox.”
2. Specify the time period and the types of statistics you would like to report by filling in the appropriate field and by checking the appropriate boxes. The boxes should be checked next to minimum and maximum, and the time period set to “daily.”
4. Click “Compute” and the results will be displayed within the same window.
5. Click the icon “Save Data to Output Ports and Exit” (Disk and red power symbol). Export the data from the output port as described in Section 17.2.9.
6. Import the contents of the resulting file to Excel as described above. Calculate the mean daily minimum and mean daily maximum for each half-month period and the entire record by using the “average” function with the relevant data range as an input. Add the data to the descriptive statistics table.

17.2.11 Summary Figures and Tables

The statistics described above are important for exploratory data analysis. However, it is not necessary to report all of them. Instead, the protocol lead should examine the results, and compare statistics over the course of the season and across years. Any interesting results should be reported, and any apparent trends should be tested.

The continuous core water quality parameter data will be summarized in graphical form with the regulatory threshold values indicated on the graphs. Continuous discharge data for the same stream and period of time should also be plotted to aid in the interpretation of the water quality data. In addition, the mean value, mean daily minimum value, and mean daily maximum water quality value for each parameter in each half-month period will be reported in table form (e.g., Table SOP 17.3).

Table SOP 17.3. Sample table for reporting mean daily values of water quality parameters. One table will be included in the annual report for each continuously-monitored stream.

Parameter		Mean Value, Jul 1-15	Mean Value, Jul 16-31	Mean Value, Aug 1-15	Mean Value, Aug 16-31	Mean Value, Sep. 1-15	Mean Value, Entire Field Season
pH	Daily Min						
	Daily Mean						
	Daily Max						
Temperature	Daily Min						
	Daily Mean						
	Daily Max						
Specific Conductance	Daily Min						
	Daily Mean						
	Daily Max						
Dissolved Oxygen	Daily Min						
	Daily Mean						
	Daily Max						

17.2.12 Trend Analysis

Trends in continuous water quality records will be analyzed using the Seasonal Kendall Test (SKT). Initially, the data will be divided into seasons based on month. Once several years of data are available, the protocol lead may decide that the seasons should be defined differently. Because of the large number of data points collected in each season, the SKT p-value corrected for serial correlation (section 17.7.2) should be reported. As described in Section 5.3 of the protocol narrative, Mann-Kendall testing (MKT) and Regional Kendall testing will be used to test for trends in all parameters during two index periods: one in late June and one in early September.

Trend analysis procedures are described in section 17.8.

17.3 Discrete Water Quality Measurements

17.3.1 Overview

The core water quality parameters identified by the NPS WRD are dissolved oxygen (DO), specific conductance (SpCond), temperature (T), and pH. In addition, the WRD requires that raw conductivity be collected because field instruments use different internal algorithms to calculate SpCond from raw conductivity. Cross-section surveys of these parameters will be collected in streams, and depth profiles will be collected in lakes.

17.3.2 Summary Figures and Tables

The depth profile for each lake will be reported in table form (Table SOP 17.4). A table will also be used to report the discrete water quality measurements made in each stream (Table SOP 17.5). In the streams table, any values that exceed regulatory thresholds for the pH, temperature, and DO (described in *SOP 8: Regulatory Status*) will be indicated in bold with an explanatory note.

Table SOP 17.4. Sample of table used to report depth profile information. The annual report will include one table of this type for each lake.

Johnson Lake Depth Profile, 9/25/2009, 12:30, Secchi Depth: 2.1 m (on bottom)

Depth (m)	T (°C)	SpCond (µS/cm)	Cond (µS/cm)	DO (mg/L)	pH
0	10.9	16.7	12.2	7.6	8.6
0.6	10.6	16.7	12.1	6.89	NM ^a
1.2	10.5	16.7	12.1	6.6	NM
1.8	9.9	16.8	11.9	7.15	NM

^a The handheld multiprobe used to collect these data does not have a pH electrode. A separate pH meter was used at the surface, but it does not have a cord enabling it to be used at depth.

Table SOP 17.5. Sample of table used to report discrete measurements of core water quality parameters in streams.

Stream	Easting (m)	Northing (m)	Date, Time	T (°C)	SpCond (µS/cm)	Cond (µS/cm)	DO (mg/L)	pH
Mill Creek			7/31/2009,					
Strawberry Creek			7/31/2009, 14:44	12.9	103.1	NR ^a	7.08	7.9
Snake Creek			8/1/2009, 10:34	8.3	45.5	NR ^a	9.52	8.4
Baker Creek			8/1/2009, 15:11	14.1	31.0	NR ^a	NM ^b	7.4
Shingle Creek			8/18/2009, 11:03	7.0	66.2	NR ^a	NM ^b	8.0
Lehman Creek			8/24/2009,					
Pine Creek			8/28/2009,					
Ridge Creek			8/28/2009,					
So. Fork Big Wash			9/2/2009,					

^a Raw conductivity was not recorded by the field crew due to oversight.

^b DO was not measured by the field crew due to instrument malfunction.

17.3.3 Trend Analysis

As described in Section 5.3 of the protocol narrative, trends in discrete measurements of core water quality parameters made in streams during the BMI and water chemistry sampling events will be analyzed both across all of the sampling sites using Regional Kendall testing (to detect

changes due to regional stressors) and on a site-by-site basis using Mann-Kendall testing (to detect changes due to local disturbances). The samples are collected in a mid-to-late summer index period, so no “de-seasonalizing” is required.

Trends in core water quality parameters measured in lakes will be analyzed in the same way. However, the trend tests will be performed on three different values for each parameter: The value measured at the surface, the value measured nearest to the bottom, and the mean of the values over the entire depth profile.

17.4 Discharge

17.4.1 Division of Duties

Currently, all discharge data analysis for the Lehman Creek is being performed by the USGS. Therefore, MOJN personnel will access these data from the USGS website. As of 2010, the Lehman Creek data can be found at:

http://waterdata.usgs.gov/nwis/dv/?site_no=10243260&referred_module=sw

Data at all of the other gages is being collected by GRBA scientists. The GRBA Aquatic Biologist also calculates discharge based on stream-gaging measurements. An outside hydrologist is contracted to review the GRBA Aquatic Biologist’s calculations and develop rating curves for each gaging site. It is the intent of the USGS to use these rating curves (or their own) to convert all of the continuous stage data collected up to the end of the 2010 water year to discharge records, which will be available on the USGS website.

After the 2010 water year, it will be the responsibility of the MOJN project lead to review the GRBA Aquatic Biologist’s calculations, develop rating curves for each gaging site, and convert the continuous stage data to discharge. Depending on the training and background of the MOJN project lead, these duties may be best performed by a hydrologist at one of the network parks or an outside contractor. The procedures described below are intended for use once MOJN takes responsibility for the data analysis, and are not intended to constrain the data processing choices of the USGS, NPS Water Rights Branch, or other qualified personnel.

17.4.2 Overview

The data analysis steps in the production of a stream discharge record are as follows:

- Calculate discrete stream discharge values from the water velocity measurements made using an anemometer during the monthly visits to the gage.
- Convert the pressure records recorded by the data-logging pressure transducer to records of stream stage.
- Use the monthly discharge measurements and the monthly stage measurements to develop a rating curve, and use this curve to convert the water level records to discharge records.

17.4.3 Discharge measurements

As noted in *SOP 8: Stream Discharge*, discharge measurements are made using the six-tenths depth method recommended in USGS WSP 2175 (Chapter 5, pages 134 to 135). The raw data for the n^{th} measurement consists of the distance in meters along the transect at which the measurement was taken (b_n), the depth in meters of the water in the stream at that point (d_n), and the measured velocity in meters per second (v_n). The discharge can be calculated from these data using the equation below (WSP 2175 Chapter 5 pages 80 and 81):

$$q = \sum_{n=1}^N v_n \frac{(b_{n+1} - b_{n-1})}{2} d_n ,$$

where b_0 and b_{N+1} are the positions along the transect of the stream banks (Figure SOP 17.1).

The equation above has been implemented in a Microsoft Excel file included in the supplementary material with this document (discharge_calc.xls). To use the spreadsheet, enter the transect positions, measured velocities, and measured water depths into the appropriate columns in the spreadsheet. Because the positions of the stream banks (b_0 and b_{N+1}) are also entered, the entered transect positions should begin one row above the other measurements and end one row below them. The stream discharge calculated by the spreadsheet should be rounded to the appropriate number of significant figures before reporting.

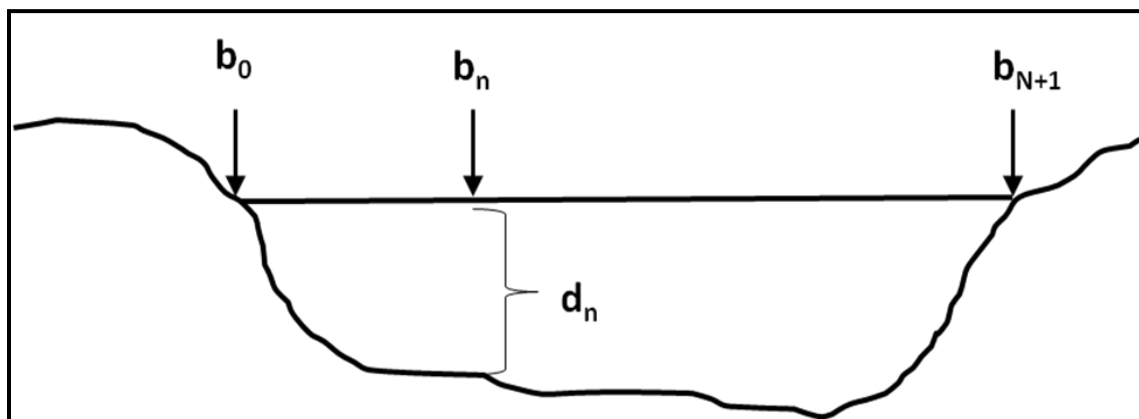


Figure SOP 17.1. Schematic diagram of discharge measurement geometry.

17.4.4 Developing Rating Curves in Aquarius

Rating curve development is a complex task that should only be undertaken by an experienced hydrologist. This section will describe the basic steps required to construct rating curves from discharge and stage measurements. Shifts in rating curves in subsequent years can be dealt with by consulting USGS Water Supply Paper 2175 and the Aquarius Help Manual (both included in the Supplementary Materials).

1. Create an Excel file with all of the stage measurements (in meters) made on a stream in the first column and the corresponding discharge measurements (in cubic meters per second) in the second column. Save this file as a comma-delimited text file.

2. In Aquarius, open the “Rating Curve Development” toolbox on it. Double-click on the toolbox to open it.
3. Select the “Import Data” option from the “File” menu. Browse to the text file created in step 1, and select the “overwrite on current rating” option. Click on the “Import” button.
4. There are two “zoom” panes in the “Rating Curve Development” toolbox. “Rating Zoom 1” displays the paired measurements on a log-log plot, while “Rating Zoom 2” displays the paired measurements on a linear plot. The standard equation for rating curves is a power law relationship, which is a straight line on a log-log plot. In the “Rating Zoom 1” pane, click the “Select all measurement points” icon.
5. In the “Rating Zoom 1” pane, click the “Initial Descriptor Points Spacing” icon. This tool sets up the points that will be used to define the rating curve. Set the toggle switches to “uniform steps in log space”, “number of points” (which should be set to 10), and “regression.” Click “OK.”
6. Open the “Rating Table” pane. Click on the “Estimate Standard Equation Coefficients” icon. Check the boxes next to “a,” “b,” and “c,” but leave the box next to “d” unchecked. Accept the default initial guesses for all parameters, ensuring that the initial guess for “d” is zero. Click “Estimate.”
7. While the non-linear algorithm used to estimate the parameters of the rating curve should produce a reasonable result, the user must use their judgment to determine if the resulting rating curve is acceptable. For example, if the highest discharge values were measured using the floats method, then the user may wish to alter the curve to fit the lower discharge data more accurately at the expense of fitting the floats data only approximately.
8. Select “Expanded Rating Table Function” from the “File” menu. Select “Export in Column Format,” then click “OK.” This file will be used as input to the “Rating Curve Player” in the next section.

17.4.5 Calculating Continuous Discharge Records in Aquarius

The MOJN will develop a whiteboard to automate the calculation of discharge records. Separate copies of the whiteboard will be needed for each monitored stream, a total of four whiteboards. Each whiteboard should have the following components:

- One copy of the “Import from File” toolbox and the “Data Correction” toolbox for each data file downloaded during the year. The whiteboard should be able to accommodate up to 12 input files.
- A copy of the “Signal Joining” toolbox to join the separate data files into a single, season-long record.
- A copy of the “Rating Curve Player” to convert the water level records to discharge records.
- Copies of the “Quick View” toolbox and “Descriptive Statistics” toolbox for visualization and reporting.

The data from each 2-3 week deployment period should be imported, and reviewed immediately after the files are downloaded so that any battery problems are detected as soon as possible. Further processing can be undertaken at the end of the field season.

1. The text files created in Global Water II can be imported using the instructions in section 17.2.3. The water level and battery voltage records should be imported.
2. Determine if there are any portions of the record with a battery voltage below the manufacturer's recommended level (3.1 V for the HOBO loggers), or if there are any portions of the record that exhibit high-frequency oscillations. These portions of the record should be deleted using the "Data Correction" toolbox, following the procedure described in Section 17.2.4 Step 3.
3. Join the signals from the year's deployment periods according to the procedure described in section 17.2.6
4. "Open the Rating Curve Player." The Inputs for the Rating Curve Player" are the water level time series and the rating curve created in the previous section. For "Output Time Series," enter "STLK_name_YYYY_Discharge," where *name* is the name of the creek and YYYY is the year. For units, enter "m³/s." Click "Apply."
5. As described in section 17.2, the "Quick View" toolbox and the "Descriptive Statistics" toolbox can be used to generate output for reporting.

17.4.6 Shifting Rating Curves

Rating curves are only valid as long as channel conditions remain unchanged. If sediments are deposited or scoured away in the channel near the stream gage, the relationship between discharge and stage changes. The stream gages in this protocol have been established at sites where the streambeds appear to be stable. However, if several discharge readings in succession plot off the rating curve, then it is likely that a rating curve shift must be applied. The identification of changes in channel conditions and the shifts that should be applied are discussed in Rantz et al. (1982) (USGS Water Supply Paper 2175 Volume 2, included in the *Supplementary Materials*) in the section beginning on page 344.

There are two types of shifts that can be applied in Aquarius: knee-bend shifts, in which the rating curve is shifted for low flows but honors older data for high flows (which are less influenced by small changes to channel geometry), and truss shifts, in which the rating curve is shifted for mid-range flows due to changes on the channel banks. Either type of shift can be applied either as a constant shift, reflecting permanent changes to channel conditions that occur during a single event, or pro-rated, reflecting gradual changes such as sand deposition or vegetation growth. As noted in Rantz et al (1982) the most common rating curve shifts at sites with natural channel control are deposition or scouring during flood events, so the most common shift used on protocol data will be a constant knee-bend shift. The steps for applying a constant knee-bend rating curve shift in Aquarius are described below:

-As described in Section 17.4.4, import all the discharge data into Aquarius using the "Rating Curve Development Toolbox" described in Section 17.4.4. Open the "Shift Manager" pane in the "View" menu.

-Click on the “Shift Properties” icon. Enter a start date (when you believe the shift occurred) and an end date of the end of the record (leave the end date blank for a pro-rated shift). Enter your name and title in the box labeled “Create User”. Click “Apply”.

-In the “Shift Diagram” window, enter the shift curve inputs. For a knee-bend shift, only the first two pairs of inputs will be used. The first pair (Input #1) consists of a low stage at which the maximum shift will be applied, and the magnitude of that shift. The second pair of inputs (Input #2) consists of the stage at above which you wish the shifted curve to match the older curve, and a shift of zero. As the input values are adjusted, the resulting shifts can be seen on the rating curve window. The user should experiment with different inputs until they are confident that the resulting rating curve honors the available data.

-Once you have chosen a final shift, click on the “Shift Report” icon. Enter your name, and save the report on the network server in the folder for discharge analysis for the current water year.

17.4.7 Summary Figures and Tables

The continuous discharge records will be included in graphical form. In addition, the mean value, mean daily minimum value, and mean daily maximum value for each month will be reported in table form (Table SOP 17.6).

Table SOP 17.6. Sample table for reporting mean daily discharge values.

Stream		Mean Value in June 2009	Mean Value in July 2009	Mean Value in August 2009	Mean Value in September 2009
Lehman Creek	Daily Minimum Discharge				
	Daily Mean Discharge				
	Daily Maximum Discharge				
Baker Creek	Daily Minimum Discharge				
	Daily Mean Discharge				
	Daily Maximum Discharge				
Snake Creek (Upper)	Daily Minimum Discharge				
	Daily Mean Discharge				
	Daily Maximum Discharge				
Snake Creek (Lower)	Daily Minimum Discharge				
	Daily Mean Discharge				
	Daily Maximum Discharge				
Strawberry Creek	Daily Minimum Discharge				
	Daily Mean Discharge				
	Daily Maximum Discharge				

17.4.8 Trend Analysis

As described in Section 5.3 of the protocol narrative, both parametric (mixed-model) testing and non-parametric (Kendall) testing will be used to examine different aspects of the stream discharge records. The mixed model will be used to test for annual minimum, maximum, and mean discharge both for each gage site and across all four 2nd-order streams. The annual

minimum trend will not be evaluated for the lower Snake Creek gage, which is dry for part of the summer each year. MKT will be used to examine trends in the date of peak discharge and mean late-season discharge, and SKT will be used to examine trends in the entire discharge record.

Trend analysis procedures are described in sections 17.8 and 17.9.

17.5 Water Chemistry and Lake Clarity

Water samples will be collected annually from each permanent stream and lake in the park, with the exception of the inaccessible stream in Williams Canyon. These samples will be analyzed by a testing laboratory for a variety of chemical constituents. The details of the laboratory testing program are described in *SOP 14: Laboratory Analysis of Water Chemistry*.

Lake clarity will be monitored using a Secchi disk as described in *SOP 10: Lakes Field Procedures*.

17.5.1 Acid Neutralization Capacity

The lab that analyzes the water chemistry samples (CCAL) refers to acid neutralization capacity (ANC) as alkalinity. However, the analyses will be performed on unfiltered samples. Therefore, according to USGS convention, MOJN will use the term ANC.

Beginning in 2010, CCAL will report ANC in mg/L of CaCO_3 . ANC is typically reported micro-equivalents per liter ($\mu\text{eq/L}$), that is, the number of micro-moles of protons that can be neutralized by 1 L of the sample. For reporting purposes, CCAL's values should be converted to $\mu\text{eq/L}$ by multiplying them by 20. This conversion factor is the product of the valence of the calcium ion (2) and the conversion factor between $\mu\text{eq/L}$ and meq/L (1000) divided by the molecular weight of CaCO_3 (100).

17.5.2 Summary Tables

All analytical results and calculated values should be reported in a table (Table SOP 17.7). Any potential problems should be reported in footnotes to the table, as not all users of the data will read the entire text of the report.

As described in *SOP 8: Regulatory Status*, the state of Nevada provides a regulatory threshold for the total phosphorus (TP) concentrations in Class A waters. All TP data collected can be compared directly to these thresholds. As TP concentrations are unlikely to exceed this threshold in the oligotrophic waters sampled by this protocol, a footnote should be appended to the table indicating that threshold was not exceeded by any of the measured values. If the threshold is exceeded, then the exceeding concentrations should be bolded and highlighted in yellow in the table, with an explanation in the footnote.

Table SOP 17.7. Nutrient concentrations in GRBA streams

Stream	Sampling Date	Total N mg/l	Total Dissolved N mg/l	Nitrate + Nitrite mg/l as N	Total P mg/l	Total Dissolved P mg/l
Snake	9/2/2009	0.05	0.06	0.002	0.013	0.011
	9/7/2010	0.05	0.06	0.003	0.007	0.005
Baker	8/27/2009 ^a	0.15	0.15	0.051	0.017	0.016
	8/31/2010	0.13	0.15	0.091	0.008	0.009
Lehman	8/27/2009 ^a	0.20	0.24	0.158	0.020	0.015
	8/30/2010	0.24	0.24	0.191	0.010	0.007
Pine	8/28/2009	0.12	0.17 ^b	0.092	0.013	0.012
	8/26/2010	0.21	0.19	0.130	0.015	0.012
Ridge	8/28/2009	0.44	0.33	0.264	0.027	0.019
	8/26/2010	0.31	0.38 ^b	0.248	0.020	0.016
S. Fk. Big Wash	9/2/2009	0.12	0.13	0.080	0.005	0.004
	9/2/2010	0.10	0.12	0.070	0.002 ^c	0.003
Mill	7/31/2009	0.45	-	-	0.074	-
	9/7/2010	0.18	0.12	0.003	0.024	0.019
Shingle	8/18/2009	0.22	-	-	0.030	-
	9/1/2010	0.08	0.11	0.008	0.010	0.009
Strawberry	9/28/2009	0.16	0.13	0.005	0.031	0.020
	8/24/2010	0.10	0.06	0.004	0.020	0.013

a. Sample collected at stream gage.

b. TDN value greater than TN value with the difference outside the expected range of variability, indicating contamination of sample.

c. Concentration is above the method detection limit (MDL) but below the minimum level of quantification (ML).

17.5.3 Trend Analysis

Trends in water chemistry and clarity will be analyzed both across all of the sampling sites using Regional Kendall testing (to detect changes due to regional stressors) and on a site-by-site basis using Mann-Kendall testing (to detect changes due to local disturbances). The samples are collected in a mid-to-late summer index period, so no “de-seasonalizing” is required. Trend analysis procedures are described in section 17.8.

17.6 Lake Level and Temperature

As discussed in *SOP 10: Lakes Field Procedures*, water pressure, temperature, and battery voltage will be recorded twice a day in each lake on a continual basis by data-logging pressure/temperature sensors. Atmospheric pressure will also be recorded so that changes in air pressure can be distinguished from changes in lake level.

17.6.1 Overview

The data analysis steps for the lake level and temperature data are as follows:

- Use HOBOWare Pro to correct the pressure records for barometric pressure variations as described in section 17.3.4.
- Export the water level, temperature, and battery voltage records to a text file, then import them to Aquarius.
- Inspect and flag any portions of the records that appear to be impacted by low battery voltage.
- Check for calibration drift in the water level record, and correct the record if necessary.
- Determine the ice-over and ice-out dates based on the temperature and water level records.

17.6.2 Barometric Pressure Correction in HOBOWare

The pressure records uploaded from the data loggers deployed in the lakes are converted to water level using the HOBOWare Pro Software package.

The manufacturer suggests that the correction can be made using any atmospheric pressure record collected within 15 km of the logger. However, mountain ranges create many distinct micro-climates, so air pressure may differ between lakes. Ongoing data collection will determine whether additional atmospheric loggers are needed for Johnson and Baker lakes. At a minimum, atmospheric loggers should be stationed at both the northern lakes and the southern lakes.

The free Barometric Compensation Assistant is needed to use HOBOWare to convert the pressure records to water levels. If “Barometric Compensation Assistant” is not an option under the “Plot Setup” menu in HOBOWare, then download the Assistant from:

<http://www.onsetcomp.com/dataAssistants>

The following steps should be followed to correct the data collected using the pressure transducers:

1. Open the data file exported from Global Logger II using the “Import Text Data” command under the “File” menu. Choose “comma” as the “data separator” (delimiter). If necessary, adjust the way the date and time are read using the “Edit Date/Time Format” option.
2. Select “Barometric Compensation Assistant” from the “Plot Setup” menu. The window below should appear.

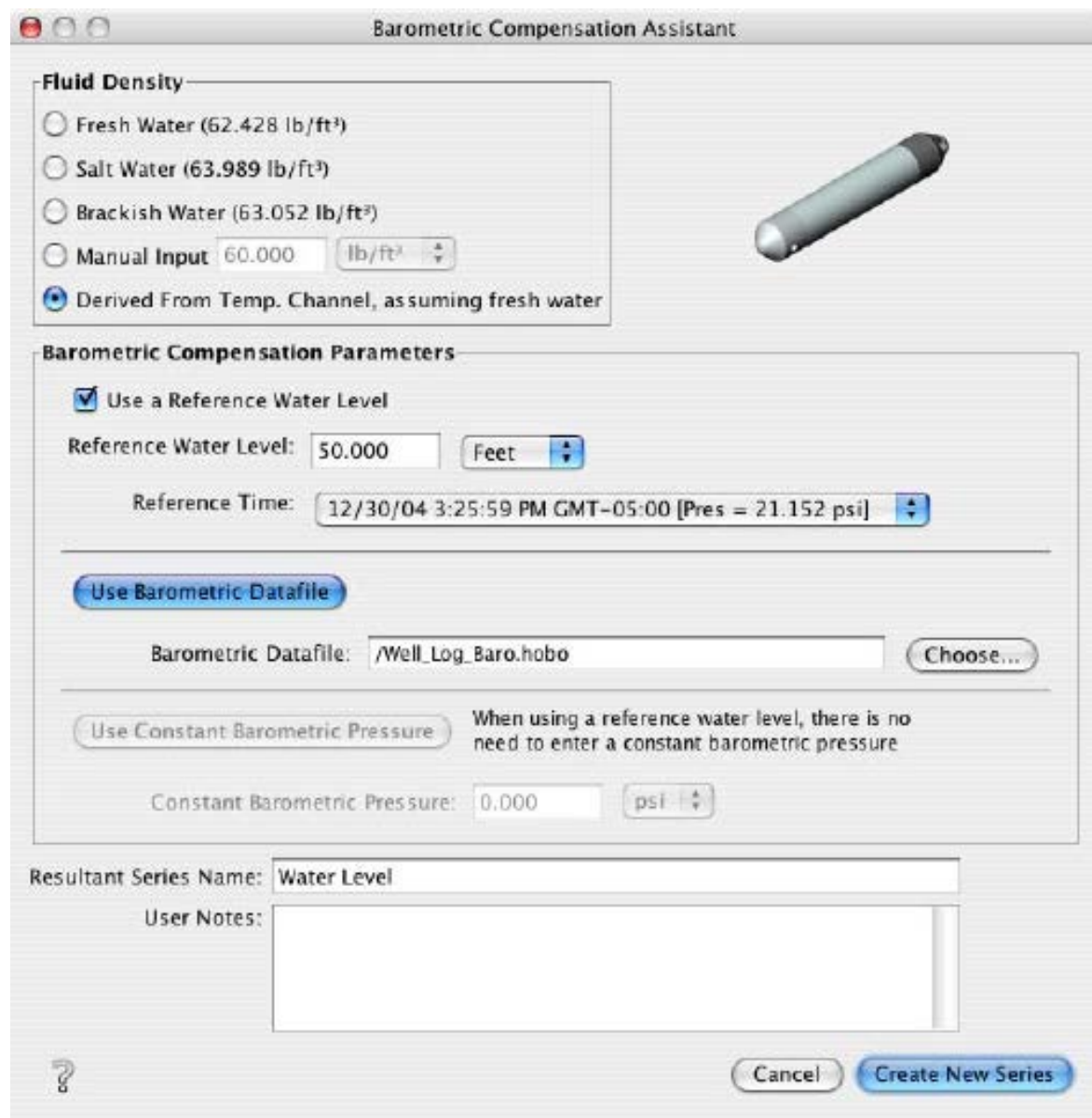


Figure SOP 17.2. HOBOWare Pro Barometric Compensation window.

3. Select the "Fresh Water" fluid density option. The density of water changes by ~0.5% between 1 °C and 35 °C, so the effect is smaller than the uncertainty in our measurements.
4. The surveyed lake level from the end of each deployment period will be used as the reference level. Select the last point in the time series as the reference time.
5. Use the "Choose..." button to browse to the atmospheric pressure file you will use to correct the pressure record. Once the correct file is selected, enter a series

name (e.g., BakerLake_WaterLevel_WY2010) and click the “Create New Series” button.

6. The water level record can now be exported to a text file using the “Export to Excel Text” option under the “File” menu.
7. The water level, temperature, and battery voltage records should be exported to a text file using the “Export to Excel Text” option under the “File” menu.

17.6.3 Data Inspection and Drift Correction in Aquarius

The whiteboard for the lakes data will have four components: the “Input from File” toolbox, the “Data Correction” toolbox, the “Quick View” toolbox, and the “Descriptive Statistics” toolbox.

The text file created in HOBOWare can be imported using the instructions in section 17.2.3. The water level, temperature, and battery voltage records should be imported.

The data loggers are powered by 3.6 V lithium batteries. According to the manufacturer, loggers are functional as long as the voltage is above 3.1 V. Therefore, the temperature and pressure records should be inspected for signs of problems in periods where the battery voltage is below 3.3 V. Determine if there are any portions of the record with a battery voltage below 3.1 V, or if there are any portions of the record that exhibit high-frequency oscillations with a battery voltage below 3.3 V. These portions of the record should be deleted using the procedure described in Section 17.2.4 Step 3.

According to the manufacturers, the “worst case” for drift in the HOBO U20 pressure sensors is 0.3% of the instruments full scale per year, which corresponds to a drift of ~1.2 cm of error in the water level readings per year. This error is removed from the record each time the water levels are compared to a reference level. As a result, instrument drift is not a significant source of error for the pressure sensors at the stream gages, where the reference level readings will occur no more than a few months apart. However, lake levels are surveyed once a year, and logistical difficulties could result in a two-year interval between readings. Therefore, it is important to check the lake level records for instrument drift using the following steps:.

1. Inspect the water level record, and determine the mean difference in lake level between the daytime reading and the nighttime reading for the last 7 days of the record. The calibration drift criterion is the greater of this value or 2.0 cm.
2. As described in the previous section, the water level record was generated using the surveyed lake level at the time of instrument deployment as the reference level. Therefore, the check can be performed using surveyed lake level at the time the record was downloaded. The “total drift” is the difference between this level and the last level in the water level record. If the total drift is greater than the criterion calculated in step 1, then the record should be corrected for instrument drift.
3. BEFORE CORRECTING THE DATA, ENSURE THAT THE APPARENT DRIFT IS NOT DUE TO ERRORS IN THE SURVEYING CALCULATIONS.

4. Inspect the record, and determine if the total drift appears to be caused by a shift in the position of the instrument (i.e., if the drift was introduced into the record in a single day). The greater the total drift, the more likely that this is the case.
5. IF THE DRIFT APPEARS TO HAVE BEEN CAUSED BY A SHIFT IN POSITION:
Open the Data Correction Toolbox. Highlight the record after the time of the shift. Click the Correction Action drop-down menu and select the “Offset Correction” option. Enter the desired correction in the “Offset” box and click “Apply.” Inspect the resulting record to ensure that the correct sign (+ or -) was used.
6. IF THE DRIFT APPEARS TO BE CAUSED BY CALIBRATION DRIFT: Open the Data Correction Toolbox. Highlight the entire record. Click the Correction Action drop-down menu and select the “Drift Correction” option. Enter the desired correction in the “Calibration Drift” box and click “Apply.” Inspect the resulting record to ensure that the correct sign (+ or -) was used.

As described in section 17.2, the “Quick View” toolbox and the “Descriptive Statistics” toolbox can be used to generate output for reporting.

17.6.4 Estimating Ice-Over and Ice-Out Dates

The continuous pressure and temperature records should allow the ice-over and ice-out dates for each lake to be estimated. In a study of water temperature records collected in a large number of lakes in the Alps, Thompson et al. (2005) found that:

“...all of the [studied] lakes freeze in winter. Consequently the thermistor logs remain relatively steady during the winter months at temperatures of between 0 and 4 °C, depending on the depth of the thermistors with respect to the ice layer. Secondly the spring thaw sees small temperature increases when the ice first breaks, or when catchment snow-melt first enters the lake. Then once the ice fully melts (ice-out), thermistor temperatures rise rapidly and begin to track the ambient air temperatures.”

The dates ice-over and ice-out can be easily determined in the temperature data sets presented in Thompson et al. (2005). In addition, the water level is unlikely to vary significantly beneath the ice, so the pressure logs may also be used to determine the frozen or ice-free status of the lakes.

Once the pressure/temperature logs have been imported to Excel (see previous section), the protocol lead and one other scientist will independently determine the ice-over and ice-out dates by visual inspection. These dates will be compared, and any differences will be resolved by reaching a consensus upon re-inspection or by choosing the mean of the two dates.

17.6.5 Summary Figures and Tables

The temperature and lake level records for each lake should be displayed in graphical form. The estimated ice-over and ice-out dates should be displayed on the figures. The ice-over and ice-out dates for each lake, along with the mean, maximum, and minimum lake level for each month, should be reported in a table (Table SOP 17.8).

Table SOP 17.8. Sample table for daily mean, maximum, and minimum lake levels for each month.

Lake		June 2009	July 2009	August 2009	September 2009
Stella Lake	Minimum Lake Level				
	Mean Lake Level				
	Maximum Lake Level				
Teresa Lake	Minimum Lake Level				
	Mean Lake Level				
	Maximum Lake Level				
Brown Lake	Minimum Lake Level				
	Mean Lake Level				
	Maximum Lake Level				
Baker Lake	Minimum Lake Level				
	Mean Lake Level				
	Maximum Lake Level				
Johnson Lake	Minimum Lake Level				
	Mean Lake Level				
	Maximum Lake Level				
Dead Lake	Minimum Lake Level				
	Mean Lake Level				
	Maximum Lake Level				

17.6.6 Trend analysis

Trends in overall lake level will be analyzed using the Seasonal Kendall Test. Initially, the data will be divided into seasons based on month. Once several years of data are available, the protocol lead may decide that the seasons should be defined differently. Because of the large number of data points collected in each season, the SKT p-value corrected for serial correlation (section 17.8.2) should be reported. MKT will be used to determine if the annual maximum and minimum lake levels are changing.

Trends in the ice-over date, ice-out date, and length of ice-free season will be analyzed both across all of the sampling sites using Regional Kendall testing (to detect changes due to regional stressors) and on a lake-by-lake basis with Mann-Kendall testing (to detect changes due to local disturbances).

Trend analysis procedures are described in section 17.8.

17.7 Benthic Macroinvertebrates

The benthic macroinvertebrates (BMI) samples collected in GRBA streams will be processed by the BLM/USU National Aquatic Monitoring Center (also known as the BugLab). The raw data reported by the BugLab will be archived in an Access database so that they can be used by future researchers to examine BMI community structure using any desired indices or metrics. MOJN will report abundance, taxon richness, EPT taxa richness, and percent dominant taxon.

Abundance is the total number of specimens in the sample.

Taxon richness is the total number of taxa observed in each sample.

EPT taxa richness is the number of taxa of the orders Ephemeroptera, Plecoptera, and Trichoptera (insects that are generally sensitive to ecosystem stressors).

Percent dominant taxon is the percentage of the counted individuals in the most abundant taxon.

These summary indices are calculated and reported by the BugLab.

17.7.3 Summary Table

The above four indices should be reported for each sample in a table (e.g., Table SOP 17.9).

Table SOP 17.9. 2009 BMI indices for GRBA streams.

Stream	Abundance	Taxon Richness	EPT Taxa Richness	% Dominant Taxon
Mill Creek	1294	53	26	27.09
Strawberry Creek	318	46	20	11.89
Baker Creek	839	60	24	23.67
Shingle Creek	627	57	21	12.39
Snake Creek	1069	55	19	23.88
Lehman Creek	578	54	26	31.83
Pine Creek	1126	51	22	8.99
Ridge Creek	1963	45	20	11.74
South Fork Big Wash	517	35	11	15.62

17.7.4 Trend Analysis

Trends in the BMI indices will be analyzed both across all of the sampling sites using Regional Kendall testing (to detect changes due to regional stressors) and on a site-by-site basis using Mann-Kendall testing (to detect changes due to local disturbances). The samples are collected in a mid-to-late summer index period, so no “de-seasonalizing” is required. Trend analysis procedures are described in section 17.8.

17.8 Non-Parametric Trend Analysis Using Kendall Tests

[This section adapted from Helsel et al., 2006]

As of 2010, the most convenient method for Kendall analysis of the Streams and Lakes data appears to be the USGS program *kendall.exe*. However, the current version of *kendall.exe* is designed to open a DOS window in Windows XP. As computer operating systems change over time, it is entirely possible that this program will not function at the time the trend analyses are performed. In this case, the protocol lead should check the USGS website for an updated version of *kendall.exe* or use any convenient software package. The instructions below are taken from USGS Scientific Investigations Report 2005-5275 (Helsel et al., 2006). This report should be consulted for a more in-depth description of the program.

Kendall.exe (which can be downloaded from <http://pubs.usgs.gov/sir/2005/5275/downloads/>) performs the Seasonal Kendall, Regional Kendall, and Mann-Kendall tests for trend. To run the program:

- Copy the “Kendall.exe” file into the directory that contains the input-data files.
- Double click on the “Kendall.exe” file name or icon.
- In the DOS window type the name of the input-data file.
- In the DOS window type the name of the output file to which results are written.

The program will then run, and write the output to a file with the specified name.

17.8.1 Input Files

The input file should be a standard text file. The first line of the file consists of the code used to instruct the program how to analyze the data. Column 1 of the first line is the code for which statistical test to perform (2 for SKT, 3 for Regional Kendall, or 4 for Mann Kendall). Column 3 of the first line contains the code used to indicate whether statistical test is to be performed on the data themselves (0) or the discharge-corrected LOWESS residuals (1). Columns 5-7 contain the number of seasons used for SKT analysis, but are not used for the procedures described in this SOP. Columns 9 to 67 are a title which will be used to identify the data set.

After the first line, each line of the input file consists of several comma-delimited columns (space-delimited columns may also be used). For SKT without LOWESS correction, the first column is the year of sampling as an integer, the second column represents the season as an integer, and the third column is the data to be tested for trend. The program assumes that season 1 starts at the beginning of the calendar year and that the largest integer number is the last season of the year. There is no requirement that the seasons represent an equal amount of time within a year. Multiple data values within a season can be entered, each on a separate line. As an example, an SKT test of discharge where each month was designated as a separate season would have an input file with the following format:

```
2 0 000 Baker Creek Discharge
2009,1,6.3
2009,1,6.7
Etc.
```

The units of the measured data are unimportant as long as they are used consistently within the file. However, the trend line reported in the output file will use the same units.

If SKT with discharge correction is desired, then a fourth column is needed for the streamflow at the time the data was collected. As an example, a discharge-corrected SKT test of temperature where each month was designated as a separate season would have an input file with the following format:

2 1 000 Baker Creek Temperature w/ Discharge Correction
2009,1,22.4,6.3
2009,1,20.6,6.7
Etc.

For Mann-Kendall tests, only two columns are needed: time and data. The time column needs to be a numerical value, so the user may wish to express it as days since the beginning of the study. As an example, an input file for a Mann-Kendall test of Invertebrate abundance would have the following format:

4 0 000 Baker Creek BMI Abundance
1,538
366,722
Etc.

If Mann-Kendall testing of discharge-corrected data is required, then the following format should be used:

4 1 000 Baker Creek [Mg]
1,5.23,7.4
366,8.95,6.2
Etc.

For Regional Kendall Testing, the first column is the year, the second column is an integer site ID assigned by the user, and the third column is the data. For example, an input file for a Regional Kendall test of trends in ANC across all lakes would have the following format:

3 0 000 Acid Neutralization Capacity of GRBA Lakes
2009,1,96
2009,2,144
Etc.

Sample input files can be downloaded from the USGS website at the same web address as the program itself. These files are described in Helsel et al., 2006.

17.8.2 Output Files

The output file reports the estimated trend equation and four parameters: the correlation coefficient, tau; the Kendall's test statistic, S; the standard normal deviate, z; and the statistical significance, p. When p is small, the likelihood that there is no trend is small, and the null hypothesis (i.e., that there is no trend in the data) is rejected. *Kendall.exe* reports two values of p: the standard version, which should be used for data collected annually, and the serial-correlation corrected version, which should be used when more than 10 samples are collected during each season (or at each site) every year. For the Streams and lakes protocol, the value of p corrected for serial correlation should be reported for continuously-recorded water quality, discharge, and lake level data, and the standard value of p should be reported for all other data. If a statistically significant trend ($p < 0.1$) is reported, then the estimated trend equation for that data set should also be reported.

17.8.3 Censored Data

Mann-Kendall, Regional Kendall, and Seasonal Kendall tests are non-parametric and based on ranked comparisons of data values, so censored data (data sets in which some measurements are below detection) can be used (Hirsch et al. 1991). The routine simply considers all below-detection data points tied with each other. There are three main limitations: non-detected data with different detection limits cannot be used, the LOWESS discharge-correction method cannot be used, and a trend equation cannot be estimated. To enter censored data into the input file for *kendall.exe*, simply assign all of the non-detected data a value of half the minimum level of quantitation (ML). The program can then be run as normal, although the user must be sure to not use discharge correction and to ignore the estimated trend equation.

17.9 Parametric Trend Analysis Using the Mixed-Model Approach

A linear mixed-model is used to test for effects of trend at extensive sites (VanLeeuwen et al. 1996; Piepho and Ogutu 2002). A mixed model allows some effects to be considered fixed and some to be considered random. Fixed effects contribute to the mean of the outcome and random effects contribute to the variance. Random effects are used to estimate variation of linear trends among subjects (e.g. lakes) and over time (e.g. years). Piepho and Ogutu (2002) improve the estimator proposed by VanLeeuwen et al. (1996) by modeling the site effect as fixed or random. A random site effect may be modeled as correlated with the random slope for each site. The ability to modify the assumptions provides additional benefits of trend test invariance and model flexibility.

The mixed model proposed in both articles is:

$$y_{ijk} = \mu + w_j\beta + b_j + a_i + w_jt_i + c_{ij} + e_{ijk},$$

where $i=1,\dots,m_a$; $j=1,\dots,m_b$; $k=1,\dots,m$ and

m_a = the number of sites in the sample;

m_b = the number of consecutive years in the sample;

m = the number of measurements taken within a site and year;

w_j = constant representing the j^{th} year (covariate);

μ and β = fixed intercept and slope of the linear time trend;

b_j = random effect of the j^{th} year;

a_i = random intercept of i^{th} site, independent and identically distributed as $N(0, \sigma_a^2)$;

t_i = random slope of i^{th} site, independent and identically distributed as $N(0, \sigma_t^2)$;

c_{ij} = random effect of site by year, independent and identically distributed as $N(0, \sigma_c^2)$; and

e_{ijk} = unexplained error, independent and identically distributed as $N(0, \sigma_e^2)$.

The null and alternative hypotheses you are testing are no trend ($\beta=0$) versus trend ($\beta\neq 0$):

$$H_O : \beta = 0 \text{ vs } H_A : \beta \neq 0$$

As defined above, β is the slope of the trend line. The test statistic is derived for the two-sided hypothesis and the rejection region is based on a t-distribution with $m_b - 2$ degrees of freedom where m_b is the number of survey years. If all sites are not visited every year, then data will be unbalanced and Kenward-Roger degrees of freedom should be used for assessing the p-value of the trend test (Spilke et al. 2005). The test is compared to a Type 1 error level of $\alpha = 0.10$.

The model is implemented using R, a high-level computer language for data analysis. R can be downloaded for free at <http://cran.r-project.org/>.

A useful resource for those wishing to learn more about R is “The R Book” (Crawley 2007) which is in the MOJN library. The trend analysis should be undertaken by an experienced R user.

The R code prepared by L. A. Starcevich for the analysis of pilot data is included in the Supplementary Materials in the document “discharge_trend_analysis.doc.” The data needed for the analysis are the annual mean, maximum, and minimum discharge for each creek. These data can be entered into the code in “discharge_trend_analysis.doc” by changing the values in the data structure “DischargeBL.” Once the data have been entered, the code can be run in R.

17.10 Annual Reports

The program will produce an annual report each year following the conclusion of the field season and the completion of the laboratory analyses. The protocol lead will work with the network coordinator to integrate reporting with the larger Vital Signs Monitoring Program reports and the Annual Administrative Report and Work Plan. Reports will be distributed to NPS-WRD, Network staff, Resource Chiefs, MOJN Technical Committee, and the MOJN Water Resources Working Group. Reports will also be made available to interested park staff and the public via the MOJN I&M web pages.

Annual reports will include the following information:

- Description of field season highlighting accomplishments
- Documentation of any deviations from the protocol, such as missed sites or samples
- Results from the past years field season, including raw data, summary statistics and graphics
- Recommendations for future improvements to monitoring activities.

The reports will be prepared according to NPS guidelines for Natural Resource Data Series reports, and will likely be published in that series. The “1 column good” format will be used. As of 2010, MS Word templates for NRDS reports are available at:

<http://www.nature.nps.gov/publications/NRPM/index.cfm>

Tables and figures included in this SOP are examples of the data summary products that will be included.

17.11 EPA STORET

The water quality component of the Natural Resource Challenge (NRC) requires that all I&M Networks archive all physical, chemical, and biological water quality data collected with NRC water quality funds in the National Park Service's STORET database maintained by the NPS' Water Resources Division (WRD) (Tucker 2010). To facilitate archiving NPS data in STORET the WRD has developed 2 methods to submit water quality data in a STORET-compatible format: a) series of Microsoft Access-based templates (NPSTORET), and b) STORET Electronic Data Deliverable (NPSEDD) specification in Microsoft Excel. MOJN will annually submit water quality data using NPSEDD. WRD reviews the data for quality assurance after it is received and reports their findings back to MOJN. After all data have been reviewed, corrected and flagged if necessary, WRD uploads a copy of the data to WRD STORET and submits monthly updates to the EPA STORET National Data Warehouse (Figure SOP 17.3).

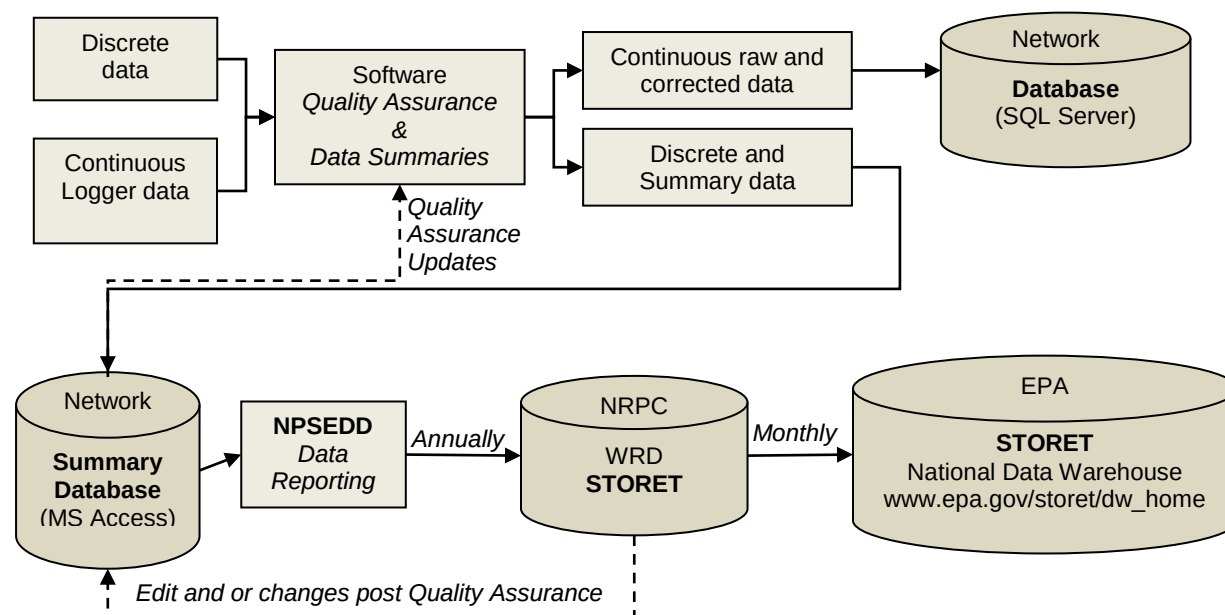


Figure SOP 17.3. Workflow for water quality and quantity data upload to EPA STORET.

MOJN uploads the 4 core water quality parameters to WRD in addition to the all collected water chemistry, benthic invertebrate, and water quantity data. Core water quality and water quantity parameters from continuous data loggers are summarized (e.g. daily, monthly, and annual metrics) before being submitted since WRD STORET cannot handle continuous logger data. All data specification must be met to submit the data to WRD and these are detailed in Tucker (2007). All specifications for uploading and archiving water quality and quantity data with WRD is detailed at Vital Signs Water Quality Data Management and Archiving (<http://www.nature.nps.gov/water/infoanddata/index.cfm>) and WRD Guidance Documents (http://www.nature.nps.gov/water/VitalSigns_index/VitalSignsdocuments.cfm).

17.12 Trend Analysis Reports

The USGS recommends that “The period of record for stations included in a trend study should be at least five years for monthly data or longer for less dense data” (Schertz et al., 1991). Trends that impact all of the streams or all of the lakes will be detectable more rapidly than trends that impact a single station. However, because water samples are collected on an annual basis, it is unlikely that significant trends will be detectable before five years of data have been collected.

Trend analyses are formally reported every four years once there is a minimum of five years of data, but they may be calculated more frequently if requested by NPS resource managers. The core of the report will be statistical tests described in this SOP. We anticipate these analyses will be supplemented by additional analyses as the program matures.

Trend analysis reports should include the following information:

- Overview of the protocol status and major accomplishments
- Status and trend analysis results
- In depth, quality assurance and quality control analysis and discussion
- Discussion of results, including management implications
- Recommendations for future improvements.

The specific details of report formatting can be determined by the protocol lead at the time of report preparation.

17.13 Version Information

Table SOP 17.10. Version information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 18. Database Design

18.1 Introduction

MOJN protocol databases are based on the master and working database strategy, each of which are designed to be compliant with the standards set forth by the NPS Inventory and Monitoring Program's Natural Resources Database Template (NRDT), version 3.2 (National Park Service 2007). The working database consists of two separate Microsoft Access database files. The front-end contains forms, linked tables, reports, queries, macros, and Visual Basic code and the back-end contains the data tables (Adams et al. 2009). This organization of the database allows new development and edits of forms and reports (housed in the front-end) to proceed without hindering use of the data (housed in the back-end) (Adams et al. 2009). The two database files are linked using the 'Linked Table Manager' utility within Microsoft Access. The purpose of the working database is to facilitate data entry, quality control of data entry, quality assurance review following data entry, summaries, and generating annual reporting products. Data in the working database are certified after the quality assurance review and then the data are transferred annually to the master database. Working databases are partial or complete mirror images of the master database tables. The purpose of the master database is to store and facilitate continued access to all project data for reporting and analyses for the protocol's life cycle. The master database lacks the front-end features of the working database and there are typically additional data tables. The master database is updated annually and retained with the project files for the monitoring project. Source files used to update the master database may include, but are not limited to, the working database, data processed by proprietary software (e.g. continuous water quality summary data), photo links, GPS data, laboratory results, etc.

There are a master and working database set for the streams data and for the lakes data, in addition to a geodatabase for geospatial data.

18.1.1 What the Streams database and Lakes Database are and are not

Each Database is/can

1. Relational MS Access database organized by subject-based tables and primary keys
2. Compliant with NRDT version 3.2
3. Manage summaries of continuous logger data
4. Provides quality control of data input
5. Provides quality assurance of discrete field data
6. Accommodate import of laboratory results
7. Accommodate annual data photo metadata
8. Accommodate export of water quality data and metadata that meets WRD STORET export requirements
9. Designed for reporting and analyses of the data

Each Database is not/can not

1. Manage large quantities of continuous logger data
2. Process continuous logger data for erroneous data and quality assurance
3. Accommodate all data photos

18.2 Database Design Considerations

The following items were considered and included in the design of the database;

- Yes/No data types are not used; instead the field is set to Text data type, field size is limited to 4, Display control is Combo Box, Row source Type is set to Value List, and the Row Source is “Yes;No”
 - Reason: Yes/No data types are check boxes in the database tables that may be true/false or binary (e.g. 0 or 1); therefore using text data type limited the data to a consistent value regardless of the software platform.
- Default values for Number data types are set to null to prevent the accidental inclusion of a zero value as data
- Non-integer numerical data are decimal data type, with appropriate scale and precision
- Use of enumeration tables for administrative information, e.g. Park unit codes, and water quantity and quality parameters that are not highly variable year to year
- Use of look-up tables for highly variable lists of information such as crew members and equipment tracking that must be updated and expanded annually
- Naming conventions of the database objects and fields followed the standards outlined in *MOJN DM SOP Database Naming Conventions*

18.3 Database Design Summary

These following database tables and relationships were developed in a back-end master database that is based on the structure and standards of I&M NRDT, version 3.2. The unifying tables for most of the Streams and Lakes data are tbl_Events and multiple *Main* tables for field data, and tbl_Event_Group for the summary data, which are not linked to a single event. Independent tables include tbl_1_Meta and tbl_1_Revisions which are used by the Network Data Manager to track the changes to and provide metadata for the database. tbl_Equipment and tbl_Equip_Maint_Log document field equipment which is tracked along with the data collection using the equipment serial number. Cameras and GPS devices are not tracked with the equipment tables.

Due to the large size of the raw files generated from the continuous data loggers, raw and corrected continuous water quantity and water quality data are archived in an ASCII file format (.txt) for a complete water year. Ideally, the data will also be uploaded and stored on a SQL server as soon as one is available to the Network, possibly in 2011. In the meantime, the Data

Manager will investigate the possibility of uploading the raw and corrected continuous data file to the working databases for ease of access to the data.

Summary data derived from the continuous logger data will be stored and accessible in the working and master database along with tracking records and descriptions of data flags and corrections associated with the summary data.

Photographs associated with the protocol will not be stored in the database with the exception of annual site images for reference. *MOJN DM SOP Image Management* documents procedures for organizing, cataloging, and creating metadata for all protocol photos.

18.4 Streams Database Structure

18.4.1 Tables

Table SOP 18.1 lists and describes the Microsoft Access tables for the streams master database. Tables include those that store field data, summary data from processed continuous logger files, calculated data fields, enumeration tables, and look-up tables. A detailed data dictionary of the tables and description of the fields is documented in [ST MasterDB DataDictionary.pdf](#), a report created using a tool developed by Kingston (2006).

Table SOP 18.1 Microsoft Access tables for the streams database.

Table Name	Table Description
tbl_1_Db_Meta	Database description and links to I&M metadata tools
tbl_1_Db_Revisions	Database revision history data
tbl_Data_Core	Core Field Collected Data
tbl_Data_Field_Discharge	Field collected discharge data
tbl_Data_WQ_AMSplus	Field collected AMS+ for water quality assurance assessment
tbl_Sum_WQ_AMSplus	Summary statistics for AMS+ data
tbl_Data_WQ_Calibration	Field water quality calibration data
tbl_Data_WQ_Discrete	Discrete (one-time) water quality data
tbl_Data_WQ_XSection	Discrete (one-time) water quality data for a cross-section sample
tbl_Equip_Maint_Log	Equipment maintenance log
tbl_Event_Details	Sampling event details
tbl_Event_Group	Event aggregations (e.g. seasons, trips).
tbl_Events	Sampling events
tbl_Lab_BMI	Benthic macroinvertebrate results from the laboratory
tbl_Lab_BMI_Vouchers	Benthic macroinvertebrate voucher data
tbl_Lab_Chemistry	Water quality chemistry data from laboratory analyses
tbl_Locations	Sampling unit locations
tbl_NPStoret_MTPC	Tool to collect and format NPStoret metadata - In Development
tbl_NPStoret_MTPC_Personnel	Tool to collect and format NPStoret metadata - In Development
tbl_NPStoret_Project	Tool to collect and format NPStoret metadata - In Development
tbl_NPStoret_Project_Citations	Tool to collect and format NPStoret metadata - In Development
tbl_Sites	Location aggregations
tbl_Sum_Metrics_Discharge	Monthly and annual metrics for discharge; Summary data derived from processed continuous logger data
tbl_Sum_Daily_Discharge	Daily metrics for discharge; Summary data derived from processed continuous logger data
tbl_Sum_Daily_WQ	Daily mean core water quality parameters Summary data derived from processed continuous logger data
tbl_Sum_Monthly_WQ	Monthly metrics core water quality parameters; Summary data derived from processed continuous logger data
tbl_Sum_WQ_AMSplus	Summary statistics for AMS+ data
tlu_WQ_Corrections	Corrections applied to the continuous logger data
tbl_WQ_Flags	Flags generating during the processing of the continuous logger data
tlu_Enum_Admin	Enumerated lookup table for administrative variables
tlu_Enum_NPSEDD	Enumerated lookup table for NPStoret
tlu_Enum_Water	Enumerated lookup table for water quality and quantity variables
tlu_Equip	Equipment list and serial numbers
xref_Event_Contacts	Cross-reference table between events and contacts

Due to the quantity of tables in the master database, the database structure presented in Figures SOP 18.1 to 18.4 was simplified by limiting the number of tables per view.

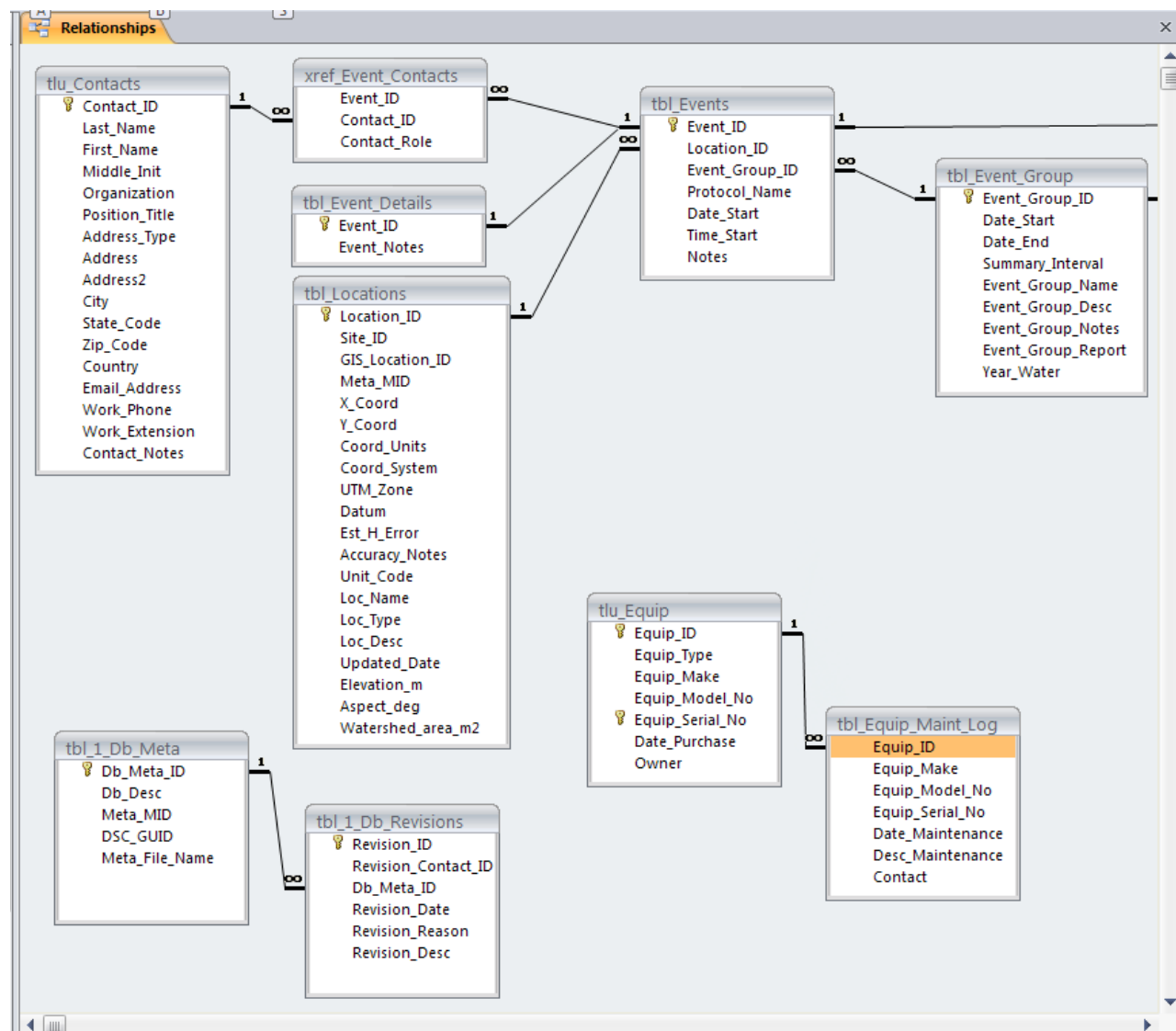


Figure SOP 18.1. Relationships among the administrative tables in the streams database.

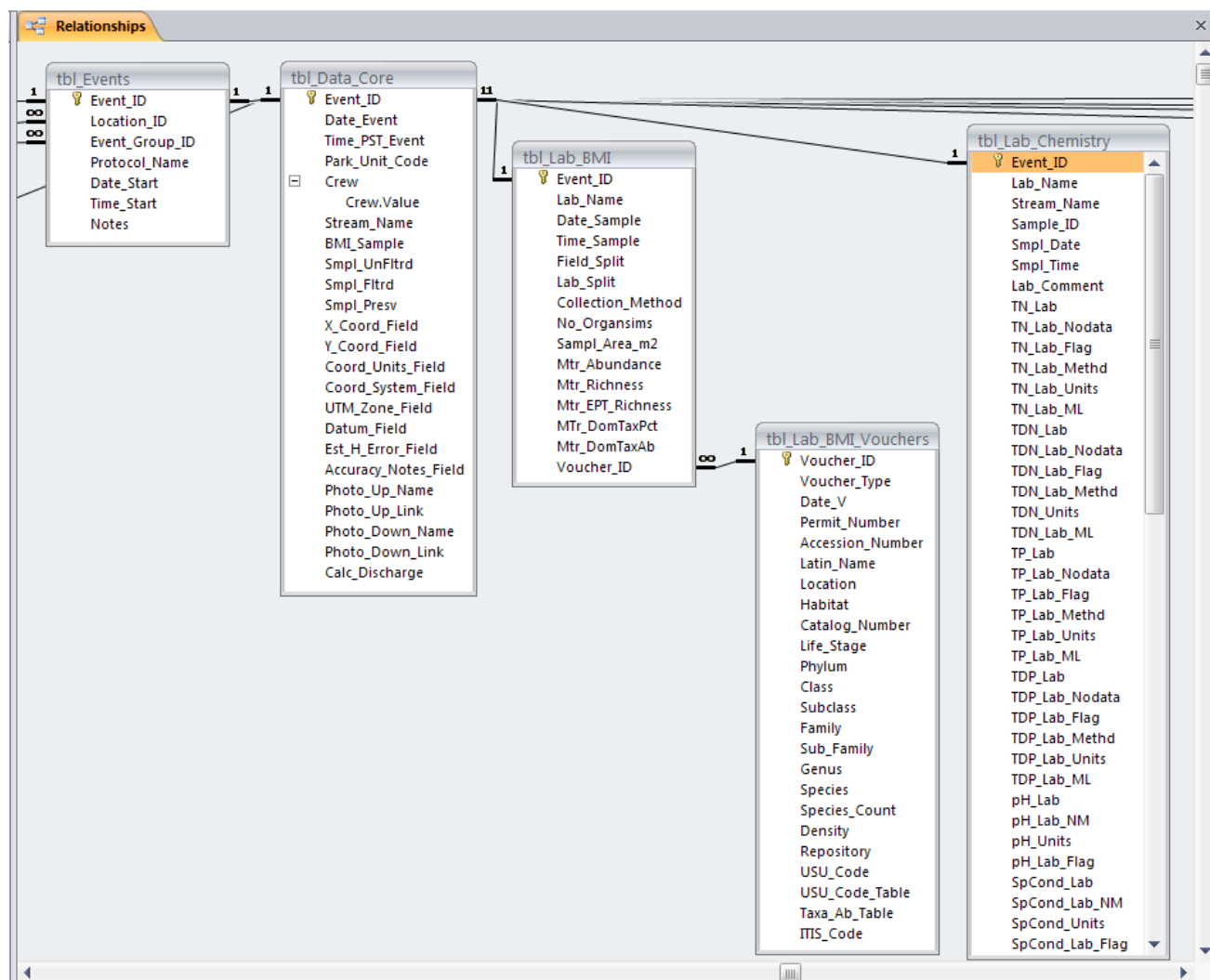


Figure SOP 18.2. Relationships among the laboratory results data and voucher documentation.

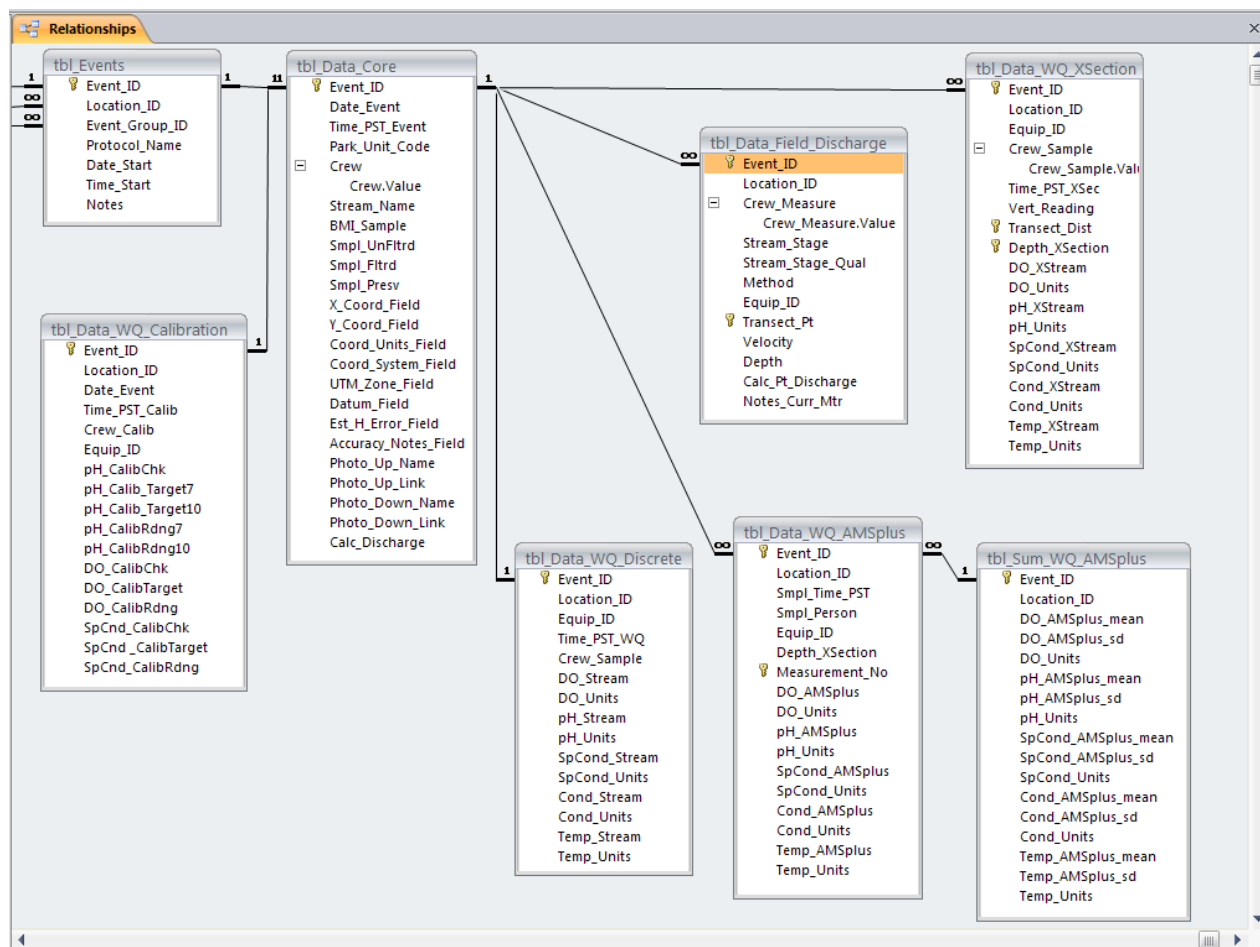


Figure SOP 18.3. Relationship among the field data tables for water discharge and water quality parameters.

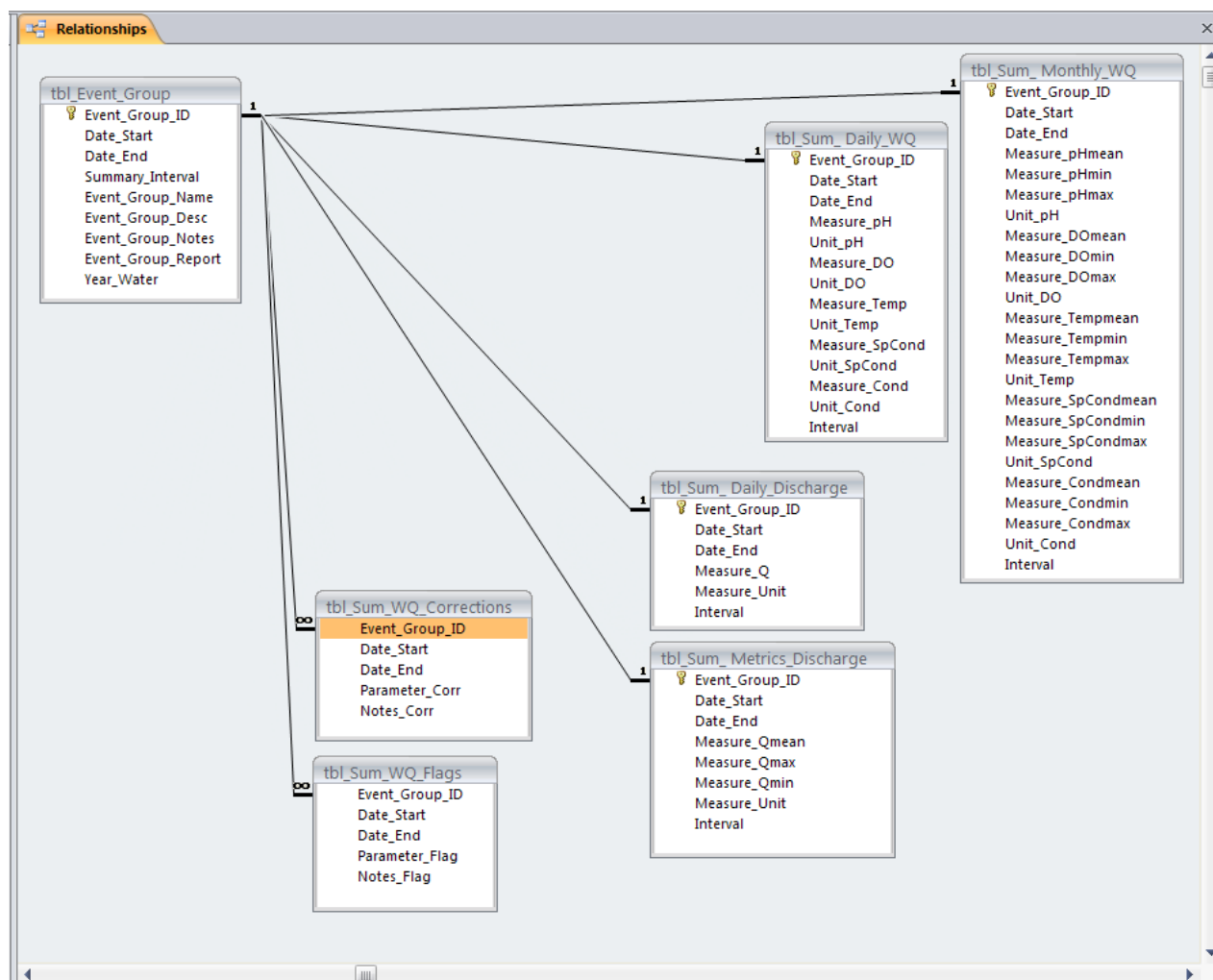


Figure SOP 18.4. Relationships among the summary data generated and imported from Aquarius for the streams database.

18.4.2 Front-end database

The front end of the working streams database is currently under development. This section will be updated when it is completed.

18.5 Lakes Database Structure

18.5.1 Tables

Table SOP 18.2 lists and describes the subject-based Microsoft Access tables for the lakes master database. Tables include those that store field data, summary data from processed continuous logger files, calculated data fields, enumeration tables, and look-up tables. A detailed data dictionary of the tables and description of the fields is documented in [LK_MasterDB_DataDictionary.pdf](#), a report created using a tools developed by Kingston (2006).

Table SOP 18.2. Microsoft Access tables for the lakes database.

Table Name	Table Description
tbl_1_Db_Meta	Database description and links to I&M metadata tools
tbl_1_Db_Revisions	Database revision history data.
tbl_Data_Core	Core Field Collected Data
tbl_Data_Secchi	Secchi disk data
tbl_Data_WQ_AMSplus	Discrete AMS+ for water quality assurance assessment
tbl_Data_WQ_Calibration	Discrete water quality calibration data
tbl_Data_WQ_Vert_Prof	Discrete (one-time) water quality data for a vertical profile on a lake
tbl_Equip_Maint_Log	Equipment maintenance log
tbl_Event_Details	Sampling event details
tbl_Event_Group	Event aggregations (e.g. seasons, trips); Summary data events for data generated by Aquarius and HOBOWare software
tbl_Events	Sampling events
tbl_Lab_Chemistry	Water quality chemistry data from laboratory analyses
tbl_Locations	Sampling unit locations
tbl_Metadata_NPStoret_MTPC	Tool to collect and format NPStoret metadata - In Development
tbl_Metadata_NPStoret_MTPC_Personnel	Tool to collect and format NPStoret metadata - In Development
tbl_Metadata_NPStoret_Project	Tool to collect and format NPStoret metadata - In Development
tbl_Metadata_NPStoret_Project_Citations	Tool to collect and format NPStoret metadata - In Development
tbl_Sites	Location aggregations
tbl_Sum_Daily_WQ	Daily water quality; Summary data derived from processed continuous logger data
tbl_Sum_Ice	Calculated ice data on lakes; derived from continuous data loggers
tbl_Sum_Lk_Level	Summary lake level data derived from processed continuous logger data
tbl_Sum_Monthly_WQ	Monthly mean core water quality parameters; Summary data derived from
tbl_Sum_WQ_AMSplus	Summary statistics for AMS+ data
tbl_Sum_WQ_Corrections	Corrections applied to the continuous logger data
tbl_Sum_WQ_Flags	Flags generating during the processing of the continuous logger data
tlu_Contacts	Contact data for project-related personnel
tlu_Enum_Admin	Enumerated lookup table for administrative variables
tlu_Enum_NPSEDD	Enumerated lookup table for NPStoret
tlu_Enum_Water	Enumerated lookup table for water quality and quantity variables
tlu_Equip	Equipment list and serial numbers
xref_Event_Contacts	Cross-reference table between events and contacts

The database structures presented in Figures SOP 18.5 to 18.7 were simplified by limiting the number of tables per view.

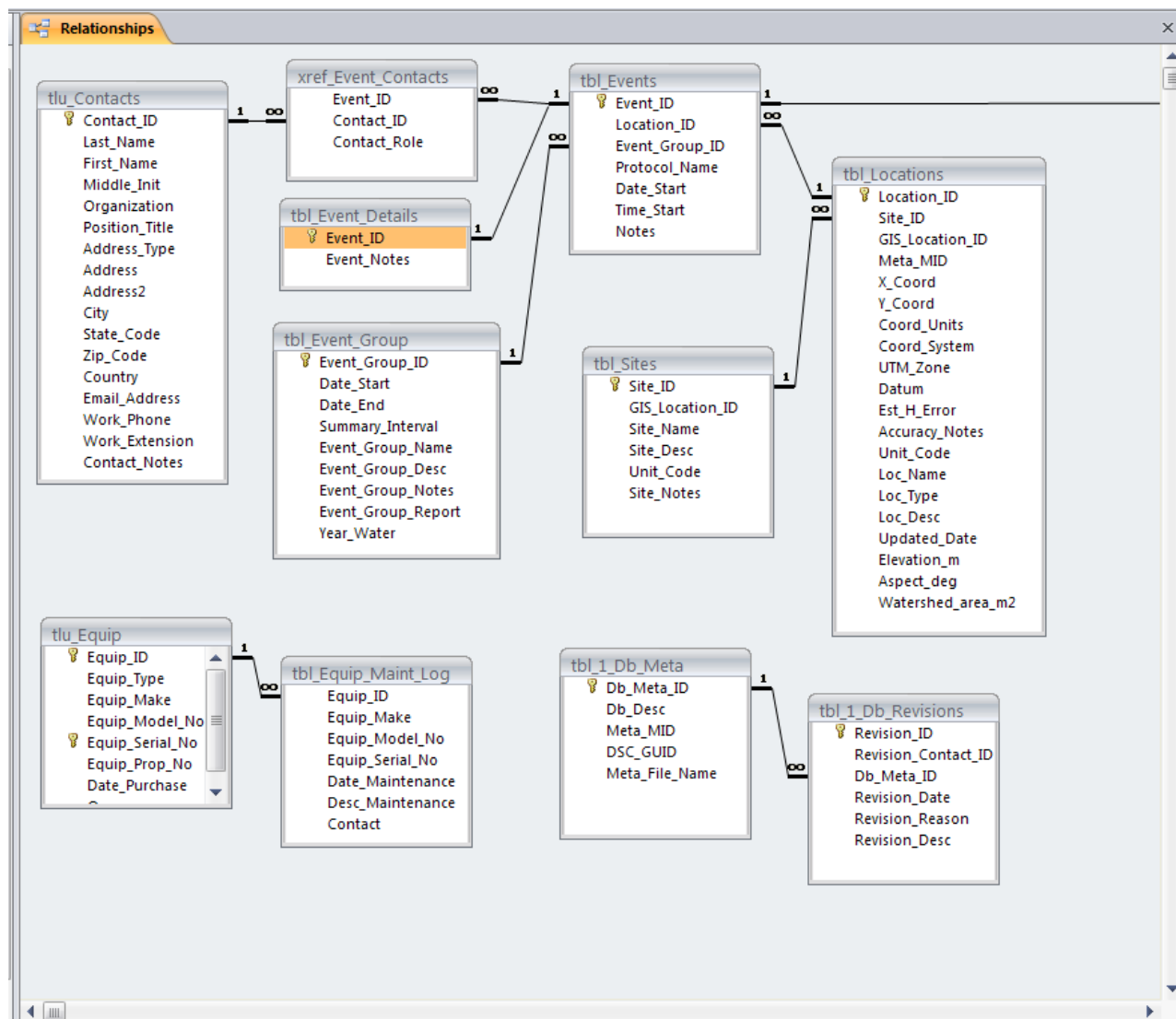


Figure SOP 18.5. Relationships among the administrative tables in the lakes master database.

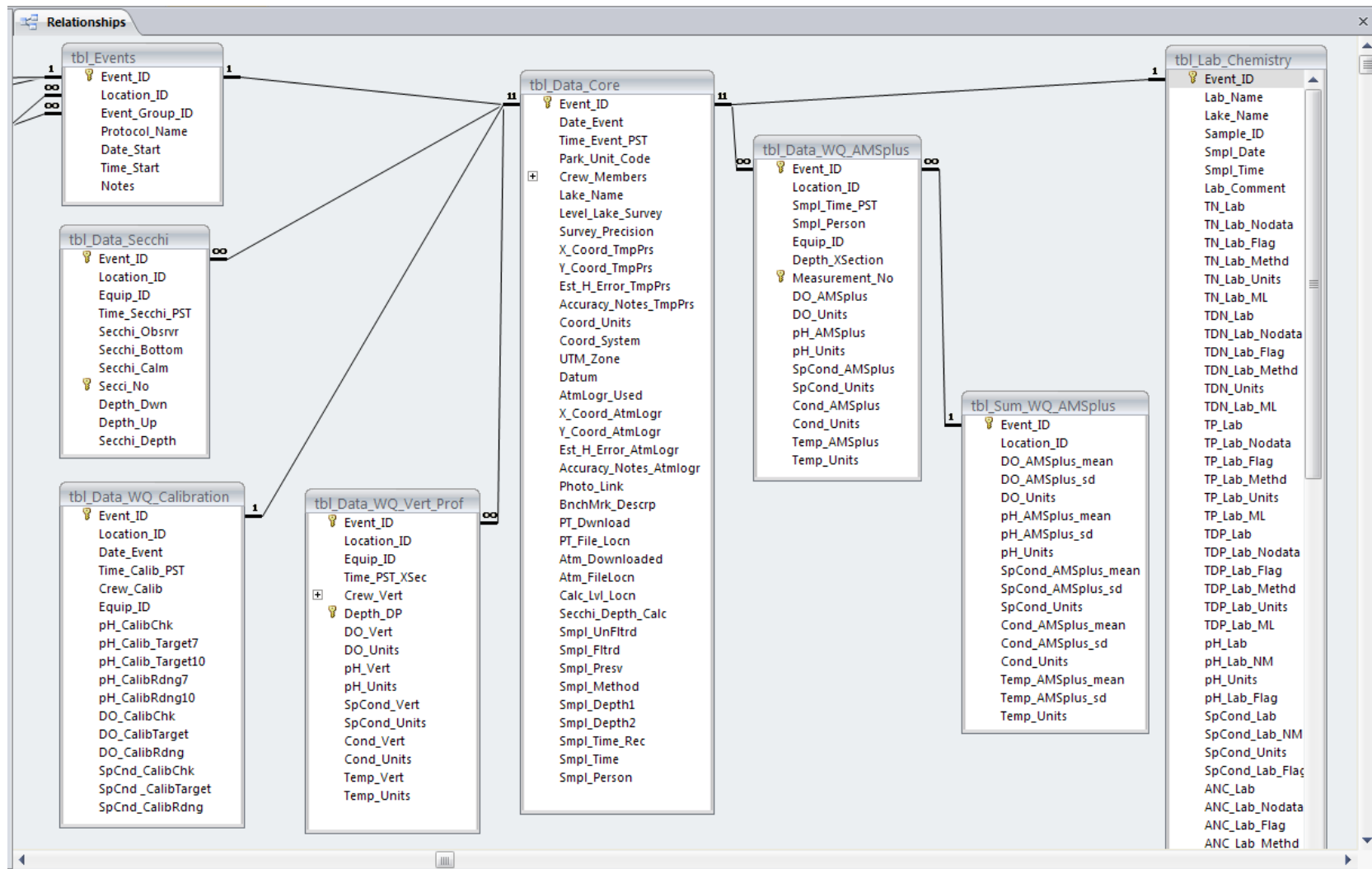


Figure SOP 18.6. Relationships among the field data tables, laboratory results, and AMS+ summary in the lakes master database.

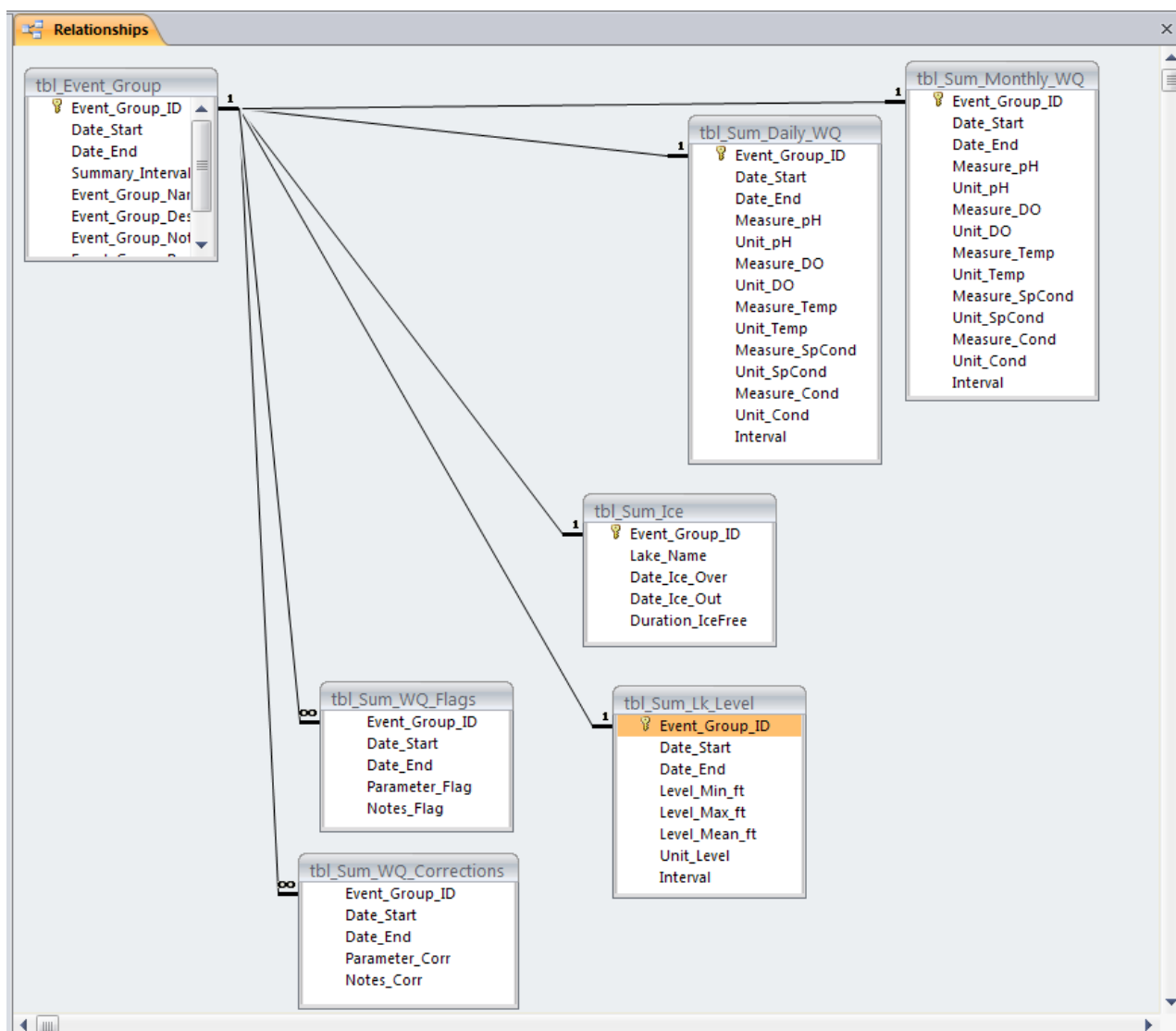


Figure SOP 18.7. Relationships among the summary data in the lakes master database. Summary data are derived from the continuous logger data.

18.5.2 Front-end database

The working lakes database is currently under developed. This section will be updated when it is completed.

18.6 Updating the Database Design

Lessons learned through years and updates to the protocol will require adjustments and additions to the master and working databases. The master and working databases changes are tracked using version controls in the **tbl_1_Db_Revisions** as well as a version number in the file name. Version numbers will be incremented by one (e.g., Version 1.3 to Version 2.0) each time there is a significant change in the structure and/or protocol methods. Version numbers will be incremented by tenths (e.g., Version 1.6 to Version 1.7...1.10...1.21) when there are changes to

field names, field structure, data entry tables, queries, and any other minor modifications that do not affect the data.

18.7 Version Information

Table SOP 18.3. Version information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 19. Information Management Workflow and Tasks

19.1 Information Management Workflow

19.1.1 Introduction

This SOP describes the numerous steps required to receive, process, and manage the data generated for the Streams and lakes protocol. Schematics in Figure SOP 19.1 and SOP 19.2 provide the overall workflow for the entire project. Streams and Lakes monitoring protocol is an integration of both water quality (e.g. chemistry) and water quantity (e.g. discharge and lake water level) procedures. Although the data for both procedures will be collected simultaneously in many instances, the processing workflows are distinctly different and are differentiated in this document. Tandem with the two workflow schematics are outlines of tasks that need to be accomplished in a timely manner throughout the life-cycle of the protocol.

19.1.2 Scope

The Streams and lakes protocol information management workflow is all inclusive description of all data generated, processed on-site by the network, processed off-site at laboratories or parks, stored on-site and off-site, reported, and archived.

19.1.3 Roles and Responsibilities

Information management tasks are the responsibility of the Data Manager and the Protocol Lead. While many of the tasks are undertaken by field technicians, the ultimate responsibility for proper training and techniques is with the Protocol Lead. The Data Manager is responsible for ensuring that all information, primarily in the form of digital and non-digital data associated with the protocol is properly received, processed, stored, and archived.

19.1.4 Stream and Lake Discharge Data

Figure SOP 19.1 summarizes the overall schema for data collection, analyses, archiving, processing, and storing water level for lakes and streams and stream discharge data. Continuous and discrete data are collected and processed.

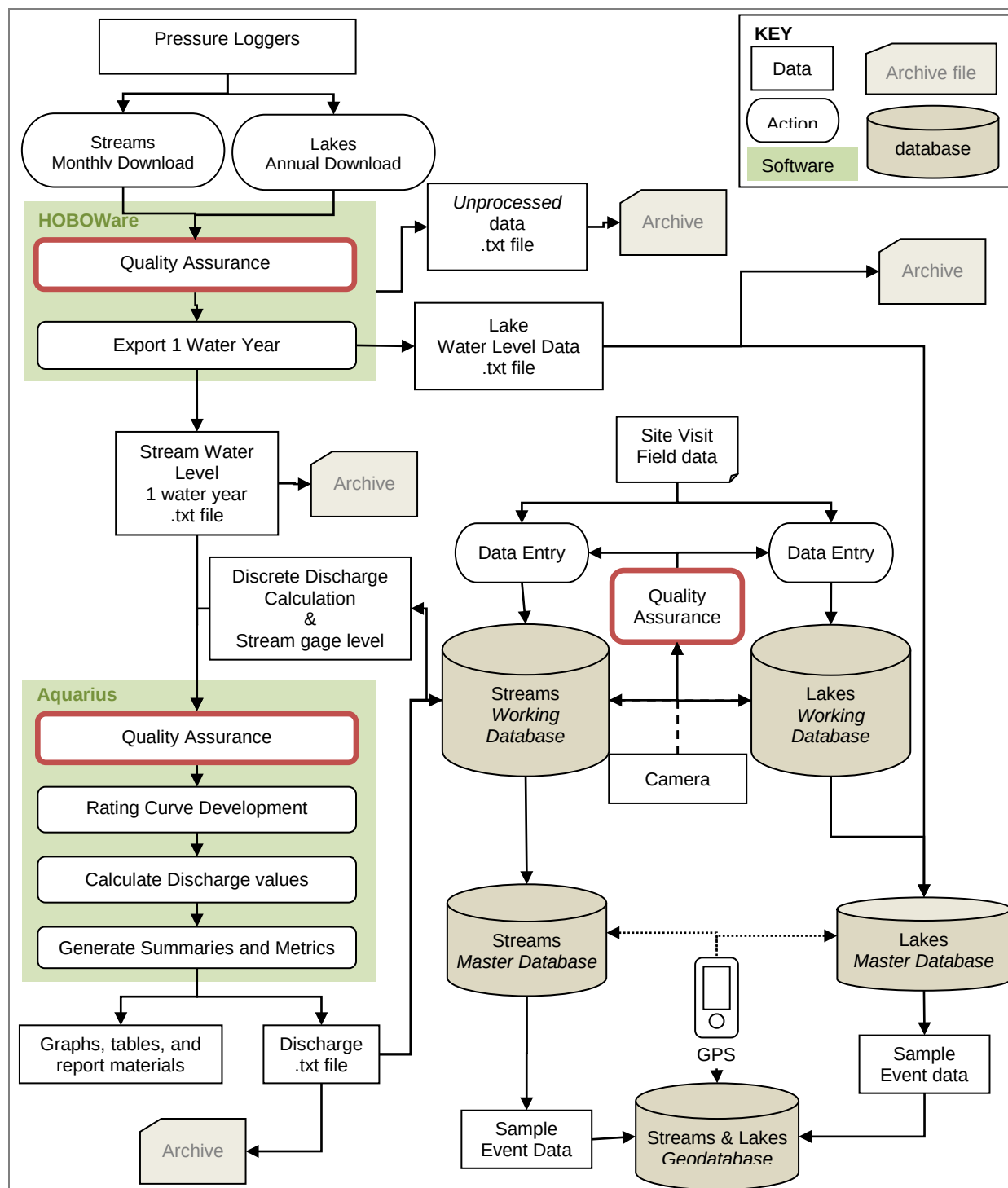


Figure SOP 19.1. Information management work flow for discharge and stream and lake water level data.

19.1.5 Stream and Lake Water Quality Data

Figure SOP 19.2 presents the overall schema for water quality data collection, analyses, archiving, processing, and storing water quality data for lakes and streams. Continuous and discrete data are collected.

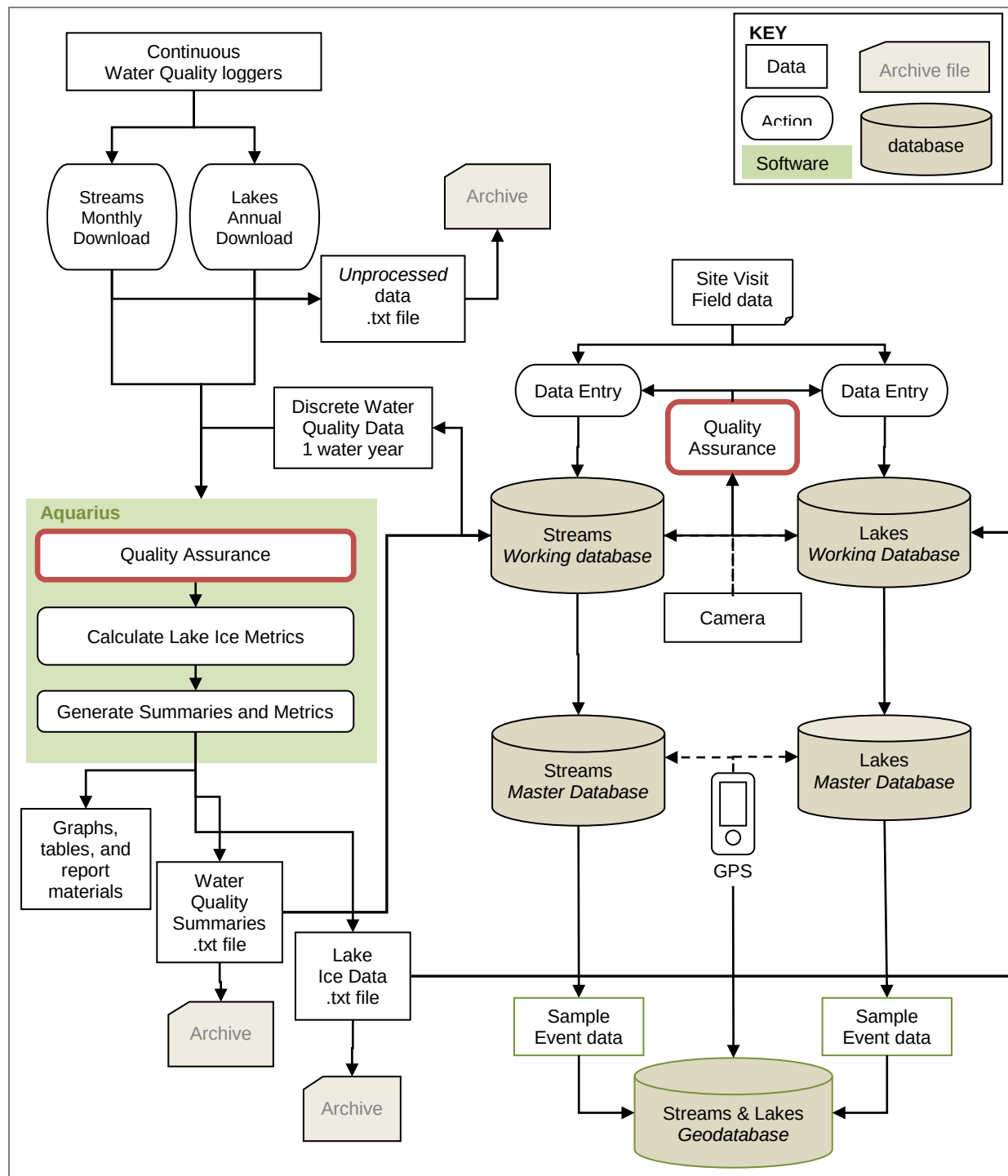


Figure SOP 19.2. Information management workflow for water quality in streams and lakes and ice data in lakes.

19.1.6 Stream and Lake Data Acquisition and Initial Processing

Figure SOP 19.3 details the data acquisition steps and products for discrete water velocity, gage level readings, and water quality data from stream site visits. All data are initially uploaded to the working database for quality assurance review. Figure SOP 19.4 presents the data acquisition steps for lake water levels and the initial products generated from lake site visits. The data are initially uploaded to the working lakes database for quality assurance review. Continuous data from loggers is downloaded and processed in HOBOWare to generate water levels for both streams and lakes data (Figure SOP 19.5). Water levels from lakes are not processed further and may be uploaded from HOBOWare export files, with a correction history and flags, to the lakes master database (Figure SOP 19.6). Stream level data is process further using Aquarius software and the discrete water levels and discharge from the site visits to generate stream discharge (Figures SOP 19.7 and SOP 19.8). Products from Aquarius are subsequently uploaded with correction history and flags to the streams master database. Water quality for streams and lakes is similar with the exception of ice cover metrics calculations that are exclusive to lakes (Figure SOP 19.9).

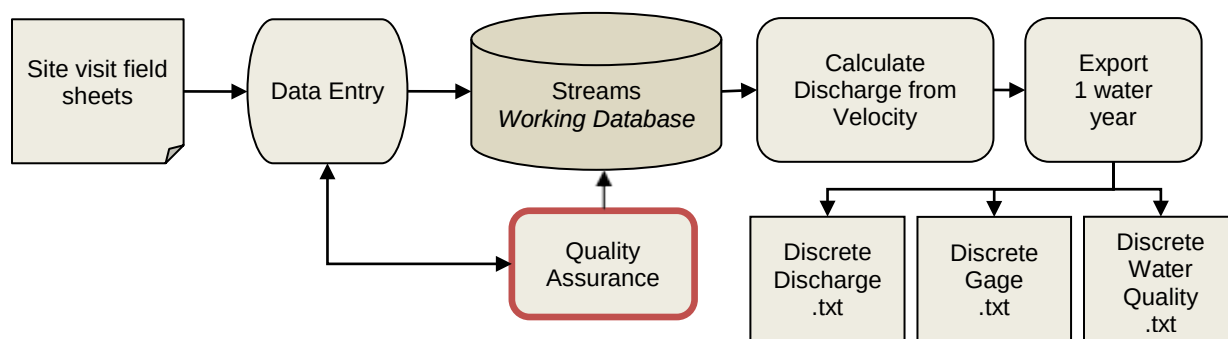


Figure SOP 19.3. Upload and process discrete water velocity, stream gage readings, and water quality data for streams.

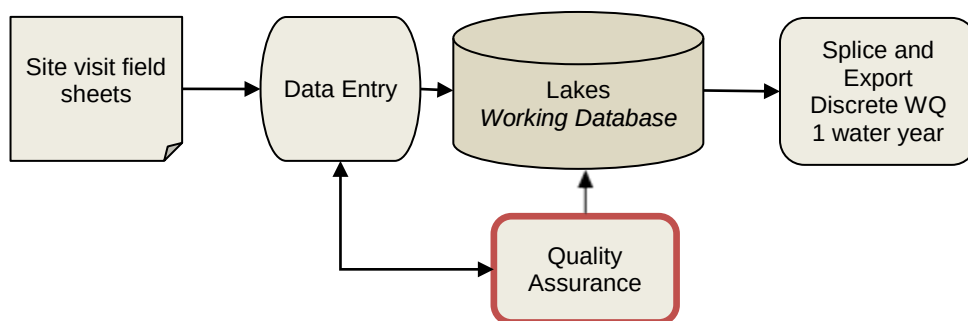


Figure SOP 19.4. Upload discrete water level and water quality data for lakes from field data sheets.

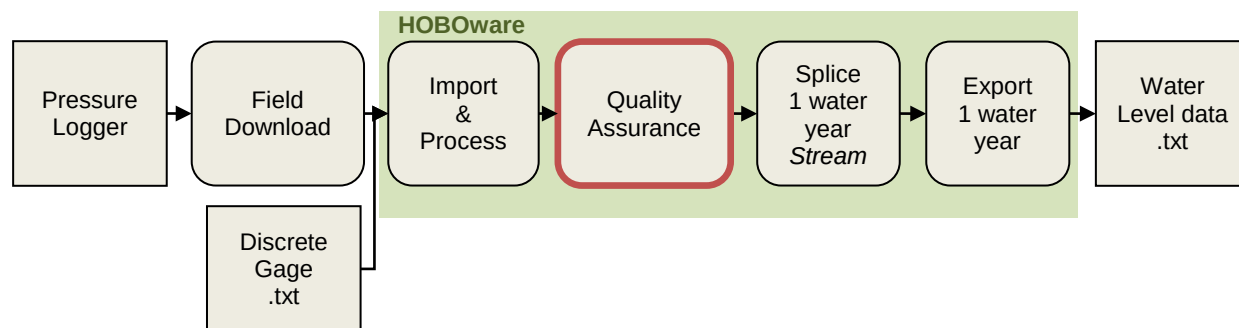


Figure SOP 19.5. Upload and process continuous stream and lake pressure data and convert to water levels using discrete water level gage readings.

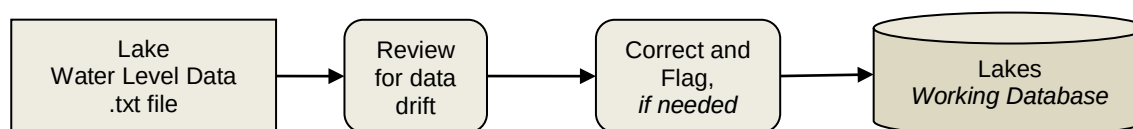


Figure SOP 19.6. Review and uploading water level data for lakes.

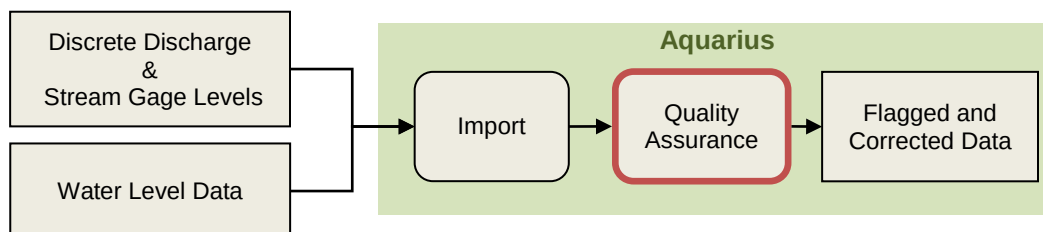


Figure SOP 19.7. Uploading and quality assurance review of the calculated discharge and continuous water level data.

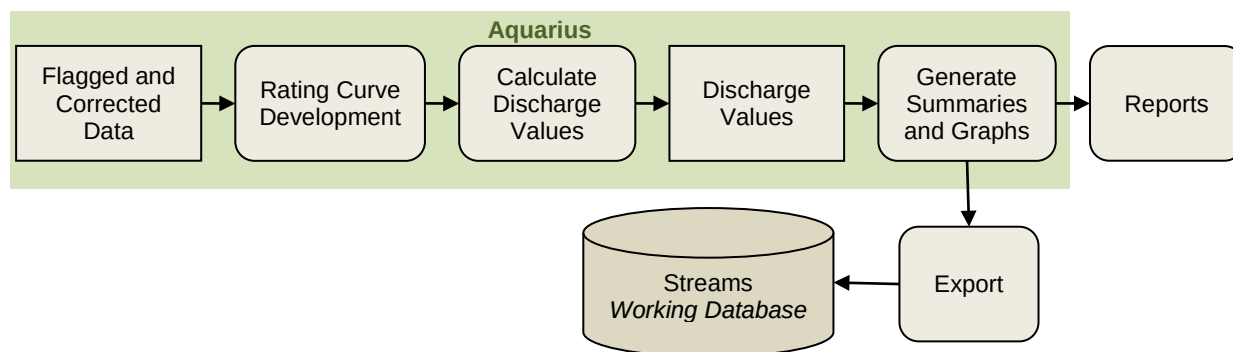


Figure SOP 19.8. Converting water level to discharge.

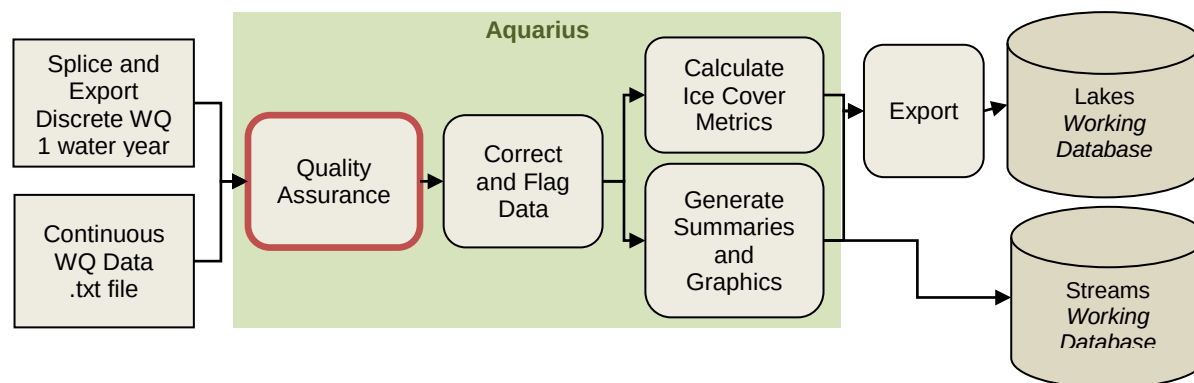


Figure SOP 19.9. Water quality processing steps for streams and lakes data.

19.1.7 Data Delivery

There are two types of data outputs required for the Streams and lakes protocol:

1. Data summary tables for the annual reports and quadrennial trend analysis reports
2. Water quality data formatted for export to WRD STORET

Data summarized and provided to the Protocol Lead for the annual reports and quadrennial trend analysis reports occur as needed in the format defined by the Protocol Lead. Water quality data uploads are conducted annually by the Data Manager as required by NPS Water Resources Division.

19.1.8 Archiving

A critical aspect of data management for all MOJN projects is the archiving of all data in a format that ensures future access and multiple locations as a safeguard against a catastrophic event. The standards and procedures are outlined in the *MOJN DM SOP Archiving*. The following sections provide a general overview of how the different types of data generated for this protocol are handled.

Field Data

The Streams and Lakes working database is archived annually at season closeout. A text file of all data tables are exported, the export file named using a standardized convention, and saved in the appropriate archive location.

Continuous Logger Files

Files downloaded from the pressure and water quality data loggers are in a proprietary format and unreadable without the proprietary software. To ensure long-term readability of all raw data logger files, data logger files are converted directly to ASCII (.txt) format and archived without any processing or changes to the original data (Figure SOP 19.10). The original raw files from the data loggers are archived with the ASCII files. Following the Quality Assurance review in Aquarius, the flagged and corrected data are exported and archived again (Figure SOP 19.11). In the coming years, MOJN will develop and implement a SQL Server database to house the original and corrected data logger values and archive the database as outlined in the *MOJN DM SOP Archiving*.

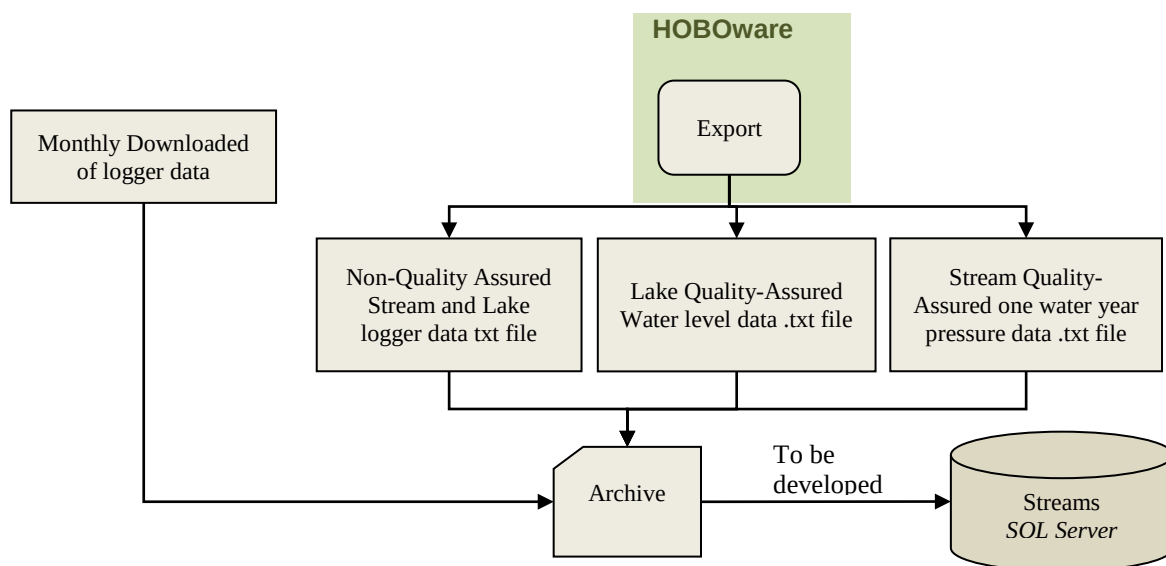


Figure SOP 19.10. Workflow for creating archive data files for continuous logger data. HOBOWare logger data are downloaded in a proprietary format and must be converted to a .txt file for archiving.

Aquarius Archive Files, including Continuous Data

The following is a summary list of the data files that must be archived:

1. HOBOWare raw data logger files readable only with proprietary software, two per location per month
2. Converted and unprocessed HOBOWare raw data files, two per location per month
3. Annual water year lake water level data files that have been quality assured, one per location
4. Annual water year stream pressure data files that have been quality assured, one to two per location
5. Discharge Rating curves for a water year (graphical and or tabular), two per location per month
6. Correction History of the discharge data, one per location

7. Discharge values on 15 minute intervals for a water year, one per location
8. Summary discharge data (e.g. daily mean, daily max, etc.) for a water year, one per location

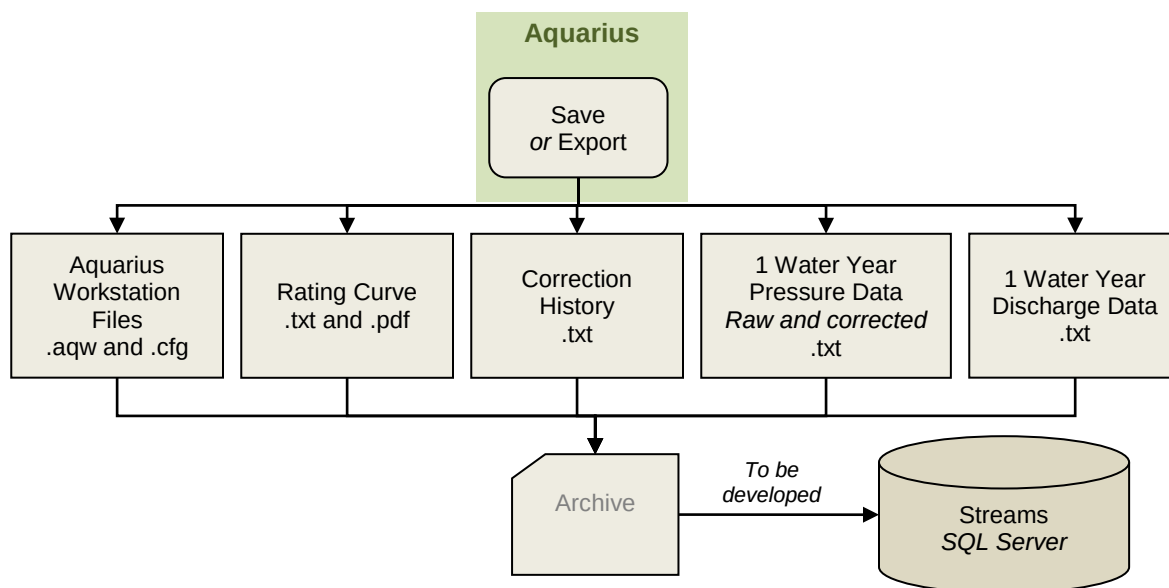


Figure SOP 19.11. Aquarius archive files.

19.2 Tasks and Schedule

Table SOP 19.1 lists the major tasks associated with the Information Management work. Each task has an estimate of the task duration for the Data Manager, GIS Specialist, and Data Technician and a frequency for the task.

Table SOP 19.1. Information Management Tasks. Acronyms for Data Manager (DM) and database (db) are used.

Task	DM Duration (hrs)	Responsibility	Completed By
Master Database			
Update structure (tables & relationships) as needed	16	DM and Protocol Lead	September 30
Working Database (field forms for data entry)			
Update structure	4	DM and Protocol Lead	June 30
Update data entry forms	24	DM and Protocol Lead	June 30
Data Acquisition (field datasheets and logger data)			
Standardize Location IDs; Update db tables	2	Protocol Lead and DM	October 31
Train data entry technician	8	DM	October 31

Table SOP 19.1. Information Management Tasks. Acronyms for Data Manager (DM) and database (db) are used (continued).

Task	DM Duration (hrs)	Responsibility	Completed By
Preliminary QA/QC and data entry	-	GRBA Field Crew	Every two weeks during field season
Upload device data (loggers, camera, etc.) to db/folders	4	DM	
Image Management (download and process)	2	DM	
Laboratory Results			
Reconcile sample events	-	Protocol Lead	March 1
Upload results from spreadsheets	4	DM	March 31
Reconcile accession and catalog numbers	4	DM	TBD
Quality Assurance (QA)			
100% verification of data entry	-	Data Entry Technician	March 31
10% validation of data entry	-	Protocol Lead	March 31
Develop QA queries	16	Protocol Lead and DM	March 31
Implement QA queries, correct, and flag data	8	Protocol Lead and DM	March 31
Data certification	4	Protocol Lead and DM	April 30
Transition data to master db	16	DM	April 30
Data Delivery			
Develop output format and contents	8	DM	May 15
Generate data output	8	DM	May 15
Upload summary data from Aquarius and QA upload	16	DM	May 15
Compile NPStoret data and metadata; Submit	16	DM and Protocol Lead	May 15
Maps and geospatial needs	10	GIS Specialist	May 15
Trend reporting needs (every 4 years, hours are 25% of total)	3	DM	May 15
Trend reporting needs (every 4 years, hours are 25% of total)	8	GIS Specialist	May 15
Project Deliverables			
Compile and disseminate project deliverables	4	DM	May 15
Post data and reports to NPS Info	2	DM	May 15
Close-out			
Season close-out (organize and eliminate)	32	DM and Protocol Lead	April 30
Season close-out (organize and eliminate)	8	GIS Specialist	April 30
Metadata for data, db, and archive files	8	DM	April 30
Metadata for geospatial data, db, and archive files	4	GIS Specialist	April 30
Archive	4	DM	May 30

19.3 Project Records Management

MOJN records management is legally mandated as per NPS Director's Orders #19. Records management ensures all items pertaining to the operation of the Network are retained, preserved, and accessible according to law and regulations. Records are all documentary materials, including books, electronic data, maps, moving images, papers, photographs and sound recordings, made or received by the National Park Service during the transaction of public business. Network protocols and data are considered records. To facilitate efficient management of these records, MOJN manages records using a structured workspace, and a standardized procedure for file naming conventions, protocol deliverables and an end-of-season closeout, and archiving.

At the end of the season, there is an annual closeout of the project files and data, during which all files are organized, reviewed for proper metadata and naming conventions, unnecessary files or duplicate files are destroyed in the project workspace and MOJN SharePoint site, and all project deliverables are verified as received (refer to *MOJN DM SOP Season Closeout*). The entire set of annual project deliverables is compiled within a single folder directory on the I&M MOJN SharePoint site and Integrated Resource Management Applications (IRMA) References for dissemination and access by the parks and archived according to *MOJN DM SOP Archiving*. The collection of project files is also maintained for long-term easy access during the project lifecycle in the project workspace for reference and in the case of the master database, long-term working files that are updated annually.

Hard copy records such as notebooks and field data sheets may be scanned to digital format; however, the original hard copy records are to be retained. Hard copy records are kept in the Protocol Lead's office until the Annual Report has been published. At that time, they are moved to a locked file cabinet in the Data Manager's office. After several years, they are moved to a secure off-site storage area.

19.4 Version Information

Table SOP 19.2. Version information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

SOP 20. Protocol Revision and Review

20.1 Overview

[This SOP was adapted from Carson and Coopridge 2006.]

This Standard Operating Procedure explains how to make changes to the Streams and lakes protocol narrative and accompanying SOPs, and explains procedures for tracking these changes. MOJN personnel editing the Protocol Narrative or any SOP need to follow this procedure to eliminate confusion in data collection and analysis methods.

This SOP also contains Table SOP 20.1, which lists the most current version of the protocol narrative and each of the SOP's. This will provide a single reference for ensuring that the most current documents are being used. Also included is a section containing comments from protocol review, responses to those comments and approvals. Information regarding the changes made in each revision is included in the "Version Information" section at the end of each SOP.

Table SOP 20.1. Most current versions of MOJN Streams and Lakes documents.

Document	Current Version	Date	Author/Contact
Streams and Lakes of the Mojave Desert Network, Protocol Narrative	1.00	9/15/2010	G. Moret
SOP 1: Safety	1.00	9/15/2010	G. Moret
SOP 2: Staff Training	1.00	9/15/2010	G. Moret
SOP 3: Field Season Preparations	1.00	9/15/2010	G. Moret
SOP 4: Post-season Activities	1.00	9/15/2010	G. Moret
SOP 5: Equipment Disinfection	1.00	9/15/2010	G. Moret
SOP 6: Handheld Water Quality Instruments	1.00	9/15/2010	G. Moret
SOP 7: Sample Handling, Storage, and Shipping	1.00	9/15/2010	G. Moret
SOP 8: Regulatory Status	1.00	9/15/2010	G. Moret
SOP 9: Stream Discharge	1.00	9/15/2010	G. Moret
SOP 10: Lakes Field Procedures	1.00	9/15/2010	G. Moret
SOP 11: Continuous Water Quality Sonde	1.00	9/15/2010	G. Moret
SOP 12: Stream Chemistry and BMI Sampling	1.00	9/15/2010	G. Moret
SOP 13: Laboratory Analysis of BMI	1.00	9/15/2010	G. Moret
SOP 14: Laboratory Analysis of Water Chemistry	1.00	9/15/2010	G. Moret
SOP 15: Quality Assurance Project Plan	1.00	9/15/2010	G. Moret
SOP 16: Cumulative Measurement Bias	1.00	9/15/2010	G. Moret
SOP 17: Data Analysis and Reporting	1.00	9/15/2010	G. Moret
SOP 18: Database Design	1.00	9/15/2010	J. Burke
SOP 19: Information Management Workflow and Tasks	1.00	9/15/2010	J. Burke
SOP 20: Protocol Revision and Review	1.00	9/15/2010	G. Moret

20.2 Protocol Revision Procedures

The Streams and Lakes Monitoring Protocol Narrative and accompanying SOPs are intended to incorporate the soundest methodologies for collecting and analyzing water quality and quantity data. However, all protocols require editing as new and different sample collection, analysis, and data management techniques becomes available. Required edits should be made as soon as they are deemed necessary and appropriate reviews conducted.

All edits will be reviewed for grammatical and technical accuracy and overall clarity. Minor changes or additions to existing methods will be reviewed “in-house” by the protocol lead. However, if a complete change in methods is anticipated, then an outside review is required. Regional (Pacific West Region) and National staff (Water Resources Division) of the National Park Service familiar with water quality monitoring and data analysis will be utilized as reviewers. Also, local and state experts in water quality monitoring and statistical methodologies outside of the National Park Service will be utilized in the review process. A group of technical experts was utilized for the external peer review of the initial Streams and lakes protocol; these individuals may be called upon again to provide input related to any significant revisions in methodology.

Edits and protocol revisions will be documented in the Revision History Log that accompanies the Protocol Narrative and each SOP. Only changes in the protocol narrative or specific SOP that has been edited will be logged. “Version numbers increase incrementally by hundredths (e.g. version 1.01, version 1.02 ...etc) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 ...). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, and the reason for making the changes along with the new version number.

The MOJN Data Manager must be notified of any changes to the Protocol Narrative or SOP so that the new version number can be incorporated in the Metadata of the WRD STORET database. The Data Manager will then edit the database per any changes to the Protocol Narrative and SOPs.

New versions should be posted on the internet and forwarded to all individuals with a previous version of the Protocol Narrative or SOP.

When any significant changes in the sampling protocol occur such as changes in sample collection techniques or equipment, a change in analytical laboratory, or changes in staff, there should be an overlap of methods and personnel (Oakley et al., 2003). The procedures for collecting and analyzing overlapping data are discussed in *SOP 16: Cumulative Measurement Bias*.

20.3 Protocol Review

The Protocol Review Checklist generated by the reviewers and the consolidated comments and responses from reviews are included in the Supplementary Materials. If significant changes to the protocol require additional review at a later date, then these comments and responses will also be included in the Supplementary Materials.

20.4 Version Information

Table SOP 20.2. Version information.

Version Number	Comment	Date
1.00	First peer-reviewed, published version	Mm/dd/yyyy

Literature Cited

- Adams, D., D. Press, M. Hester, H. Nevins, D. Roberts, B. Becker, H. Jensen, E. Flynn, M. Koenen, and S. Allen. 2009. San Francisco Bay Area Network pinniped monitoring protocol. Natural Resource Report NPS/SFAN/NRR—2009/170. National Park Service, Fort Collins, Colorado.
- APHA. 2005. Standard methods for the examination of water and wastewater; 21st Edition. American Public Health Association, Washington, D.C.
- Carson, R., and M. Coopridge. 2006. SFAN Freshwater quality monitoring protocol SOP #1: Protocol revision and review. National Park Service, Fort Collins, Colorado.
- Crawley, M. J. 2007. The R book. John Wiley and Sons, Ltd. Chichester, England.
- Cuffney, T. F., M. E. Gurtz, and M. R. Meador. 1993. Methods for collecting benthic invertebrate samples as part of the National Water-Quality Assessment Program. United States Geological Survey Open-File Report 93-406.
- EPA 2001. Environmental Protection Agency requirements for quality assurance project plans, EPA QA/R-5. EPA Office of Environmental Information, Washington, D.C.
- Helsel, D. R. 2005. Nondetects and data analysis: Statistics for censored environmental data. Wiley, New York, New York.
- Helsel, D. R., D. K. Mueller, and J. R. Slack. 2006. Computer program for the Kendall family of trend tests: U.S. Geological Survey Scientific Investigations Report 2005-5275.
- Hirsch, R. M., R. B. Alexander, and R. A. Smith. 1991. Selection of methods for the detection and estimation of trends in water quality. *Water Resources Research* 27:803–813.
- Hoffman, R. L., T. J. Tyler, G. L. Larson, M. J. Adams, W. Wente, and S. Galvan. 2005. Sampling protocol for monitoring abiotic and biotic characteristics of mountain ponds and lakes: U.S. Geological Survey Techniques and Methods 2-A2.
- Irwin, R. J. 2004. Draft Part B of aquatic habitat Park Service guidance for Park Service Vital Signs monitoring. Planning process steps: Issues to consider and then to document in a detailed study plan that includes a quality assurance project plan (QAPP) and monitoring “Protocols” (Standard Operating Procedures). Available at: <http://science.nature.nps.gov/im/monitor/protocols/wqPartB.doc>.
- Irwin, R. J. 2008. Draft Part B lite (Just the Basics) QA/QC review checklist for aquatic Vital Sign monitoring protocols and SOPs. National Park Service, Water Resources Division. Fort Collins, Colorado. Distributed online only at: http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/PartBLite.pdf

- Kingston, S. 2006. DataDictionary_2.mdb. Tool to extract a simple data dictionary from an MS Access database. http://www1.nrintra.nps.gov/im/datamgmt/databases/links_sources/index.cfm NPS access only.
- Ledder, T. 2003. Water resource information and assessment for the Great Lakes Inventory and Monitoring Network. Great Lakes Technical Report: GLKN/2003/05. National Park Service, Great Lakes Inventory and Monitoring Network, Ashland, Wisconsin.
- Moulton, S. R. II, J. L. Carter, S. A. Grotheer, T. F. Cufney, and T. M. Short. 2000. Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory - processing, taxonomy, and quality control of benthic macroinvertebrate samples. United States Geological Survey Open-File Report 00-212.
- National Park Service. 2007. Natural Resource Database Template version 3.2 documentation. Natural Resource Program Center, Office of Inventory, Monitoring, and Evaluation, Fort Collins, Colorado. Available at: <http://science.nature.nps.gov/im/apps/template/index.cfm>.
- National Park Service Director's Order #19. Available at: <http://www.nps.gov/policy/DOrders/DOrder19.html>
- Nordstrom, D. K., and F. D. Wilde. 2005. Reduction oxidation potential (electrode method). U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6., section 6.5. Available online: <http://pubs.water.usgs.gov/twri9A6/> (accessed April 2010).
- Peck, D. V., A. T. Herlihy, B. H. Hill, R. M. Hughes, P. R. Kaufmann, D. Klemm, J. M. Lazorchak, F. H. McCormick, S. A. Peterson, P. L. Ringold, T. Magee, and M. Cappaert. 2006. Environmental Monitoring and Assessment Program - surface waters western pilot study: Field operations manual for wadeable streams. EPA/620/R-06/003. U.S. Environmental Protection Agency, Washington, D.C.
- Penoyer, P. 2003. Vital Signs long-term aquatic monitoring projects: Part C draft guidance on WRD required and other field parameter measurements, general monitoring methods and some design considerations in preparation of a detailed study plan. National Park Service, Water Resources Division. Fort Collins, Colorado. Distributed online only at: http://www.nature.nps.gov/water/VitalSigns_index/VitalSignsdocuments.cfm.
- Piepho, H. P., and J. O. Ogutu. 2002. A simple mixed model for trend analysis in wildlife populations. Journal of Agricultural, Biological, and Environmental Statistics 7(3):350-360.
- Rantz, S. E., and others. 1982. Measurement and computation of streamflow. U.S. Geological Survey Water Supply Paper 2175.
- Ritz, G. F., and J. A. Collins. 2008. pH. U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6., section 6.4. Available at: http://water.usgs.gov/owq/FieldManual/Chapter6/6.4_contents.html (accessed April 2011).
- Schertz, T. L., R. B. Alexander, and D. J. Ohe. 1991. The computer program Estimate Trend (ESTREND), a system for the detection of trends in water-quality data. U.S. Geological

- Survey Water Resources Investigation Report 91-4040. U.S. Geological Survey, Reston, Virginia.
- Schweizer, D. W. 2007. Sierra Nevada Network lake monitoring protocol. Draft. National Park Service, Fort Collins, Colorado.
- Spilke, J., H. P. Piepho, and X. Hu. 2005. Analysis of unbalanced data by mixed linear models using the MIXED procedure of the SAS system. *Journal of Agronomy and Crop Science* 191:47-54.
- Starkey, E. 2009. UCBN integrated water quality monitoring protocol: Standard Operating Procedures. National Park Service, Ft. Collins, Colorado.
- Thoma, D., D. Sharrow, K. Wynn, J. Brown, M. Beer, and H. Thomas. 2009. Water quality Vital Signs monitoring protocol for park units in the Northern Colorado Plateau Network. National Park Service, Fort Collins, Colorado. Available at: http://science.nature.nps.gov/im/units/ncpn/Bib_Library/water_quality/NCPN_Water_Quality_Protocol.pdf.
- Thompson, R., C. Kamenik, and R. Schmidt. 2005. Ultra-sensitive alpine lakes and climate change. *Journal of Limnology* 64(2):139-152.
- Tucker, D. 2007. Part E: Draft guidance on data reporting and archiving in STORET, February 6, 2007 (Draft). Available at: http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/wqPartE.pdf.
- Tucker, D. 2010. Vital Signs water quality data management and archiving. Available at: <http://www.nature.nps.gov/water/infoanddata/index>.
- Turnipseed, D. P., and V. B. Sauer. 2010. Discharge measurements at gaging stations. U.S. Geological Survey Techniques and Methods 3-A8. U.S. Geological Survey, Washington D.C.
- VanLeeuwen, D. M., L. W. Murray, and N. S. Urquhart. 1996. A mixed model with both fixed and random trend components across time. *Journal of Agricultural, Biological, and Environmental Statistics* 1(4):435-453.
- Vinson, M. R., and C. P. Hawkins. 1996. Effects of sampling area and subsampling procedures on comparisons of taxa richness among streams. *Journal of the North American Benthological Society* 15:393-400.
- Wagner, R. J., R. W. Boulger, Jr., C. J. Oblinger, and B. A. Smith. 2006. Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1-D3.
- Wilde, F. D. 2006. Temperature. U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6., section 6.1. Available at: <http://pubs.water.usgs.gov/twri9A6/> (accessed April 2010).

YSI. 2005. YSI pH sensor performance. YSI Tech Note. Available at:
<http://www.ysi.com/media/pdfs/T611-YSI-pH-Sensor-Performance.pdf> (accessed April 2011).

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 963/117583, November 2012

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov