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Yakima Valley Dairies

Quality Assurance Project Plan

Groundwater Monitoring

Administrative Order on Consent

SDWA-10-2013-0080

June 17, 2013

ARCADIS
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Imagine the result

Quality Assurance Project Plan

Groundwater Monitoring

Administrative Order on Consent SDWA-10-2013-0080

Yakima Valley Dairies, Washington

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Quality Assurance Project Plan

Groundwater Monitoring

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Acronyms and Abbreviations

AOC	Administrative Order on Consent
CSM	conceptual site model
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FTL/SSC	Field Team Leader/Site Safety Coordinator
HSP	Health and Safety Plan
LHG	Licensed Hydrogeologist
MCL	maximum contaminant level
mg/L	milligrams per liter
PARCC	precision, accuracy, representativeness, comparability, and completeness
PC	Project Coordinator
QAM	Quality Assurance Manager
QAPP	Quality Assurance Project Plan
QC	quality control
SOP	standard operating procedure
SOW	Statement of Work

Distribution List (A3)

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1. Project Management (Group A)

1.1 Project/Task Organization (A4)

This section presents the organization structure and lines of communication that will be followed to implement the monitoring well installation and groundwater sampling and analysis activities presented in this Groundwater Monitoring Quality Assurance Project Plan (QAPP).

The Yakima Valley Dairies (Dairies) have retained ARCADIS U.S., Inc. (ARCADIS) to develop and implement the Groundwater Monitoring QAPP. The QAPP has been developed in accordance with requirements identified in Section III.E of the Statement of Work (SOW) (Appendix B of Administrative Order on Consent (AOC) SDWA-10-2013-0080). The QAPP was prepared in accordance with "Guidance for Quality Assurance Project Plans (QA/G-5)" (EPA 2002) and "EPA Requirements for Quality Assurance Project Plans (EPA QA/R-5) (EPA 2001, reissued May 2006). To ensure usability, completeness, and compliance with U.S. Environmental Protection Agency (EPA) guidance, QAPP elements are designated throughout this document by EPA guidance-defined groups, identified by numbers in parentheses next to headings and titles (e.g., A1, A2). In addition to the above guidance, data quality objectives (DQOs) were developed using the requirements included in the AOC SOW and in accordance with the "Guidance on Systematic Planning Using the Data Quality Objectives Process (QA/G-4)" (EPA 2006).

The project organization and lines of authority and communication are illustrated schematically on Figure 1.

The Project Coordinator (PC) will be responsible for the implementation of activities identified in the QAPP and will maintain communication with the EPA PC as required to communicate progress and resolve issues that may arise during the implementation of the QAPP, if necessary. The PC has overall authority over the project team and implementation of the QAPP.

The project chemist and Quality Assurance Manager (QAM) will assist in the development and review of project planning documents, evaluation of data, and preparation of deliverables.

Laboratory analysis of project samples will be performed by TestAmerica Analytical Laboratories, Inc. (TestAmerica) located at 11922 E 1st Avenue, Spokane, Washington, 509.924-9200. TestAmerica is a state of Washington-certified analytical laboratory.

The Field Team Leader/Site Safety Coordinator (FTL/SSC) will be responsible for sample collection activities and will implement the QAPP and Health and Safety Plan (HSP). A licensed hydrogeologist (LHG) will lead monitoring well completion activities.

The PC, project chemist, and QAM will develop appropriate corrective actions to address any potential quality assurance issues or deficiencies that may occur. Corrective actions will be communicated to the EPA PC and will be implemented and documented by the FTL or laboratory, as required.

1.2 Problem Definition/Background (A5)

1.2.1 Purpose

This Groundwater Monitoring QAPP defines and describes the processes and methods that will be employed to perform monitoring well installation and groundwater monitoring required under Section III.E of the AOC SOW. This QAPP was developed to document the type, quantity, and quality of data needed to meet project objectives and support key decisions, and describes the methods for collecting and assessing data collected as part of QAPP implementation.

1.2.2 Problem Statement

Pursuant to Section III.E of the AOC SOW, the objectives of the Groundwater Monitoring QAPP are to establish a baseline of groundwater quality information at the Dairies to evaluate whether actions taken to reduce nitrogen loading are effective over time, and to collect information to supplement and verify existing information on the environmental setting at the Dairies, including further clarification of the hydraulic gradient of the aquifer beneath the Dairies.

1.2.3 Conceptual Site Model

A conceptual site model (CSM) for the Dairies was developed in accordance with the guidance document: *Environmental Cleanup Best Management Practices, Effective Use of the Project Life Cycle Conceptual Model* (EPA 2011). The CSM is presented in Figure 2. The CSM provides a graphic description of how nitrogen from various

potential dairy facility sources may reach groundwater and eventually drinking water wells as nitrate. Potential sources of nitrogen from the dairy facilities include animal waste lagoons, animal waste management or storage ponds, and irrigated cropland. With respect to irrigated crop fields, the potential nitrogen sources include solid manure, liquid manure, and synthetic fertilizers applied to the surface soils. Different forms of nitrogen typically migrate through unsaturated subsurface soils and enter into the shallow alluvial aquifer. Nitrogen forms are converted to nitrate via nitrification through chemical and biological processes. Groundwater containing nitrate could be pumped from the shallow aquifer to drinking water wells for human consumption.

1.3 Project/Task Description and Schedule (A6)

1.3.1 Project/Task Description

The scope of this Groundwater Monitoring QAPP includes provision to collect information to supplement and verify existing information on the environmental setting at the Dairies and includes groundwater monitoring well installation, quarterly groundwater sampling, and laboratory analysis of groundwater samples. Information collected in accordance with this QAPP will be reported in the Groundwater Monitoring Well Installation Report and the Groundwater Monitoring Data Reports. Specific activities to be performed as part of this QAPP include the following:

- Drill and install up to 23 groundwater monitoring wells at locations identified in the AOC SOW (Table 1; Figures 3 and 4). Twenty wells will be completed in the shallow portion of the surficial aquifer with three of these wells located upgradient of the Dairies at the Dairies discretion. Three wells will be completed in the deep portion of the surficial aquifer. Monitoring wells will be drilled, installed, and developed as described in the Monitoring Well Installation Work Plan (Appendix A).

- Collect lithologic information from well boreholes to supplement and verify existing information on the environmental setting.

- Set well screens in monitoring wells completed in the shallow portion of the surficial aquifer across the water table as determined at the time of monitoring well installation (e.g., 15 feet of screen below the water table and 5 feet of screen above the water table). Set the top of the screen in monitoring wells completed in the deeper portion of the surficial aquifer at approximately 45 feet below the water table at the time of installation.

- Develop monitoring wells in accordance with the method presented in the *Monitoring Well Development Guidelines for Superfund Project Managers* (April 1992).

- Monitor groundwater wells on a quarterly basis. Monitoring will include gauging water levels, measuring field parameters, and collecting water samples for laboratory analysis.

- Analyze quarterly groundwater samples for analytes presented in Section 2.4 at a state of Washington-certified analytical laboratory.

- Install pressure transducers in up to six monitoring wells within the boundary of the Dairies to measure fluctuations in the water table and provide additional information regarding hydraulic gradient. Two of the pressure transducers will be installed in a shallow / deep well pair to evaluate changes in head between the shallow and deep zones. Measurements from the transducers will initially be collected on a weekly basis.

- Survey monitoring well locations and elevations. The survey will be performed by a Washington State licensed professional land surveyor. Wells will be surveyed and existing well elevations converted to the National Geodetic Vertical Datum (NGVD), 1929, or updated to North American Vertical Datum of 1988 (NAVD88) to an accuracy of within 0.01 foot. Horizontal surveying accuracy will be within 1.0 foot using the Washington State Coordinate System.

- Prepare a Groundwater Monitoring Well Installation Report including lithologic logs and well construction details. This report, as well as subsequent Groundwater Monitoring Data Reports, will present a comprehensive discussion on the environmental setting in accordance with Section III.E.1.a of the AOC SOW including geology and hydrogeology beneath the Dairies, hydrogeologic characteristics affecting groundwater flow and contaminant migration. The reports will present discussions on human influences, including off-site structures and conditions that may affect hydrology, hydrogeology, and migration of contaminants at or from the Dairies. The reports will include descriptions of surface water flow regimes, both regional and on/near the Dairies.

1.3.2 Project Schedule

Task	Start Date	Completion Date
Groundwater Monitoring QAPP	Upon the Effective Date of the AOC	May 20, 2013 (60 days after the Effective Date of the AOC)
Monitoring well drilling, installation, and development	Upon EPA Approval of the Groundwater Monitoring QAPP	45 days after approval of the QAPP
Install pressure transducers	Within 5 days of completion of installation and development of monitoring wells	5 days after completion of well installation and development activities
Survey wells	Within 5 days of completion of installation and development of monitoring wells	10 days after completion of well installation and development activities
Initial groundwater sampling	Within 5 days of completion of installation and development of monitoring wells	30 days after completion of well installation and development activities
Submittal of Groundwater Monitoring Well Installation Report	Upon completion of field activities	60 days after completion of monitoring well installation and development activities
Quarterly groundwater sampling.	3 months after commencement of the previous sampling event	3 months after completion of the previous sampling event
Submittal of validated groundwater nitrate analytical results	Upon receipt of laboratory data	Within 30 days of collecting last sample of each sampling event

Task	Start Date	Completion Date
Quarterly Groundwater Monitoring Data Reports		60 days after each quarterly monitoring event for at least the first year, with later adjustment at the discretion of EPA
Annual Groundwater Monitoring Data Reports		March 1 of each year after the Effective date beginning in 2014 (as part of the Annual Report described in Section III.K.2 of the AOC SOW)

1.4 Quality Objectives and Criteria (A7)

1.4.1 Project Quality Objectives

Project-specific Data Quality Objectives (DQOs) were identified through the DQO process (EPA 2006) to meet the data user's needs for each activity. The specific data needs for the Groundwater Monitoring focus primarily on nitrate concentrations in groundwater that may be used for drinking water purposes. The DQO decision-making process for the Groundwater Monitoring is described in Appendix B.

The data needs for the Groundwater Monitoring are summarized in Table 2. This table lists the specific analytes, regulatory limits and measurement criteria, and data uses. The different criteria that were evaluated to develop the data needs are described in the DQO decision-making process (Appendix B).

1.4.2 Measurement Performance Criteria

Measurement performance criteria are often expressed in terms of data quality indicators. The principal indicators of data quality are precision, accuracy, representativeness, comparability, and completeness (PARCC criteria). The following are definitions for the assessment of data quality indicators summarized from "Guidance for Quality Assurance Project Plans (EPA QA/G-5) (EPA 2002):

Precision is the measure of agreement among repeated measurements of the same property under identical or substantially similar conditions and is calculated as either the range or standard deviation.

Accuracy is a measure of the overall agreement of a measurement to a known value. It includes a combination of random error (precision) and systematic error (bias) components of both sampling and analytical operations.

Representativeness is a qualitative term that expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process conditions, or an environmental condition.

Comparability is a qualitative term that expresses the measure of confidence that one data set can be compared to another and can be combined for the decision to be made.

Completeness is a measure of the amount of valid data needed to be obtained from a measurement system.

Precision, accuracy, and completeness criteria are shown in Table 3.

1.5 Special Training/Certification (A8)

All personnel working on the project site will be trained in health and safety in accordance with the Health and Safety Plan (HSP). All personnel will comply with the requirements included in the HSP regarding site-specific hazards and conditions. Training requirements, documentation, and tracking are included in the HSP.

The laboratory performing analysis of groundwater samples is TestAmerica Analytical Laboratories, Inc. (TestAmerica). Section III.A.3.a of the AOC SOW requires laboratories analyzing non-drinking water samples to be accredited by the state of Washington, National Environmental Laboratory Accreditation Program (NELAP) or equivalent as determined by EPA. TestAmerica's certification is included in Appendix C. TestAmerica will comply with the requirements for analytical laboratories described in Section III.A.3.a of the AOC SOW.

1.6 Documents and Records (A9)

All field activities will be documented in field notebooks and the appropriate field forms included in Appendix D. Field documentation may include, but is not limited to:

- Boring/Monitoring Well Log
- Well Development Record
- Groundwater Sampling Record
- Chain-of-Custody Form
- Daily Field Activities Record

All field team-generated documentation will be compiled and submitted to the FTL and PC for distribution, inclusion in the project records, and use in subsequent reporting.

Laboratory documentation will be provided in accordance with the methods and protocols discussed in Section 4 of this QAPP. Laboratory analytical data will be distributed to the PC. The PC will distribute the data to the EPA, project team members, and others as required.

2. Data Generation and Acquisition (Group B)

Considering the primary objective of the project (as detailed in Section 1.2.2), a field activity and sampling strategy has been designed to ensure that all information, sample collection, analytical data and resulting decisions are technically sound, scientifically valid, and properly administered.

2.1 Sampling Design (Experimental Design) (B1)

The objectives of the project will be accomplished by the installation of groundwater monitoring wells and sampling groundwater from the surficial aquifer. Monitoring wells will be completed in both the shallow and deep portions of the surficial aquifer. Table 1 presents a summary of the proposed monitoring wells, well locations, and the rationale for each wells' location.

2.1.1 Groundwater Monitoring Well Installation and Development

The procedures for drilling and developing the monitoring wells are presented in the Groundwater Monitoring Well Installation Work Plan (Appendix A).

2.1.2 Groundwater Well Sampling

Groundwater samples will be collected from newly installed groundwater monitoring wells and previously installed EPA monitoring wells. Groundwater monitoring wells that will be included in groundwater sampling efforts are shown in Figures 3 and 4 and summarized in Table 1. As noted in Table 1, not all monitoring wells located at the upgradient boundary of the Dairy Facilities may be installed. Well drilling locations will be approved by EPA in the field prior to the commencement of drilling, and that the Dairies will coordinate with EPA to facilitate EPA's approval.

Section III.3.b of the AOC SOW requires groundwater samples to be analyzed for nitrate, nitrite, ammonia, phosphorus, total Kjeldahl nitrogen, select inorganic anions and metals, and alkalinity. Section 2.2 presents a description of the sampling methodology that will be employed to collect samples.

Laboratory analytical results will be used to establish baseline groundwater quality at the Dairies. Quarterly results from subsequent sampling events will be used to evaluate nitrate concentrations in groundwater over time to evaluate the effectiveness of nitrogen source actions taken as part of the AOC SOW.

2.1.3 Groundwater Level Monitoring

Long-term groundwater levels will be monitored using pressure transducers in six monitoring wells to evaluate seasonal fluctuations and trends in groundwater elevations. Two pressure transducers will be installed in one of the shallow/deep monitoring well pairs to evaluate differences in head between the shallow and deep portions of the surficial aquifer. The remaining transducers will be placed in monitoring wells located within the Dairy Facilities to allow evaluation of groundwater gradients. Transducers will be vented in order to compensate for barometric pressure changes. Transducers will be suspended in the well screen intervals below the water table to the extent that water level fluctuations will not expose the transducers to air. Further, the transducers will be appropriately rated for the respective anticipated head in each well. Transducers will be secured within the steel surface casing to prevent vandalism and/or tampering.

Recorded data will be downloaded from transducers on a weekly basis. During the weekly downloads, water levels in wells will be manually gauged using a water level meter.

2.2 Groundwater Sampling Methods (B2)

This section presents the sampling methodology for the collection of laboratory analytical samples from groundwater monitoring wells. Groundwater monitoring well sampling activities will be conducted by field teams comprised of two field staff.

2.2.1 Sample Collection

Groundwater samples will be collected from the newly installed and developed monitoring wells and previously installed EPA wells summarized in Table 1 and presented in Figures 3 and 4. Groundwater samples will be collected using low-flow sample collection procedures described in the Standard Operation Procedure (SOP) entitled *Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells* (Appendix E). Low-flow sample collection is a method that minimizes the impact of the purging process on groundwater chemistry and results in a smaller volume of purge water.

The low-flow sample collection method requires water quality indicator parameters and water levels to be measured during purging, prior to sample collection. Stabilization of the water quality indicator parameters, and monitoring water levels, is a prerequisite to sample collection. The water quality indicator parameters to be measured include dissolved oxygen, oxidation-reduction potential, pH, specific conductance, temperature, and turbidity. Analyte specifications for field parameters and stabilization criteria are presented in Table 4. Sample container types, the number of containers, holding times, and preservation for required analytes are specified in Table 3.

2.2.2 Sampling Equipment Decontamination

Decontamination of sampling equipment will follow the procedures presented in the SOP entitled Field Equipment Decontamination (Appendix F).

2.3 Sample Handling and Custody (B3)

This section describes sample management and documentation procedures that will be followed during Groundwater Monitoring to ensure that samples keep their original condition during sample collection, transportation, storage, and analysis. All sample control and chain-of-custody procedures will follow the SOP entitled Chain-of-Custody, Handling, Packing and Shipping (Appendix G) except where noted.

2.3.1 Sample Labeling Methodology

All samples collected for laboratory analysis will be assigned a unique sample number and will include samples, field duplicates, and field blanks using the nomenclature system described in this section. Sample identification for well samples, duplicates, and field blanks will be as follows:

Well sample	YVD-01-date
Field duplicate	YVD-D1-date
Field blank	YVD-F1-date

where “date” is in the form of year, month, and day (i.e., yymmdd). One field duplicate sample will be collected for every ten samples. Field blanks will be prepared daily. For example, sample no. YVD-07-130815 would refer to groundwater sample collected from monitoring well YVD-07 on August 15, 2013. Comparatively YVD-D3-131110 would refer to field duplicate number 3 collected on November 10, 2013, and YVD-F2-140217 would refer to field blank number 2 collected on February 17, 2014.

Each sample collected in the field will be labeled for future identification. Sample labels will be filled out as completely as possible by a member of the sampling team prior to the start of the day’s field sampling activities. The date, time, sampler’s signature, and the last field of the sample identification number should not be completed until the sample is actually collected. All sample labels will be filled out using waterproof ink. At a minimum, each label will contain the following information:

- Sampler’s initials
- Sampler’s company affiliation
- Site location
- Sample identification number
- Date and time of sample collection
- Analyses required
- Sample matrix
- Sampler’s signature.

2.3.2 Sample Chain-of-Custody

Sample designation, sampling time and date, sampling personnel, and analyses will also be recorded on the field records, sample labels, and chains of custody. The purpose of the chain-of-custody is to ensure that the possession of samples is

traceable from the time of sample collection until the samples are analyzed. A sample is considered to be in custody when:

- It is in your possession.
- It is in your view, after being in your possession.
- It was in your possession and then you secured it.
- It is in a designated secure area that has restricted access.

To ensure proper control of samples in the field, it is important that as few people as possible handle the samples. The field sampler is the primary person responsible for the care and custody of samples until they are transferred or shipped. The PC and FTL will determine if proper custody procedures have been followed during field activities and, if deficiencies are found, will determine if additional sample collection is warranted.

All samples will be accompanied by a chain-of-custody record. When custody of samples is transferred, the individuals relinquishing and receiving the samples will sign and date the chain-of-custody record. The chain-of-custody record documents custody transfer from the sampler, often through another agent (shipping/transport company), to the laboratory sample custodian.

Prior to shipment, samples will be packaged properly and a chain-of-custody record will accompany each shipping container. All shipping containers will be sealed with custody seals for shipment/transport to the laboratory. Custody seals will be placed in a manner that will indicate if the container has been opened during shipment. Courier names and other pertinent information will be documented on the chain-of-custody record. All shipments will be accompanied by the chain-of-custody record that identifies the contents of the shipment. The original and one copy will be included in the shipment, an additional copy will be retained by the sampler and provided to the PC. All shipping documentation (e.g., freight bills) will be retained as part of the chain-of-custody documentation by the PC.

All samples collected for laboratory nitrate concentration analysis will be received by Ms. Cat Stapleton, or her designee, at TestAmerica located at 11922 E 1st Avenue, Spokane, Washington, 509.924-9200. Because of the 48-hour holding time for nitrate analysis by EPA method 300.0, samples will be shipped using an overnight delivery service each day (Monday through Thursday). TestAmerica will analyze the samples immediately upon receipt to ensure holding time compliance.

Upon arrival at the laboratory, the TestAmerica sample custodian will accept custody of the samples from the carrier and enter information about the shipment into a sample receipt log that will include the initials of the person delivering the package and the status of custody seals on the containers. The sample custodian will log in the samples following the laboratory standard operating procedure. Following sample analysis, the unused portions of all samples will be disposed of by TestAmerica in accordance with their laboratory SOP.

2.3.3 Field Logbooks and Field Sampling Forms

In addition to the chain-of-custody documentation described above, field log books and field sampling forms will be completed to document daily activities and observations. Field sampling forms will be completed at each groundwater monitoring well and will indicate if samples are collected, sample numbers, duplicate samples, and other pertinent information including significant events and observations that occur during sampling activities.

Data entry for sample collection, field measurements, and field equipment will follow the approach provided in the Field Log Book Entries SOP (Appendix H). Sufficient information will be noted in the field log books and on field sampling forms to enable participants to reconstruct events that occurred and to refresh the memory of field personnel if needed. Original copies of all field log books, field forms, and chain-of-custody documents will be retained by the PC in the project files.

2.4 Analytical Methods (B4)

Groundwater samples will be analyzed for the following analytes and methods:

- Nitrate (as Nitrogen) – EPA Method 300.0
- Nitrite (as Nitrogen) – EPA Method 300.0
- Ammonia – EPA Method 350.1
- Total phosphorus – EPA Method 365.1
- Total Kjeldahl nitrogen – EPA Method 351.2
- Inorganic anions (chloride, fluoride, sulfate) – EPA Method 300.0
- Metals (calcium, potassium, magnesium, sodium) – EPA Method 200.7
- Alkalinity (total and bicarbonate) – Standard Method 2320B

Table 3 presents the analytes, method, container, preservation method, and holding times for the groundwater samples collected during the Groundwater Monitoring.

2.5 Quality Control (B5)

This section presents the field and laboratory quality control (QC) requirements for Groundwater Monitoring.

2.5.1 Field Quality Control Samples

Groundwater Monitoring includes the collection of field QC samples including field duplicates and field blanks. The field duplicate samples will be collected immediately following collection of target samples using the same collection procedures. Field duplicate samples will be collected at a frequency of one in every ten samples. A field blank QC sample will be prepared by the sampling team at the beginning of each sampling day by filling a sample bottle with laboratory supplied deionized water. The field blank will remain in the sample container throughout the day. Field blanks will be prepared for each sample container and will be sent to the laboratory for analysis.

2.5.2 Laboratory Quality Control Procedures

Laboratory QC procedures include the following:

- Nitrate analysis of water samples according to EPA Method 300.0
- Instrument calibration and standards as defined in EPA Method 300.0
- Ammonia – EPA Method 350.1
- Total phosphorus – EPA Method 365.1
- Total Kjeldahl nitrogen – EPA Method 351.2
- Inorganic anions (chloride, fluoride, sulfate) – EPA Method 300.0
- Metals (calcium, potassium, magnesium, sodium) – EPA Method 200.7
- Alkalinity (total and bicarbonate) – Standard Method 2320B
- Laboratory blank measurements at a minimum 5 percent or one per batch frequency
- Accuracy and precision measurements at a minimum of one in 20 or one per set
- Data reduction and reporting according to the specified EPA Methods
- Laboratory documentation according to the specified EPA methods and laboratory SOP requirements.

2.6 Instrument/Equipment Testing, Inspection, and Maintenance (B6)

Instrument maintenance logbooks will be maintained in the laboratory at all times and will include a schedule of maintenance as well as a complete history of past maintenance for equipment used for the analysis of groundwater monitoring samples.

2.7 Instrument/Equipment Calibration and Frequency (B7)

The analytical laboratory will follow all calibration procedures and frequencies specified in the EPA methods listed in Section 2.5.2. The Horiba U50 multi-parameter water quality meter will be used to collect measurements during well purging and sampling. This instrument features an intetgrated control unit and sensors and is capable of making a maximum of 11 simultaneous measurements for various parameters (i.e., dissolved oxygen, oxidation-reduction potential, pH, specific conductance, temperature, and turbidity). The Horiba is composed of the sensor unit that is lowered into the water, and the hand-held monitor, which allows the user to view and log sensor readings. The field instrument will be calibrated daily or as recommended by the manufacturer using the manual calibration procedures specified in the SOP (Appendix I).

2.8 Inspection/Acceptance of Supplies and Consumable (B8)

Supplies and consumables will be inspected upon receipt. All sample bottles used for the collection of laboratory analysis samples will be provided by the laboratory and will be new and certified clean. Field sampling team members will make note of the information on the certificate of analysis that accompanies sample containers to ensure that they meet the specifications and guidance for contaminant-free sample containers. Any discrepancies will be brought immediately to the attention of the FTL.

2.9 Non-direct Measurements (B9)

Other than the data generated by EPA's sample collection in January 2013 from the monitoring wells included in this QAPP, no pre-existing data will be used to make decisions in support of the Groundwater Monitoring. All data used to support decision-making will be collected during the Groundwater Monitoring.

2.10 Data Management (B10)

All field data collected during the Groundwater Monitoring will be recorded on field forms. Pertinent information will be transferred to an Excel spreadsheet or similar electronic data management tool.

The analytical data obtained from the laboratory will be maintained in an electronic data management tool. All data will undergo review and validation as described in Section 4.

In addition, the data provided to the EPA will be in accordance with the procedures presented in “EPA Region 10 Monitoring and Analytical Data Deliverables Data Submission Process for Water Quality Exchange (WQX) Compatible Deliverables for Yakima Dairies (Docket No. SDWA-10-2013-0080), and “EPA Region 10 Geographic Information System Data Deliverable Guidance for Yakima Dairies (Docket No. SDWA-10-2013-0080). These documents are presented in Appendix J.

Data submitted to the EPA will be provided in the requested format which will be consistent with the examples provided by the EPA to ARCADIS. An example of the required file format was provided to ARCADIS in EPA file R10WQXEDD.zip.

3. Assessment and Oversight (Group C)

3.1 Assessments and Response Actions (C1)

The PC, QAM, and project chemist will monitor the performance of the QA procedures presented in this QAPP. The PC has the ultimate responsibility for implementation of this QAPP. If problems arise, or if directed by the PC, the QAM will conduct a field audit for the purpose of evaluating compliance with the guidance presented in this QAPP.

Laboratory analysis of samples collected during Groundwater Monitoring will be conducted by TestAmerica. Through their contract(s) with TestAmerica, the Dairies will require Test America to comply with EPA Methods listed in Section 2.5.2 of this QAPP and internal SOPs for sample analyses; QC; and instrument testing, inspection, maintenance, and calibration. If deficiencies are noted, TestAmerica will notify the PC. If such cases occur, the PC will notify the EPA PC and corrective action procedures will be implemented.

3.2 Reports to Management (C2)

3.2.1 Groundwater Monitoring Well Installation Report

The Groundwater Monitoring Well Installation Report will include, at a minimum, the following information for all groundwater monitoring wells used to meet the project objectives described in Section II of the AOC SOW.

- A description (in the form of a table) and map showing all well locations, including each well's surveyed surface reference point, vertical reference point elevation, well depth, and screened interval. The table which provides these data will reference the datum used for all measurements.

- Base map identifying monitoring well locations in reference to the potential source areas present. Base maps prepared from aerial photographs will reference: source of the photograph, date, north arrow, scale, altitude, name, photograph number or identification code, photo provider, camera calibration, etc. Image maps will be based on orthorectified or georegistered imagery.

- Site maps will show the locations of major features such as structures (buildings, tanks, lagoons, irrigated fields, fertilized fields, manure piles, unlined corrals, etc.), natural features, monitoring wells, other sampling locations, major surface topography characteristics, spill areas, discharge points (pipes, culverts, weirs, etc.), roads (including names), property and fence lines, etc. Site maps will also include the base map reference, date of latest revision, project name and number, site location, north arrow, scale, and legend with the appropriate information depicted on the map.

- Well logs will include boring and casing diameter and total depth of each well, description of the well screen interval including screen slot type, size, and length, depth of screen, filter pack materials, and method of filter pack emplacement.

- Documentation of methods used to seal each well from the surface to prevent infiltration of water into the well and downward migration of contaminants through the well annulus.

- Description of well development methods and procedures, including volume purged and parameter measurements.

- Documentation that all boring, well installation, and well abandonment procedures comply with all applicable federal, state, and local laws, and were conducted by a well driller licensed in the state of Washington.

- The Groundwater Monitoring Well Installation Report will be submitted within 60 days after completion of monitoring well installation and development activities

3.2.2 Groundwater Monitoring Data Reports

Quarterly and Annual Groundwater Monitoring Data Reports will be prepared following quarterly sampling events and annually starting in 2014, respectively. The Groundwater Monitoring Data Reports will present the findings of the groundwater monitoring work at the Dairies. Reports will include, but are not limited to, the following components:

- Each Quarterly Groundwater Monitoring Data Report will present, in tabular format, the field parameters and validated data with qualifiers, if applied, and complete analytical data package for constituents monitored in groundwater for each quarterly groundwater monitoring event. Each quarterly report will include figure(s) that depict, at a minimum, water level elevations and gradient and constituent concentrations.

- The second Quarterly Groundwater Monitoring Data Report will include all of the information, interpretation, and cumulative data presentation and be formatted to be representative of an Annual Groundwater Monitoring Data Report. Quarterly Groundwater Monitoring Data Reports will be submitted to the EPA after each quarterly data collection effort as required in Section III.A.e of the AOC SOW.

- Each Annual Groundwater Monitoring Data Report will include the same information contained in the Quarterly Groundwater Monitoring Data Reports, and will include a cumulative presentation of all data collected to date.

- Each Annual Groundwater Monitoring Data Report will contain a chart for each sample parameter at each well (e.g., time-concentration plots). The charts will include all historical data collected from each well.

- Each Annual Groundwater Monitoring Data Report will be submitted as part of the Annual Report described in Section III.K.2 of the AOC SOW.

3.2.3 Analytical Data Reporting

The analytical laboratory, TestAmerica, will submit sufficient laboratory documentation such that sample results are traceable to the field samples, and the analytical data can be verified and validated by an independent third-party review. Preliminary and validated data reports will be provided by the laboratory to the PC. The PC, QAM, and project chemist will review the data reports from the laboratory and will evaluate the data validation and usability as described in Section 4. Validated data, the validation report, and associated raw data will be submitted to EPA in accordance with the AOC.

The following information will either be supplied by the laboratory as a hard copy deliverables to support project activities, data validation and the documentation of data quality or maintained at the laboratory and available on request:

Data Deliverables (or maintained at the laboratory)
Case narrative including a discussion of nonconformance and corrective actions
Sample data and QC data summary forms
Chain-of-custody (COC) forms, sample receipt forms, logbook pages, shipping manifests
Verification of sample temperature on receipt
Copies of temperature logs for storage coolers used to store samples
Certificate of cleanliness for all laboratory-supplied sample bottles
Internal COC
Copies of SOPs
Sample and Standard preparation logs
Instrument Operating Conditions
Copies of sample analysis logbooks and analyst's notes
Instrument Run Log including copies of autosampler loading and verification of the autosampler loading
Raw data for instrument – hardcopy or electronic for field, calibration, and QC samples
Data review sheets

Data Deliverables (or maintained at the laboratory)
Example calculations
Control charts for method blanks, replicates, matrix spikes, matrix spike duplicates, laboratory control samples, and surrogates
Pertinent Method Detection Limit (MDL) studies and supporting information
Standards, standards reference materials, balance weights, and thermometer certificates
Verification of autopipettors and volumetric glassware
Balance calibration logs
Equipment maintenance records
Consumables acceptance and tracking records
Analyst's demonstration of precision and accuracy

The validated data, the data validation report, and the associated laboratory data will be submitted to the EPA in accordance with the AOC.

4. Data Validation and Usability (Group D)

4.1 Data Review, Verification, and Validation (D1)

Data verification will be conducted by the laboratory prior to submission to the PC. Data review, validation, and verification performed by the laboratory will comply with EPA requirements and laboratory SOPs for the EPA Methods specified in Section 2.5.2 of this QAPP.

4.2 Verification and Validation Methods (D2)

Prior to submitting the analytical samples to the laboratory, the sampling team leader or a designate will review the field notes and chain of custody for accuracy and completeness. The notes will be reviewed for appropriate documentation of the field work pertinent activities, including verifying complete residential information. The chain of custodies will be reviewed for appropriate sample nomenclature and selected analysis.

The analytical data generated shall be reduced, verified, and reported by the laboratory according to the EPA methods listed in Section 2.5.2 above. Data verification will be performed by the laboratory for all analyses prior to the release of the data to ARCADIS. The laboratory will archive the analytical data in their own laboratory data management system. In addition, the project chemist will validate laboratory data upon receipt.

4.2.1 Validation

An ARCADIS chemist will validate laboratory data upon receipt. The chemist will perform a Level II validation consistent with the National Functional Guidelines (EPA 2010). The checklist to be used in the validation process is presented in Table 5.

4.3 Reconciliation with User Requirements (D3)

Analytical data results obtained during the Groundwater Monitoring will be reconciled with precision, accuracy, and completeness criteria shown in Table 3.

5. References Cited

U.S. Environmental Protection Agency (EPA). 2001. EPA Requirements for Quality Assurance Project Plans (EPA QA/R-5). Office of Environmental Information, Washington, D.C. EPA/240/B-01/1003. March (reissued 2006).

EPA. 2002. Guidance for Quality Assurance Project Plans (EPA QA/G-5). Office of Environmental Information, Washington, D.C. EPA/240/R-02/009. December.

EPA. 2006. Guidance on Systematic Planning Using Data Quality Objectives Processes (EPA QA/G-4). Office of Environmental Information, Washington, D.C. EPA/240/B-06/001. February.

EPA. 2010. National Functional Guidelines for Inorganic Superfund Data Review. EPA/540/R-10/011. Contract Laboratory Program. January.

EPA. 2011. Environmental Cleanup Best Management Practices, Effective Use of the Project Life Cycle Conceptual Model. Office of Solid Wste and Emergency Response. EPA 542-F-11-011. July.

EPA. 2013. Administrative Order on Consent (AOC) Docket No. SDWA-10-2013-0080, March 19.

Puls, R.W. and M.J. Barcelona. 1996. Groundwater Issue Paper: Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures; U.S. Environmental Protection Agency, EPA/540/S-95/504, 12 pp.

Wild, F.D., D.B. Radtke, J.Gibs and R.T. Iwatsubo, eds., 1998, National Field Manual for the Collection of Water-Quality Data; U.S. Geological Survey Techniques of Water-Resources Investigations, variously paginated.

6. Certifications

6.1 Cow Palace Certification

I certify under the penalty of law that this document and all attachments were prepared by me or under my direction or supervision in accordance with a system designed to assure that qualified personnel gathered and evaluated the information submitted. Based on my inquiry of any and all persons directly responsible for gathering and analyzing the information obtained, I certify that the information contained in or accompanying this submittal is to the best of my knowledge and belief, true, accurate and complete. As to those identified portion(s) of this submittal for which I cannot personally verify the accuracy, I certify that this submittal and all attachments were prepared in accordance with procedures designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those directly responsible for gathering the information, or the immediate supervisor of such person(s), the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Cow Palace LLC

Signature: [redacted]

Name: [redacted]

Title: Member

Date: 5-17-13

6.2 D & A Dairy and George DeRuyter & Son Dairy Certification

I certify under the penalty of law that this document and all attachments were prepared by me or under my direction or supervision in accordance with a system designed to assure that qualified personnel gathered and evaluated the information submitted. Based on my inquiry of any and all persons directly responsible for gathering and analyzing the information obtained, I certify that the information contained in or accompanying this submittal is to the best of my knowledge and belief, true, accurate and complete. As to those identified portion(s) of this submittal for which I cannot personally verify the accuracy, I certify that this submittal and all attachments were prepared in accordance with procedures designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those directly responsible for gathering the information, or the immediate supervisor of such person(s), the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

D & A Dairy, LLC (also known as D and A Dairy L.L.C.),
George DeRuyter & Son Dairy, L.L.C

Signature: [redacted]

Name: [redacted]

Title: Member

Date: 5/20/13

6.3 George & Margaret Certification

I certify under the penalty of law that this document and all attachments were prepared by me or under my direction or supervision in accordance with a system designed to assure that qualified personnel gathered and evaluated the information submitted. Based on my inquiry of any and all persons directly responsible for gathering and analyzing the information obtained, I certify that the information contained in or accompanying this submittal is to the best of my knowledge and belief, true, accurate and complete. As to those identified portion(s) of this submittal for which I cannot personally verify the accuracy, I certify that this submittal and all attachments were prepared in accordance with procedures designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those directly responsible for gathering the information, or the immediate supervisor of such person(s), the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

George & Margaret, L.L.C.

Signature: [redacted]

Name: [redacted]

Title: Member

Date: 5/20/13

6.4 Liberty Dairy Certification

I certify under the penalty of law that this document and all attachments were prepared by me or under my direction or supervision in accordance with a system designed to assure that qualified personnel gathered and evaluated the information submitted. Based on my inquiry of any and all persons directly responsible for gathering and analyzing the information obtained, I certify that the information contained in or accompanying this submittal is to the best of my knowledge and belief, true, accurate and complete. As to those identified portion(s) of this submittal for which I cannot personally verify the accuracy, I certify that this submittal and all attachments were prepared in accordance with procedures designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those directly responsible for gathering the information, or the immediate supervisor of such person(s), the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Liberty Dairy, LLC and its associated dairy facility
H & S Bosma Dairy

Signature: [redacted]

Name: [redacted]

Title: Partner

Date: 5-17-13

Tables

Table 1
Proposed Monitoring Wells
Yakima Valley Dairies

	Coordinates[1]		PLS[2]							
Well ID	**Latitude**	**Longitude**	**Q-Q-Q[3]**	**Section**	**Township**	**Range**	**Landmarks**	**U/D[4]**	**Ground Elevation[5]**	**Anticipated Well Depth[6]**
YVD-01	-120.148065	46.417218	NW-NE-NE	26	11N	21E	Along southside of Houghton Road; 950 feet west of Canal Road	Upgradient	1260	200
YVD-02	-120.113624	46.421791	SW-NW-SE	19	11N	22E	Along southside of unimproved canal road; 600 feet west of Chapelle Road	Upgradient	1292	200
YVD-03	-120.138205	46.414107	NE-SE-NW	25	11N	21E	Along southside of Roza Canal; [redacted]	Upgradient	1144	200
YVD-04	-120.154032	46.408434	SE-NW-SE	26	11N	21E	Along southside of Roza Canal; 1650 feet west of Liberty Road	Upgradient	1126	200
YVD-05	-120.142472	46.405572	SW-SW-SW	25	11N	21E	Along northside of Zilla Drive; 620 feet east of Liberty Road	Upgradient	1063	200
YVD-06	-120.136571	46.407449	NE-SE-SW	25	11N	21E	[redacted] 1275 feet north of Zilla Drive; 140 feet west of Arms Road	Downgradient	1041	200
YVD-07	-120.125180	46.404709	SW-SW-SW	30	11N	22E	Northeast of intersection of Zillah Drive and Dekker Road	Upgradient	1073	200
YVD-08	-120.152198	46.396731	NE-NW-SE	35	11N	21E	[redacted] 1625 feet west of Liberty Road	Downgradient	1011	150
YVD-09	-120.144120	46.396740	NE-NW-SW	36	11N	21E	Middle of H&S Bosma Dairy; 675 feet east of Liberty Road	Downgradient	981	150
YVD-10	-120.136329	46.396756	SW-SW-NE	36	11N	21E	Along Arms Road; halfway between Zillah Drive and Kirks Road	Upgradient	969	150

Table 1
Proposed Monitoring Wells
Yakima Valley Dairies

	Coordinates[1]		PLS[2]							
Well ID	**Latitude**	**Longitude**	**Q-Q-Q[3]**	**Section**	**Township**	**Range**	**Landmarks**	**U/D[4]**	**Ground Elevation[5]**	**Anticipated Well Depth[6]**
YVD-11	-120.122838	46.393649	SW-NE-SW	31	11N	22E	Near southeast corner of triangle lagoon; 480 feet east of Dekker Road, 1385 feet north of Kellum Road	Downgradient	967	150
YVD-12	-120.166274	46.389838	SW-SW-SW	35	11N	21E	Southwest corner of field at intersection of Beam Road and Kirks Road	Downgradient	959	100
YVD-13	-120.150243	46.389670	SW-SE-SE	35	11N	21E	Along northside of Kirks Road; 640 feet west of Liberty Road	Downgradient	958	60
YVD-14	-120.144806	46.390185	SW-SW-SW	36	11N	21E	Along northside of Kirks Road; 400 feet east of Liberty Road	Downgradient	916	60
YVD-15	-120.137213	46.389932	SE-SE-SW	36	11N	21E	Southeast corner of field; 160 feet north of Kirks Road and 300 feet west of Arms Road	Downgradient	941	60
YVD-16	-120.116322	46.389227	NE-NE-NW	6	10N	22E	Northeast corner of field along southside of Kellum Road and 2650 feet east of Dekker Road	Downgradient	972	60
YVD-17	-120.142252	46.381488	SE-NW-SW	1	10N	21E	Along northside of Sunnyside Canal 680 feet south of Knowles Road	Downgradient	861	60
YVD-18	-120.147007	46.388516	SW-SE-SE	35	11N	21E	Along northside of Kirks Road; 720 feet west of Liberty Road	Downgradient	960	100
DC-03D	-120.146082	46.385979	SW-NW-NW	1	10N	21E	Along Liberty Road near DC-03 (MW-3)	Downgradient	915	125
DC-05D	-120.121629	46.382184	NE-NW-SW	6	10N	22E	Along Knowles Road near DC-05 (MW-5)	Downgradient	913	120
YVD-19	-120.131637	46.412528	NW-NW-SE	25	11N	21E	[redacted] southside of Roza Canal	Upgradient	1128	200

Table 1
Proposed Monitoring Wells
Yakima Valley Dairies

	Coordinates[1]		PLS[2]							
Well ID	**Latitude**	**Longitude**	**Q-Q-Q[3]**	**Section**	**Township**	**Range**	**Landmarks**	**U/D[4]**	**Ground Elevation[5]**	**Anticipated Well Depth[6]**
YVD-20	-120.120512	46.411808	NW-NE-SW	30	11N	22E	[redacted] southside of Roza Canal	Upgradient	1129	200
YVD-21	-120.114506	46.404196	NE-NE-NW	31	11N	22E	Along southside of Zillah Drive; 2760 feet east of Dekker Road	Upgradient	1074	200
DC-01	-120.138097	46.418786	NE-NE-NW	24	11N	21E	Along south side of E Houghton Road in Right-of-Way, 3,200 feet west of Dekker Road	Upgradient	1199.56 [7]	160 [8]
DC-03	-120.146117	46.386553	SW-NW-NW	1	10N	21E	Along east side of N Liberty Road in Right-of-Way, 1,100 feet south of Kirks Road	Downgradient	911.09 [7]	85 [8]
DC-04	-120.131111	46.382427	SE-SW-NE	1	10N	21E	Along south side of Knowles Road in Right-of-Way, 1,425 feet west of Dekker Road	Downgradient	877.82 [7]	51 [8]
DC-05	-120.120414	46.382457	SE-SE-NW	6	10N	22E	Along north side of Knowles Road in Right-of-Way, 1,300 feet east of Dekker Road	Downgradient	912.51 [7]	86 [8]
DC-07	-120.141583	46.389581	NE-NW-NW	1	10N	21E	Along south side of Kirks Road in Right-of-Way, 1,180 feet east of N. Liberty Road	Downgradient	889.91 [7]	61 [8]
DC-09	-120.121056	46.404209	NE-NW-NW	31	11N	21E	Along south side of E Zillah Drive in Right-of-Way, 1,090 feet east of Dekker Road	Downgradient	1049.10 [7]	196 [8]
DC-14	-120.139764	46.404274	NW-NE-NW	36	11N	21E	Along south side of E Zillah Drive in Right-of-Way, 1,300 feet west of N Arms Road	Downgradient	1037.13 [7]	151 [8]

Notes:
(1) Coordinates are approximate; actual coordinates may vary
(2) PLS = Public Land Survey - Williamette Meridian
(3) Q-Q-Q = 1/4-1/4-1/4 of the Section
(4) U/D = Upgradient/Downgradient
(5) Ground elevations are approximate; actual ground elevations may vary
(6) Total depth is approximate; actual depths may vary
(7) Elevation represnts Top Of Casing as reported by EPA
(8) Completed well depth as reported by EPA

Table 2
Data Needs
Groundwater Monitoring
Yakima Valley Dairies

Matrix	Analyte	Units	Lowest Potential Regulatory Level/Measurement Criteria	Data Use
Groundwater				
Field Measurements	Depth to water	feet	NA	Groundwater purging criteria
Field Measurements	Dissolved Oxygen	mg/L	+/- 0.3 mg/L	Groundwater purging criteria
Field Measurements	Oxidation-Reduction Potential	mV	+/- 10mV	Groundwater purging criteria
Field Measurements	pH	standard units	+/- 0.1 pH units	Groundwater purging criteria
Field Measurements	Specific Conductance	mmhos/cm	+/- 3% mmhos/cm	Groundwater purging criteria
Field Measurements	Temperature	Celsius	NA	Groundwater purging criteria
Field Measurements	Turbidity	NTU	+/- 10% NTUs (when turbidity is greater than 10 NTUs)	Groundwater purging criteria
Analytical Laboratory	Nitrate (as Nitrogen)	mg/L	10	Support decision for groundwater monitoring
Analytical Laboratory	Nitrite (as Nitrogen)	mg/L	1	Support decision for groundwater monitoring
Analytical Laboratory	Ammonia	mg/L	NA	Support decision for groundwater monitoring
Analytical Laboratory	Total Phosphorus	mg/L	NA	Support decision for groundwater monitoring
Analytical Laboratory	Total Kjeldahl Nitrogen	mg/L	NA	Support decision for groundwater monitoring
Analytical Laboratory	Choride	mg/L	250*	Support decision for groundwater monitoring
Analytical Laboratory	Fluoride	mg/L	4	Support decision for groundwater monitoring
Analytical Laboratory	Sulfate	mg/L	250*	Support decision for groundwater monitoring
Analytical Laboratory	Calcium	mg/L	NA	Support decision for groundwater monitoring
Analytical Laboratory	Potassium	mg/L	NA	Support decision for groundwater monitoring
Analytical Laboratory	Magnesium	mg/L	NA	Support decision for groundwater monitoring
Analytical Laboratory	Sodium	mg/L	NA	Support decision for groundwater monitoring
Analytical Laboratory	Alkalinity (total and bicarbonate)	mg/L	NA	Support decision for groundwater monitoring

Note:
NA = Not applicable
mg/L = milligrams per liter
mV = millivolts
mmhos/cm = micromhos per centimeter
NTU = nephelometric turbidity units
* = National Secondary Drinking Water Standard

Table 3
Data Needs
Groundwater Monitoring
Yakima Valley Dairies

Analyte	Method	Reporting Limit	Container	No. of Containers	Container Designation	Hold Time	Preservation	Accuracy	Precision	Completeness
Laboratory Measurements										
Nitrate (as Nitrogen)	EPA 300.0	0.2 mg/L	1 L polyethylene	1	1	48 hrs	≤6 °C	80-120%	+/-20%	90%
Nitrite (as Nitrogen)	EPA 300.0	0.2 mg/L	1 L polyethylene	1	1	48 hrs	≤6 °C	80-120%	+/-20%	90%
Ammonia	EPA 350.1	0.05 or 0.3 mg/L	1 L polyethylene	1	2	28 days	pH<2 with H_2SO_4 ≤6 °C	80-120%	+/-20%	90%
Total Phosphorus	EPA 365.1	0.02 mg/L	1 L polyethylene	1	2	28 days	pH<2 with H_2SO_4 ≤6 °C	80-120%	+/-20%	90%
Total Kjeldahl Nitrogen	EPA 351.2	0.5 mg/L	1 L polyethylene	1	2	28 days	pH<2 with H_2SO_4 ≤6 °C	80-120%	+/-20%	90%
Chloride	EPA 300.0	0.06 mg/L	1 L polyethylene	1	1	28 days	≤6 °C	80-120%	+/-20%	90%
Fluoride	EPA 300.0	0.04 mg/L	1 L polyethylene	1	1	28 days	≤6 °C	80-120%	+/-20%	90%
Sulfate	EPA 300.0	0.03 mg/L	1 L polyethylene	1	1	28 days	≤6 °C	80-120%	+/-20%	90%
Calcium	EPA 200.7	30 μg/L	1 L polyethylene	1	3	6 mos.	pH<2 with HNO_3 ≤6 °C	80-120%	+/-20%	90%
Potassium	EPA 200.7	700 μg/L	1 L polyethylene	1	3	6 mos.	pH<2 with HNO_3 ≤6 °C	80-120%	+/-20%	90%

Table 3
Data Needs
Groundwater Monitoring
Yakima Valley Dairies

Analyte	Method	Reporting Limit	Container	No. of Containers	Container Designation	Hold Time	Preservation	Accuracy	Precision	Completeness
Magnesium	EPA 200.7	50 µg/L	1 L polyethylene	1	3	6 mos.	pH<2 with HNO_3 ≤6 °C	80-120%	+/-20%	90%
Sodium	EPA 200.7	100 µg/L	1 L polyethylene	1	3	6 mos.	pH<2 with HNO_3 ≤6 °C	80-120%	+/-20%	90%
Total Alkalinity	SM2320B	5.0 mg/L	1 L polyethylene	1	1	14 days	≤6 °C	80-120%	+/-20%	90%
Bicarbonate Alkalinity	SM2320B	5.0 mg/L	1 L polyethylene	1	1	14 days	≤6 °C	80-120%	+/-20%	90%

Notes:
EPA = U.S. Environmental Protection Agency
mg/L = milligrams per liter
µg/L = micrograms per liter
NA = Not applicable
ml = milliliter
L = liter
°C = celsius

Table 4
Analyte Specifications for Field Parameters
Groundwater Monitoring
Yakima Valley Dairies

Analyte	Units of Measurement	Stabilization Criteria	Reference
Field Measurements			
Depth to water	feet	NA	NA
Dissolved Oxygen	mg/L	+/- 0.3 mg/L	Wilde et al., 1998
Oxidation-Reduction Potential	mV	+/- 10mV	Puls and Barcelona, 1996
pH	pH units	+/- 0.1 pH units	Puls and Barcelona, 1996; Wilde et al., 1998
Specific Conductance	mmhos/cm	+/- 3% mmhos/cm	Puls and Barcelona, 1996
Temperature	°C	NA	NA
Turbidity	NTU	+/- 10% NTUs (when turbidity is greater than 10 NTUs)	Puls and Barcelona, 1996; Wilde et al., 1998

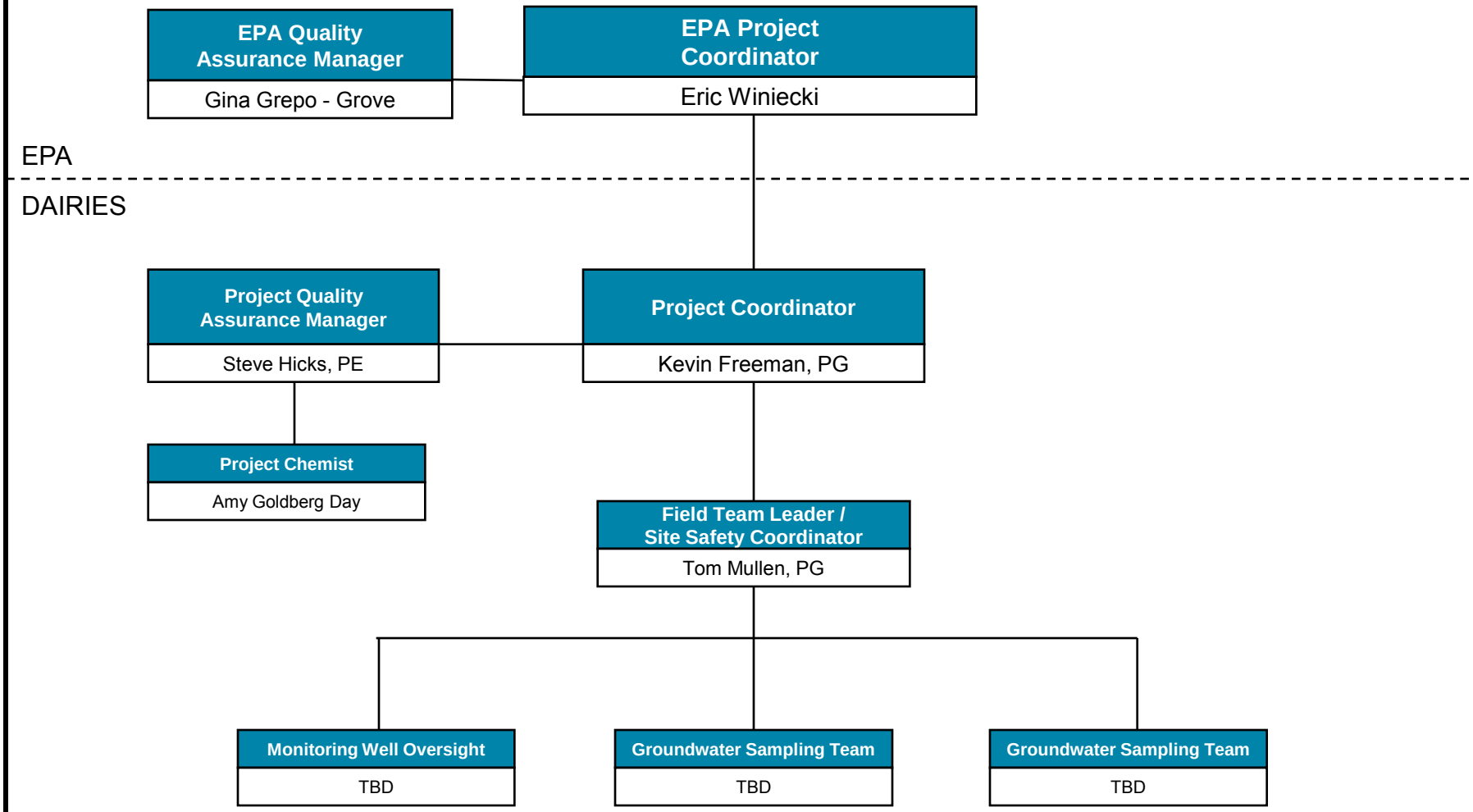
Notes:
NA = not applicable
mg/L = milligrams per liter
mV = millivolts
mmhos/cm =micromhos per centimeter
°C = celsius
NTU = nephelometric turbidity units

Table 5
Validation Checklist
Yakima Valley Dairies

Tier II Validation Criteria	Reported		Performance Acceptable		Not Required
	No	Yes	No	Yes	
Holding times					
Reporting limits (units)					
Blanks					
A. Method blanks					
B. Equipment blanks					
C. Trip blanks					
Laboratory Control Sample (LCS)					
Laboratory Control Sample Duplicate (LCSD)					
LCS/LCSD Precision (RPD)					
Matrix Spike (MS)					
Matrix Spike Duplicate (MSD)					
MS/MSD Precision (RPD)					
Field/Lab Duplicate (RPD)					
Dilution Factor					

%RSD Relative standard deviation
%R Percent recovery
RPD Relative percent difference
%D Percent difference

Figures

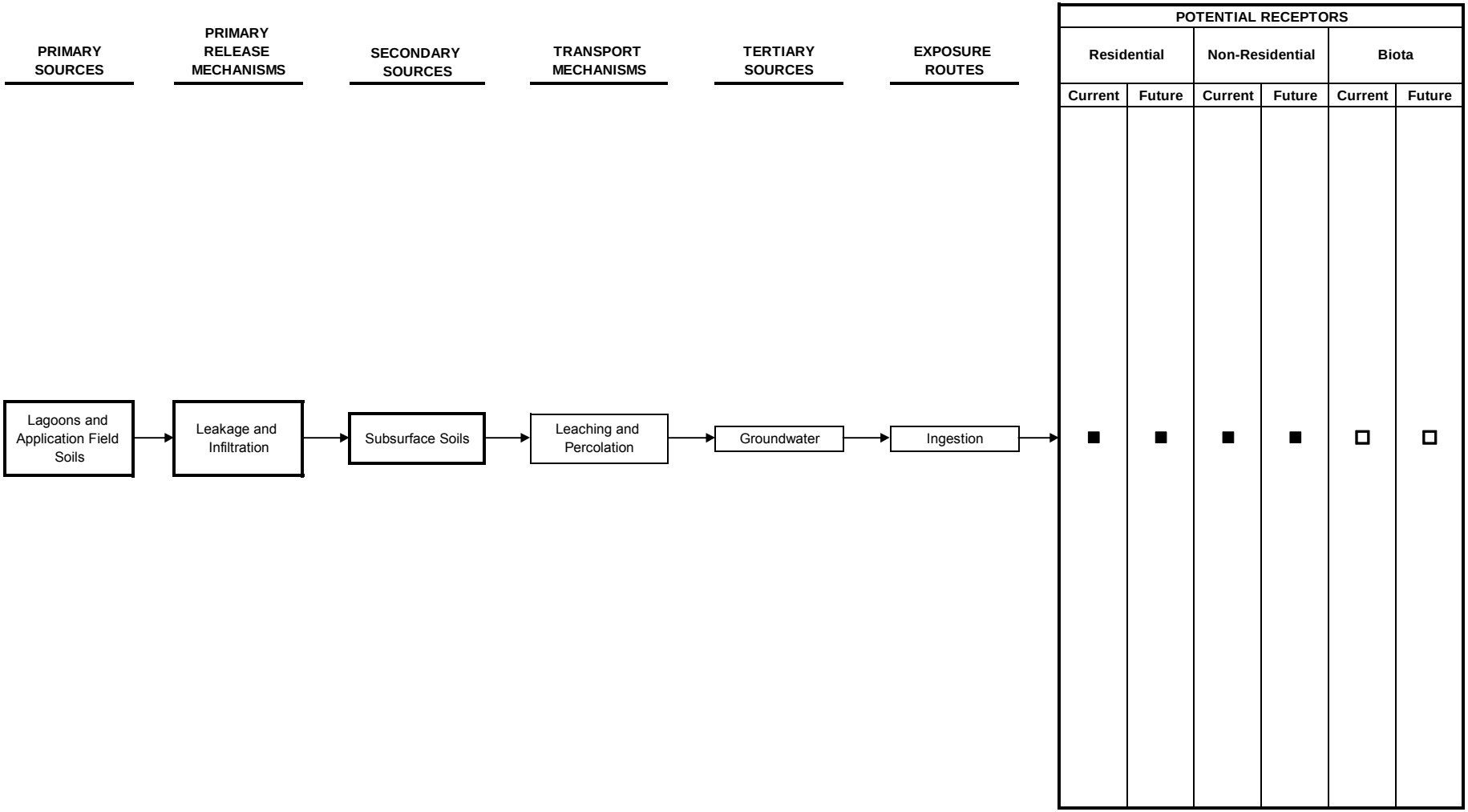


YAKIMA VALLEY DAIRIES

Project Organization
Groundwater Monitoring

ARCADIS

FIGURE
1



Notes:

■ This route is a primary source of exposure.

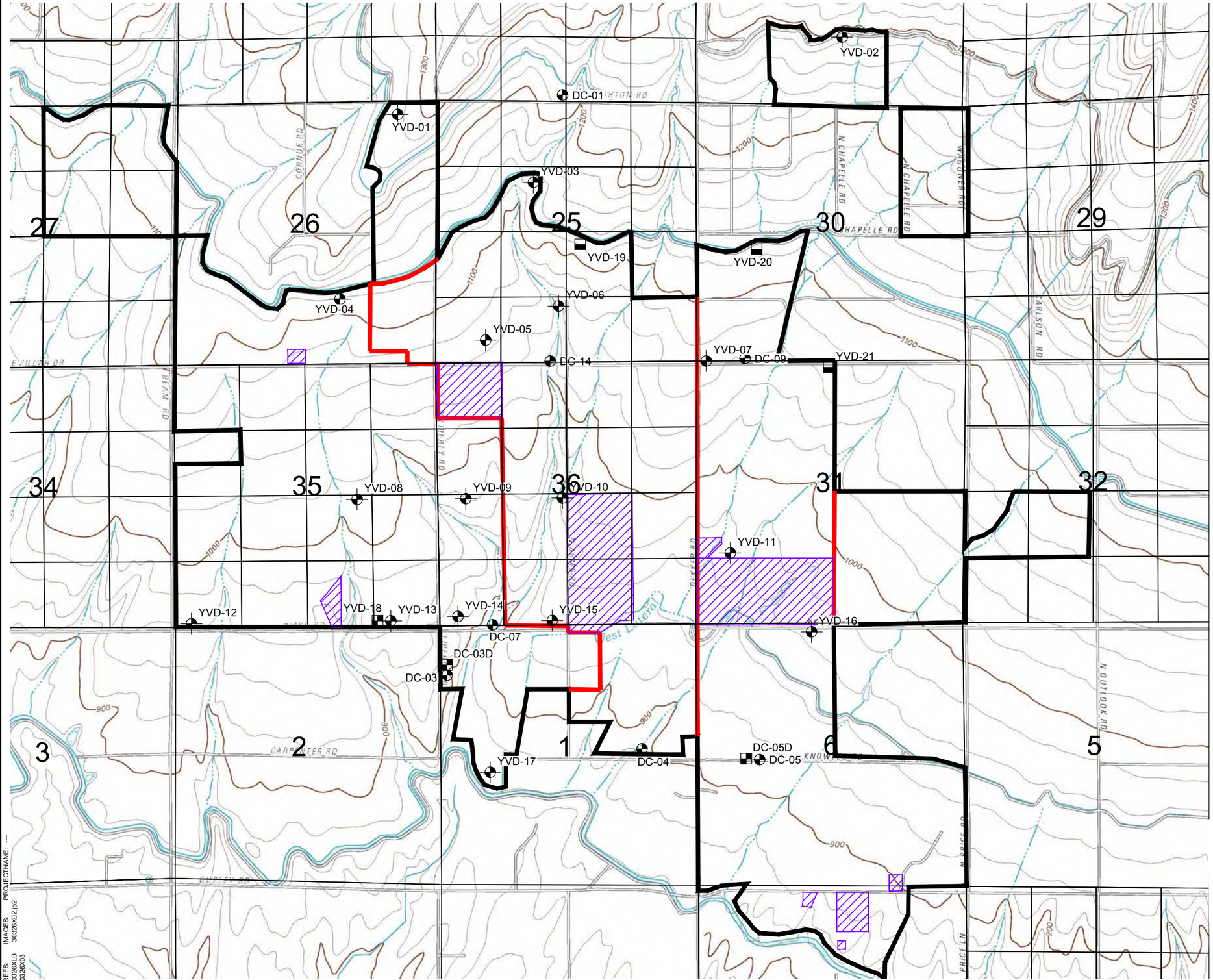
□ There is no exposure by this route.

YAKIMA VALLEY DAIRIES
SDWA-10-2013-0080
GROUNDWATER MONITORING

CONCEPTUAL SITE MODEL

ARCADIS

FIGURE
2



LEGEND:

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YVD-10	PROPOSED SHALLOW SURFICIAL AQUIFER MONITORING WELL)
DC-03D	PROPOSED DEEP SUFICIAL AQUIFER MONITORING WELL
YVD-19	PROPOSED ADDITIONAL UPGRADIENT SHALLOW SURFICIAL AQUIFER MONITORING WELL
	APPROXIMATE BOUNDARY OF DAIRY FACILITIES
	RESPONDENTS OWNERSHIP BOUNDARIES
	LAND WITHIN BOUNDARY NOT OWNED OR OPERATED BY RESPONDENTS

0 2000' 4000'

GRAPHIC SCALE

YAKIMA VALLEY DAIRIES
SDWA-10-2013-0080
GROUNDWATER MONITORING

SITE MAP

ARCADIS

FIGURE
3

SOURCE: USGS 7.5-MINUTE GRANGER, GRANGER NW, GRANGER NE & SUNNYSIDE, WA (2011)

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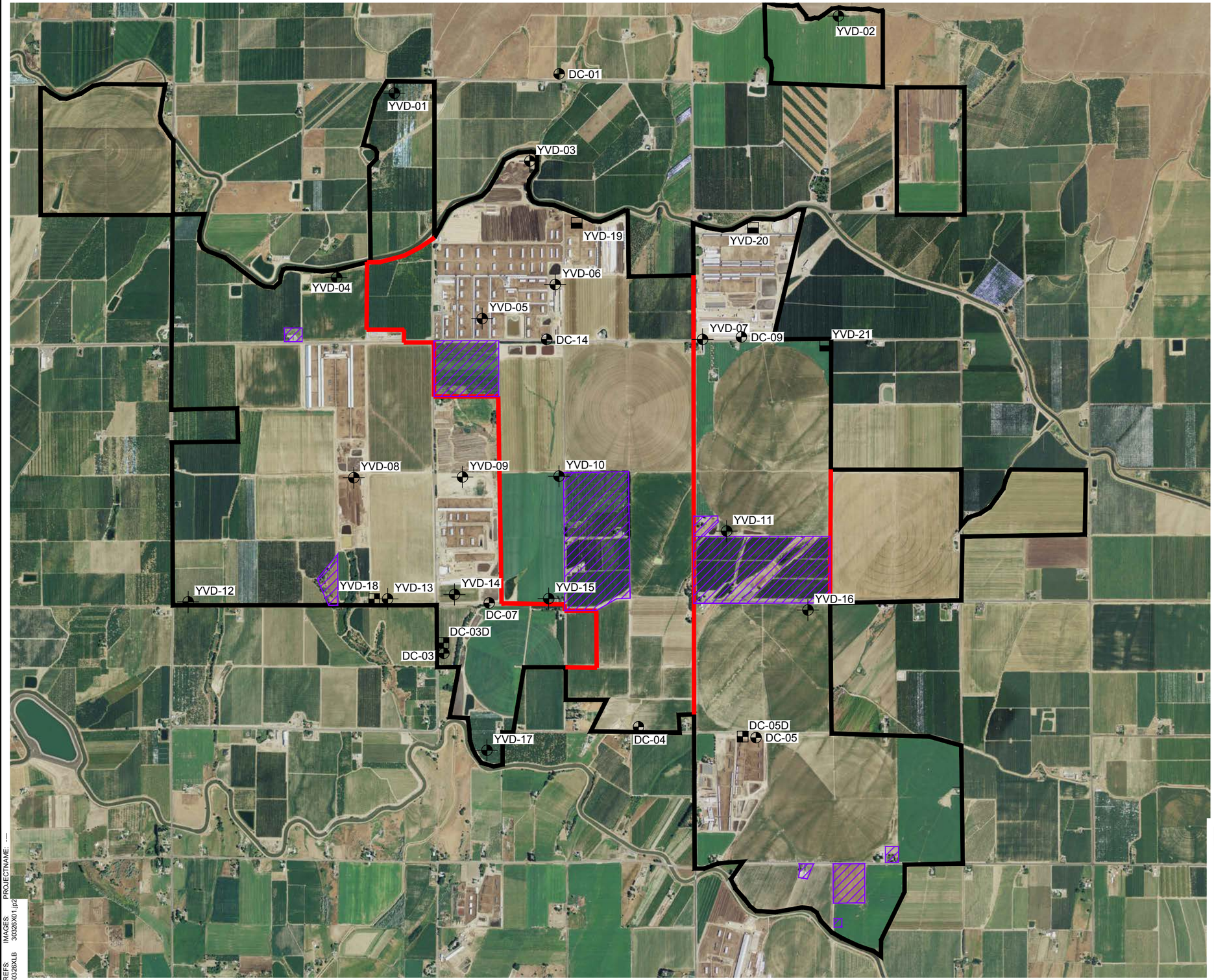

SOURCE: WASHINGTON 2011 NAIP ORTHO-IMAGERY-18 INCH DATA, WASHINGTON STATE ORTHOIMAGE PORTAL [HTTP://GEOGRAPHY.WA.GOV/ORTHO]

LEGEND:

- DC-01 — EXISTING EPA WELL (LOCATION APPROXIMATE)
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0 2000' 4000'
GRAPHIC SCALE

YAKIMA VALLEY DAIRIES
SDWA-10-2013-0080
GROUNDWATER MONITORING

AERIAL PHOTOGRAPH

ARCADIS

FIGURE
4

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Appendix A

Monitoring Well Installation
Work Plan

Imagine the result

Yakima Valley Dairies

Groundwater Monitoring Well Installation Work Plan

Administrative Order on Consent

SDWA-10-2013-0080

May 20, 2013

ARCADIS

Kevin M. Freeman, PG
Project Coordinator

Thomas F. Mullen, LHG
Senior Hydrogeologist

Groundwater Monitoring Well Installation Work Plan

SDWA-10-2013-0080

Prepared for:
Yakima Valley Dairies

Prepared by:
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Our Ref.:
SK030326.0001
SK030334.0001
SK030335.0001

Date:
May 20, 2013

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A Soil Drilling and Sample Collection SOP

B Monitoring Well Installation SOP

C Monitoring Well Development SOP

1. Introduction

ARCADIS U.S. Inc. (ARCADIS) has prepared this Groundwater Monitoring Well Work Plan (the "Work Plan") for the Yakima Valley Dairies (the "Dairies"). The Work Plan has been developed in accordance with requirements identified in Section III.E of the Statement of Work (SOW) (Appendix B of Administrative Order on Consent [AOC] SDWA-10-2013-0080) as they pertain to the drilling and installation of monitoring wells. The drilling and installation of monitoring wells at the Dairies is required under the Groundwater Monitoring requirement of the AOC and is a component to the Groundwater Monitoring Quality Assurance Project Plan (QAPP). This Work Plan includes the following sections: Environmental Setting, Groundwater Monitoring Well Installation, Decontamination, Investigation Derived Wastes, Well Survey, and Health and Safety.

1.1 Background

This Work Plan defines and describes that processes and methods that will be employed to complete monitoring well installation in support of performing the Groundwater Monitoring required under Section III.E of the AOC SOW. As a component to the Groundwater Monitoring QAPP, this Work Plan was developed to provide the means to meet project objectives and support key decisions as part of the Groundwater Monitoring QAPP implementation.

1.2 Purpose and Scope

This Work Plan describes the installation of monitoring wells to characterize the hydrogeology and ground water quality beneath the Dairies. The objectives of groundwater monitoring are to establish baseline of groundwater quality information at the Dairies, to evaluate whether actions taken to reduce nitrogen loading are effective over time, and to collect information to supplement and verify existing information on the environmental setting at the Dairies, including further clarification of the hydraulic gradient on the aquifer beneath the Dairies.

2. Environmental Setting

2.1 Site Description

The Dairies include the George DeRuyter & Son Dairy, D and A Dairy, Cow Palace 1 and 2, Liberty Dairy, and Bosma Dairy. The Dairies are located in an area that

occupies both the easternmost portion of the Toppenish Basin and the westernmost portion of the Benton Basin within the south-central part of the Yakima Basin just south of the Rattlesnake Hills in Yakima County, Washington. The Dairies are located approximately 10 road miles northwest of Sunnyside, Washington. The Dairies occupy portions or all of Sections 25, 26, 27, 35, and 36 of Township 11 North, Range 21 East; Sections 19, 30, 31, and 32 of Township 11 North, Range 22 East; Section 1 of Township 10 North, Range 21 East; and Sections 6 and 7 of Township 10 North, Range 22 East, Willamette Meridian. Figure 1 shows the location of the Dairies and general topography of the area.

Topography of the area containing the Dairies consists of gently rolling hills. Land use is predominantly large dairy farms, which are concentrated animal feeding operations (CAFOs), and irrigated cropland including apple and cherry orchards and grape vineyards. Residences are interspersed throughout the area and are serviced by private water wells for drinking water.

2.2 Regional and Site Geology and Hydrogeology

The information presented below is summarized from the U.S. Geological Survey (USGS) publication *Hydrogeologic Framework of the Yakima River Basin Aquifer System, Washington* (USGS 2009) and the U.S. Environmental Protection Agency (EPA) publication *Relation Between Nitrate in Water Wells and Potential Sources in the Lower Yakima Valley, Washington* (EPA 2012).

The Toppenish and Benton Basins consist of fine- and coarse-grained sediments overlying a sequence of three major basalt flows. The structural setting is created by bounding ridges such as the Rattlesnake Mountains, Ahtanum Ridge, Toppenish Ridge, and Horse Heaven Hills. The uppermost basalts of the Saddle Mountain Unit of the Columbia River Basalt Group are typically exposed in these upland ridges. This unit averages more than 500 feet thick. The underlying Wanapum unit averages 600 feet thick. These units are separated by the Mabton Interbed, with an average thickness of 70 feet.

The valley is filled with a variety of sediments that pinch out along the flanks of the ridges. These sediments include Touchet Beds, loess and thick alluvial sands and gravels, and significant thickness of Ellensburg Formation. The thickness of these sedimentary unites decreases from an average of more than 500 feet in the Toppenish Basin to less than 200 feet in the lower Benton Basin.

Groundwater is found in fractures and interbeds formed of clinkers, permeable lave, lake deposits or paleosols and may occur at significant depths in the upland ridges, such as Horse Heaven Hills, and especially in the basalts. The water table is found at shallower depths as the valley is approached from these ridges. Near the Yakima River, it may be less than 10 feet to water, especially during the irrigation season.

There are two main aquifer types underlying the Dairies. They include a surficial unconfined to semiconfined alluvial aquifer and an extensive basalt aquifer of great thickness underlying the sedimentary deposits. The basalt aquifer is believe to be semi-isolated from the surficial aquifer and stream systems. Groundwater flow within the surficial aquifer generally follows topography, with natural recharge occurring within the headlands and on the sides of the valley and discharge occurring to the Yakima River. Flow within the uppermost portions of the underlying basaltic aquifer also generally follows this pattern.

Because the basalts extend to great depths, the deeper basaltic layers may convey waters across local flow divides to more regionally significant discharge locations such as the Columbia River. This pattern produces a major flow direction from northwest to southeast as water moves down the valley parallel to the course of the Yakima River. Other, more localized directions of flow, typically at shallower depths in the uppermost sediments, tend to flow toward the Yakima River. Locally, the flow direction may be modified by geologic structures and by irrigation practices, drains, ditches, canals, and other hydrologic features.

The Lower Yakima Valley is filled with sediments shed by the ridges at the margins of the study area and those deposited in the valley bottom by the Yakima River. These sediments have an internal structure that strongly controls groundwater movement. As the water moves through these sediments, it tends to follow preferential flow paths composed of coarser sediments.

2.3 Facilities

The information presented below is summarized from the EPA publication *Relation Between Nitrate in Water Wells and Potential Sources in the Lower Yakima Valley, Washington* (EPA 2012).

The Dairies are situated about 5 miles north of the Yakima River, and about 3 miles north of the town of Outlook, near the northern edge of the irrigated area in the Yakima Valley. The facilities generally consist of cow pens, milking parlors, animal waste

lagoons, and application fields (e.g., irrigated cropland). Irrigation ditches run through the dairy properties. Further, two irrigation canals, the Roza and Sunnyside Canals, run along portions of the north and south Dairy boundaries, respectively. Several irrigation wells located throughout the Dairies provide water for the application fields.

2.4 Surface Water

The information presented below is summarized from the U.S. Geological Survey (USGS) publication *Hydrogeologic Framework of the Yakima River Basin Aquifer System, Washington* (USGS 2009).

Surface water in the area containing the Dairies includes the Yakima River, located approximately 5 miles south, two major irrigation canals, the Roza and Sunnyside Canals, and numerous irrigation ditches and lagoons. The Yakima River is the main surface water body that flows through the Yakima River Basin. The basin encompasses about 6,200 square miles. The head waters of the basin are on the upper, eastern slope of the Cascade Range. The basin terminates at the confluence of the Yakima and Columbia Rivers. Eight major rivers and numerous smaller streams are tributary to the Yakima River. Most of the precipitation in the basin falls during the winter months as snow in the nearby mountains.

The Dairies are located in the lower third of the Yakima River Basin. In the area containing the Dairies, intermittent streams flow off of the Rattlesnake Hills to the Yakima River. The Roza and Sunnyside canals typically transect the intermittent drainages. Flow in the canals is from west to east. The Roza and Sunnyside Canals are operated by the Roza Irrigation District and the Sunnyside Valley Irrigation District, respectively. Ancillary facilities to the canals include numerous laterals, drains, and pumps.

3. Groundwater Monitoring Well Installation

Groundwater monitoring and water quality characterization of groundwater beneath the Dairies will be conducted by means of monitoring wells. This section describes well locations, drilling and installation activities.

3.1 Monitoring Well Locations

A total of twenty-three groundwater monitoring wells will be located at the Dairies. Groundwater monitoring wells will include 17 wells completed in the “shallow” surficial

aquifer, three wells completed in the “deep” surficial aquifer, three upgradient wells completed in the “shallow” surficial aquifer. Figure 2 presents the locations of the proposed monitoring wells.

3.2 Access

Monitoring wells will be located and drilled on Dairy-owned properties. ARCADIS will coordinate timing and access to the properties with the Dairies prior to initiating well drilling activities. Monitoring wells will be access by either paved or unimproved roads that extend through the Dairies. Proposed well locations will be marked with a lathe stake. Two alternate locations within 30 feet of the original location will be selected by ARCADIS.

3.3 Utility Clearance

ARCADIS will mark the proposed boring locations shown on Figure 2 and consult with the Washington State One Call. In addition, ARCADIS will contract a private utility locating company to locate underground utilities prior to the initiation of drilling activities. ARCADIS staff will also conduct a visual site inspection of the property to identify potential utility lines. In this way ARCADIS will establish three lines of evidence of utility location prior to implementation of drilling activities.

One of these locations will be used if underground utilities are exposed in the first location (see below). If after the three locations, underground utilities cannot be avoided, the drilling location will be abandoned and an alternate and suitable location will be proposed.

3.4 Drilling

Monitoring wells will be installed within borings in accordance with Chapter 173-160 WAC, Minimum Standards for Construction and Maintenance of Wells and as described below. Additional information relevant to drilling and sampling is included in ARCADIS SOP “Soil Drilling and Sample Collection” (Appendix A).

Drilling of monitoring well borings will be conducted using a truck-mounted, air rotary drill rig capable of drilling a minimum 8-inch diameter boring. Borings will be advanced in unconsolidated alluvial materials to depths ranging from 60 to 150 feet below ground surface (bgs). Temporary steel casing will be advanced with the drilling bit assembly to maintain the borehole open.

The initial 5 feet of the boreholes will be advanced by Vac-Truck/Air Knife to reduce potential for damage to undetected underground utilities. If underground utilities are exposed, the borehole will be backfilled and the borehole will be advanced at an alternate location. If after the three locations, underground utilities cannot be avoided, the drilling location will be abandoned and an alternate and suitable location will be proposed.

Boreholes will be drilled until groundwater is encountered or observed in the drill cuttings. Drilling will continue for approximately 5 feet at which point drilling will be stopped to gauge the depth-to-water. Depth-to-water measurements will be gauged as soon as drilling has stopped and then in 5-minute intervals for up to 30 minutes or until water levels in the borehole stabilize, whichever occurs first. Final depth-to-water measurements will be recorded by the geologist. Boreholes designated for installation of shallow and deep surficial aquifer monitoring wells will be advanced approximately 15 and 45 feet, respectively, below the recorded static water level.

As the drilling advances, drill cuttings will be logged by a qualified, state-registered geologist or hydrogeologist. Soils will be described using ASTM Method D2488-84 titled “Standard Practice for Description and Identification of Soils (Visual-Manual Procedures)". Soil descriptions will include color, grain size, sorting, qualitative moisture content, visual evidence of oxidation, various layers and conditions, and other notable characteristics.

3.5 Well Installation

Well construction materials will be chosen based on parameters to be monitored, and the nature of contaminants that could potentially exist and migrate at or from the Dairies. Well materials will 1) minimize the potential of adsorption of constituents from the samples, and 2) not be a source of sample contamination. Wells will be constructed for the purpose of long-term monitoring in accordance with all applicable federal, state, and local laws. Additional information relevant to monitoring well installation is included in ARCADIS SOP “Monitoring Well Installation” (Appendix B).

Monitoring wells will be constructed of 2-inch diameter, Schedule 40, National Sanitation Foundation (NSF)-approved, polyvinyl chloride (PVC) flush-threaded casing. The wells will be screened with a 20-foot section of 2-inch diameter, Schedule 40 PVC slotted screen with 0.020-inch openings (20-slot), or equivalent. A 0.5-foot, 2-inch, Schedule 40 PVC, matching thread, NSF-approved sump will be attached at the base

of the well screen. Riser casings will extend above ground approximately 2.5 feet and completed with protective steel surface casings and cement surface seals.

All PVC casing joints will be of matching flush-threaded design with Viton O-rings and well be screwed together with the use of glues, epoxies, or petroleum-based lubricants. All materials will be brought on site in factory-sealed polyethylene bags; the bags will remain sealed until the time of installation. Screens and casing that are factory cleaned and sealed can be installed directly into the borehole without further decontamination.

A minimum annular space of 2 inches between the borehole wall and the well casing will be maintained. Centralizers will be installed below the well screen and within 4 feet of the top of the well screen and every 50 feet up the riser casing until a maximum depth of 20 feet bgs.

Well screens in monitoring wells completed in the shallow portion of the surficial aquifer will be placed across the water table as determined at the time of monitoring well installation (e.g., 15 feet of screen below the water table and 5 feet of screen above the water table). The top of the screen in monitoring wells completed in the deeper portion of the surficial aquifer will be set approximately 45 feet below the water table at the time of installation.

The filter pack will extend from the bottom of the borehole to a least 2 feet above the top of the screen. A filter pack of No. 10 x 20 Colorado Silica Sand or equivalent will be placed around the screen, initially extending approximately 4 feet above the top of the screen. The well screen will then be surged in 5-foot intervals for 5 minutes in each interval. This will assure that the filter sand is settled and that the seal will not sink into the screen. The field geologist will calculate the volume of filter pack expected to fill the annular space in the filter pack interval and record this in a field logbook.

The remaining annular space will be backfilled with bentonite chips to within approximately 3 feet below the ground surface. The bentonite chips will be added to the borehole annulus within temporary drive casing in 2.5-foot increments and hydrated. As bentonite chips are added and hydrated, the temporary drive casing will be withdrawn in equal increments. The bentonite chips will be hydrated after placement only if they are above the water table. At approximately 3 feet below the ground surface, a steel riser casing will be placed over the well and secured in place using concrete. Temporary steel casings will be removed concurrent with well installation.

Materials used for the construction and completion details of each monitoring well will be recorded on individual borehole logs. Total depths and placement depths of well construction materials will be measured to the nearest 0.1 foot during installation using a weighted fiberglass tape.

3.6 Well Development

After installation of the well, the screened zone will be developed by pumping or bailing. Information relevant to monitoring well installation is included in ARCADIS SOP "Monitoring Well Development" (Appendix C).The water-bearing zone will be considered developed when discharge water is visually non-turbid and free of sediment. However, if after 1 to 2 hours of development suspended sediment remains in the discharge water, then development will be terminated. Water levels and field measurements (e.g., pH, temperature, turbidity, specific conductance, water color, clarity, odor, etc.) will be made periodically during development. Data collected during development procedures will be recorded on a development log. Development water will be discharged to the land surface at the drill site so long as it does not enter surface water and result in cloudy/turbid water or other water quality criteria exceedances. The pump, tubing, and all other equipment used during development will be decontaminated between each use as specified in the relevant SOP.

4. Decontamination

The drill rig and sampling equipment will be decontaminated using a high-pressure sprayer prior to beginning and upon conclusion of the drilling activities. Furthermore, sampling equipment, drill bits, and casing will be decontaminated between borings. Sampling devices will be visually inspected for soil; a stiff brush will be used to remove any visible material. A high-pressure sprayer will be used to initially rinse the equipment. The initial rinse will be followed by washing with Alconox or an equivalent soap and a final rinse with the high-pressure sprayer. Water used for decontamination will be disposed in the immediate vicinity of the respective boring. All disposable items such as paper towels, disposable gloves and wash cloths will be deposited into a garbage bag and disposed in a solid waste landfill.

5. Investigation Derived Waste

Investigation derived wastes (IDW) generated during field activities is expected to consist of the following waste types:

- Drill cuttings from monitoring wells
- Groundwater from well development
- Wastewater from well development activities
- Wastewater from drilling operations
- Decontamination fluids

Drill cuttings generated during drilling activities may be spread at the drill site so long as it does not enter surface water and result in cloudy/turbid water or other water quality criteria exceedances. Water generated from development and decontamination activities will be discharged to the land surface at the drill site so long as it does not enter surface water and result in cloudy/turbid water or other water quality criteria exceedances. In some cases, IDW generated during drilling operations may need to be placed in subcontractor-supplied 55-gallong Department of Transportation (DOT)-approved drums and relocated as designated by the Project Coordinator.

6. Well Survey

Following installation and development, groundwater monitoring wells will be surveyed by a Washington State licensed professional land surveyor. Wells will be surveyed using, or existing well elevations converted to, the National Geodetic Vertical Datum (NGVD), 1929, or updated to North American Vertical Datum of 1988 (NAVD88) to an accuracy of within 0.01 foot. Horizontal surveying accuracy will be within 1.0 foot and will include the Washington State Coordinate System of each location.

7. Health and Safety

All work activities referenced in this work plan will be conducted in accordance with applicable OSHA rules and regulations, as well as those specifically established in the Project Health and Safety Plan (ARCADIS 2013). All personnel involved in the work will be current with respect to required OSHA training and refresher requirements of 29 CFR Part 1920.120. It is expected that the majority of the work can be conducted in Level D personal protective equipment.

8. References

ARCADIS, 2013. Site Specific Health and Safety Plan. April 4.

ARCADIS, 2010. Monitoring Well Development, Rev. #: 2.2, Rev. Date: March 22, 2010.

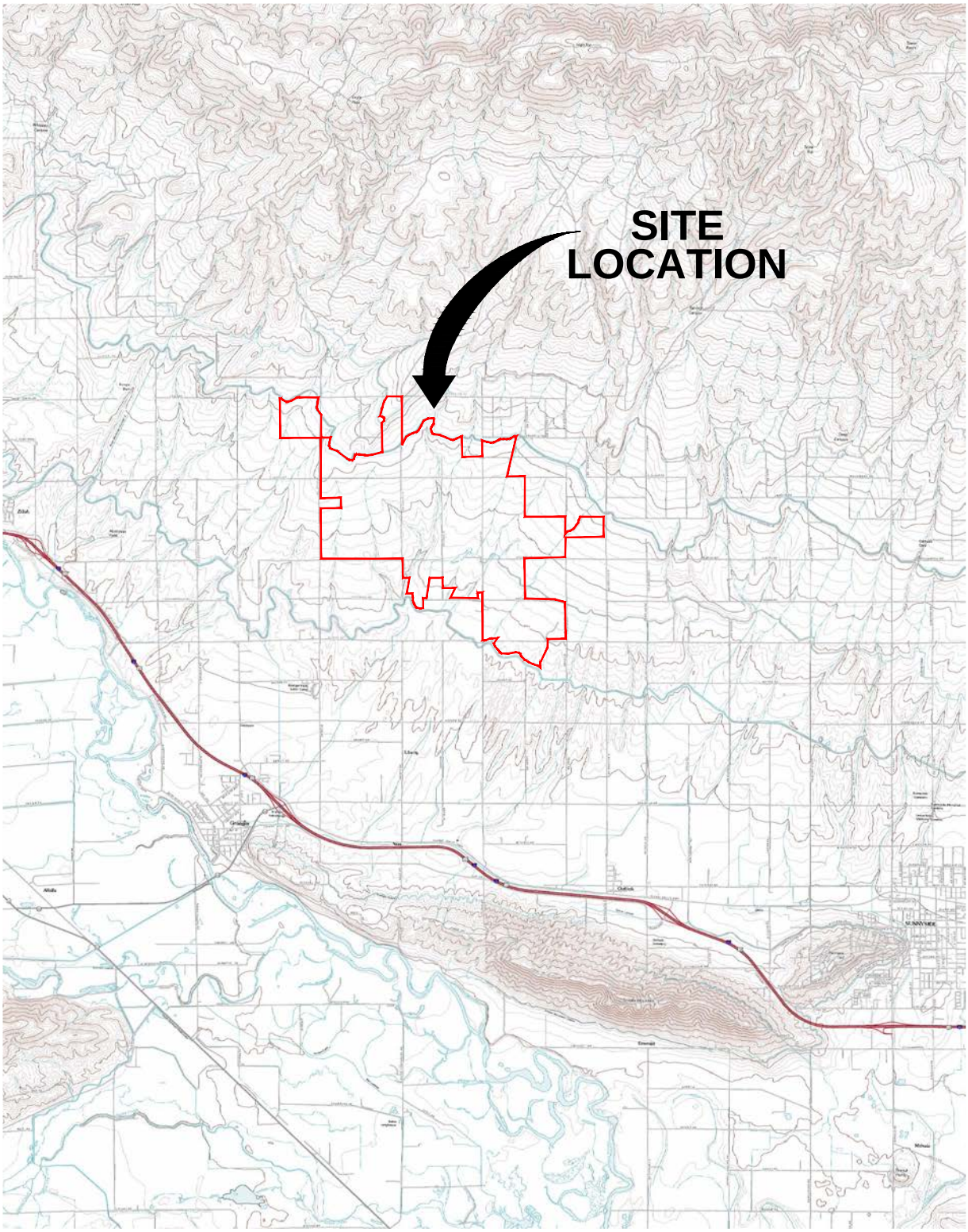
ARCADIS, 2011. Monitoring Well Installation, Rev. #: 3, Rev Date: February 2, 2011.

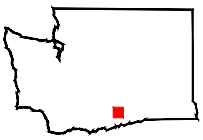
ARCADIS, 2011. Soil Drilling and Sample Collection, Rev. #: 2, Rev Date: March 8, 2011.

U.S. Environmental Protection Agency (EPA). 2012. Relation Between Nitrate in Water Wells and Potential Sources in the Lower Yakima Valley, Washington: EPA 910-R-12-003. September.

U.S. Geological Survey (USGS). 2009. Hydrogeologic Framework of the Yakima River Basin Aquifer System: Scientific Investigations Report (SIR) 2009-5152, Washington.

Figures





0 10,000' 20,000'

GRAPHIC SCALE

YAKIMA VALLEY DAIRIES
SDWA-10-2013-0080
GROUNDWATER MONITORING

SITE LOCATION MAP

ARCADIS

FIGURE
1

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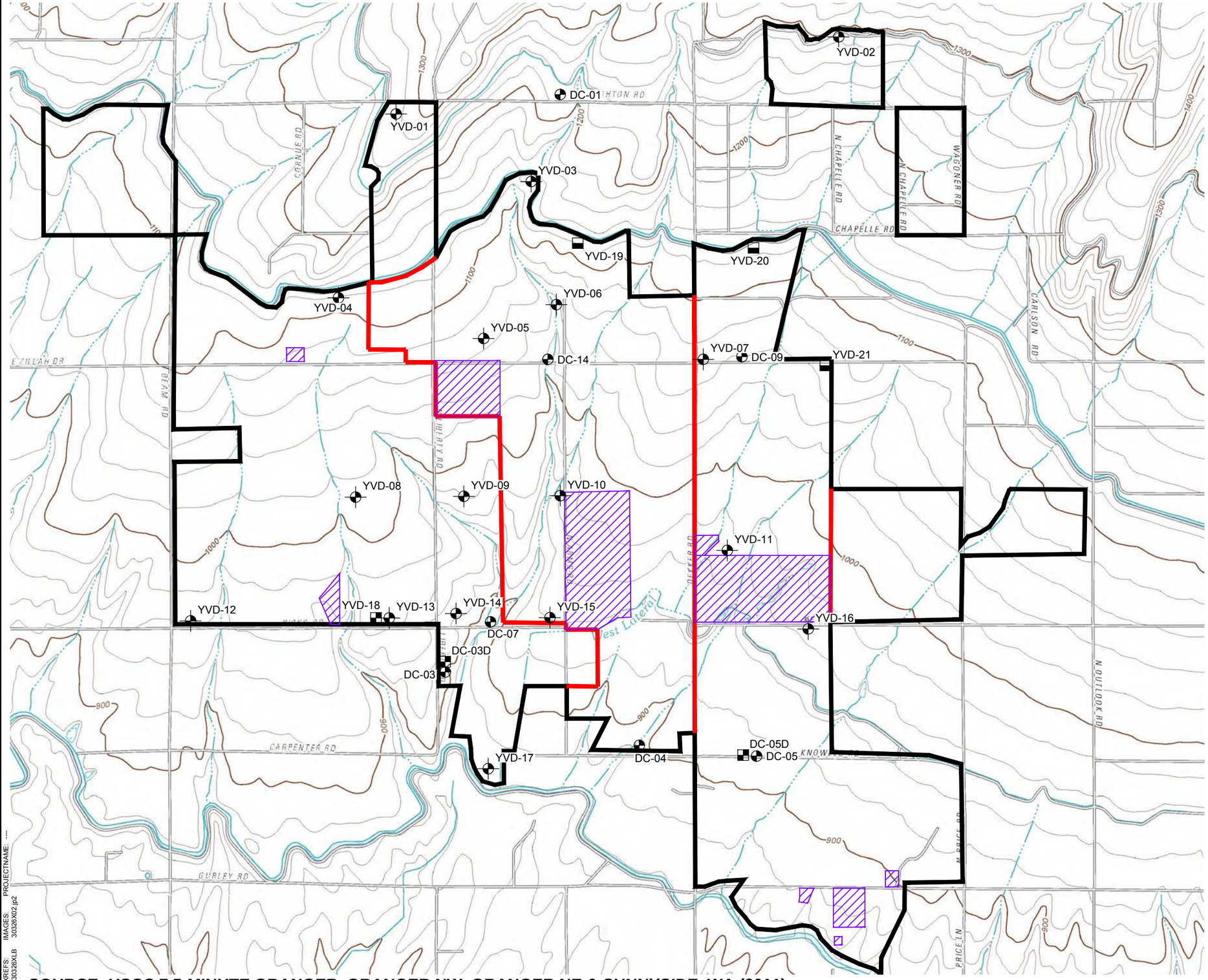

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	APPROXIMATE BOUNDARY OF DAIRY FACILITIES
	RESPONDENTS OWNERSHIP BOUNDARIES
	LAND WITHIN BOUNDARY NOT OWNED OR OPERATED BY RESPONDENTS

0 2000' 4000'

GRAPHIC SCALE

YAKIMA VALLEY DAIRIES
SDWA-10-2013-0080
GROUNDWATER MONITORING

PROPOSED MONITORING WELL NETWORK

ARCADIS

FIGURE
2

SOURCE: USGS 7.5-MINUTE GRANGER, GRANGER NW, GRANGER NE & SUNNYSIDE, WA (2011)

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Appendix A

Soil Drilling and Sample Collection SOP

Imagine the result

Soil Drilling and Sample Collection

Rev. #: 2

Rev Date: March 8, 2011

Approval Signatures

Prepared by: Caron Koll Date: 03/08/2011

Caron Koll
Principal Geologist

Reviewed by: Michael J. Gefell Date: 03/08/2011

Michael J. Gefell
National Expert / Principal Geologist

I. Scope and Application

Overburden drilling is commonly performed using the hollow-stem auger drilling method. Other drilling methods suitable for overburden drilling, which are sometimes necessary due to site-specific geologic conditions, include: drive-and-wash, spun casing, Rotasonic, dual-rotary (Barber Rig), and fluid/mud rotary. Direct-push techniques (e.g., Geoprobe or cone penetrometer) may also be used. The drilling method to be used at a given site will be selected based on site-specific consideration of anticipated drilling depths, site or regional geologic knowledge, types of sampling to be conducted, required sample quality and volume, and cost.

No oils or grease will be used on equipment introduced into the boring (e.g., drill rod, casing, or sampling tools).

II. Personnel Qualifications

The Project Manager (a qualified geologist, environmental scientist, or engineer) will identify the appropriate soil boring locations, depth and soil sample intervals in a written plan.

Personnel responsible for overseeing drilling operations and the logging of soil borings will be a qualified, state-registered geologist.

III. Equipment List

The following materials will be available during soil boring and sampling activities, as required:

- Site Plan with proposed soil boring/well locations;
- Work Plan or Field Sampling Plan (FSP), and site Health and Safety Plan (HASP);
- personal protective equipment (PPE), as required by the HASP;
- drilling equipment required by the American Society for Testing and Materials (ASTM) D 1586, when performing split-spoon sampling;
- disposable plastic liners, when drilling with direct-push equipment;
- appropriate soil sampling equipment (e.g., stainless steel spatulas, knife);

- equipment cleaning materials;
- appropriate sample containers and labels;
- chain-of-custody forms;
- insulated coolers with ice, when collecting samples requiring preservation by chilling;
- photoionization detector (PID) or flame ionization detector (FID); and
- field notebook and/or personal digital assistant (PDA).

IV. Cautions

Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be identified by one of the following three actions (lines of evidence):

- Contact the State One Call
- Obtain a detailed site utility plan drawn to scale, preferably an “as-built” plan
- Conduct a detailed visual site inspection

In the event that one or more of the above lines of evidence cannot be conducted, or if the accuracy of utility location is questionable, a minimum of one additional line of evidence will be utilized as appropriate or suitable to the conditions. Examples of additional lines of evidence include but are not limited to:

- Private utility locating service
- Research of state, county or municipal utility records and maps including computer drawn maps or geographical information systems (GIS)
- Contact with the utility provider to obtain their utility location records
- Hand augering or digging
- Hydro-knife
- Air-knife
- Radio Frequency Detector (RFD)

- Ground Penetrating Radar (GPR)
- Any other method that may give ample evidence of the presence or location of subgrade utilities.

Overhead power lines also present risks and the following safe clearance must be maintained from them.

Power Line Voltage Phase to Phase (kV)	Minimum Safe Clearance (feet)
50 or below	10
Above 50 to 200	15
Above 200 to 350	20
Above 350 to 500	25
Above 500 to 750	35
Above 750 to 1,000	35

ANSI Standard B30.5-1994, 5-3.4.5

Avoid using drilling fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions.

Water used for drilling and sampling of soil or bedrock, decontamination of drilling/sampling equipment, or grouting boreholes upon completion will be of drinking water quality from a know and documented source. Testing of water supply should be considered.

Specifications of materials used for backfilling borehole will be obtained, reviewed and approved to meet project quality objectives.

V. Health and Safety Considerations

Field activities associated with overburden drilling and soil sampling will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

VI. Procedure

Drilling Procedures

The drilling contractor will be responsible for obtaining accurate and representative samples; informing the supervising geologist of changes in drilling pressure; and

keeping a separate general log of soils encountered, including blow counts (i.e., the number of blows from a soil sampling drive weight [140 pounds] required to drive the split-barrel sampler in 6-inch increments). The term “samples” means soil materials from particular depth intervals, whether or not portions of these materials are submitted for laboratory analysis. Records will also be kept of occurrences of premature refusal due to boulders or construction materials that may have been used as fill. Where a boring cannot be advanced to the desired depth, the boring will be abandoned and an additional boring will be advanced at an adjacent location to obtain the required sample. Where it is desirable to avoid leaving vertical connections between depth intervals, the borehole will be sealed using cement and/or bentonite. Multiple refusals may lead to a decision by the supervising geologist to abandon that sampling location.

Soil Characterization Procedures

Soils encountered while drilling soil borings will be collected using one of the following methods:

- 2-inch split-barrel (split-spoon) sampler, if using the ASTM D 1586 - Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils
- Plastic internal soil sample sleeves if using direct-push drilling.

Soils are typically field screened with an FID or PID at sites where volatile organic compounds are present in the subsurface. Field screening is performed using one of the following methods:

- Upon opening the sampler, the soil is split open and the PID or FID probe is placed in the opening and covered with a gloved hand. Such readings should be obtained at several locations along the length of the sample
- A portion of the collected soil is placed in a jar, which is covered with aluminum foil, sealed, and allowed to warm to room temperature. After warming, the cover is removed, the foil is pieced with the FID or PID probe, and a reading is obtained.

Samples selected for laboratory analysis will be handled, packed, and shipped in accordance with the procedures outlined in the Work Plan, FSP, or Chain-of-Custody, Handling, Packing, and Shipping SOP.

- percent recovery;
- structure and degree of sample disturbance;
- soil type;
- color;
- moisture condition;
- density;
- grain-size;
- consistency; and
- other observations, particularly relating to the presence of waste materials

Further details regarding geologic description of soils are presented in the Soil Description SOP.

Particular care will be taken to fully describe any sheens observed, oil saturation, staining, discoloration, evidence of chemical impacts, or unnatural materials.

VII. Waste Management

Water generated during cleaning procedures will be collected and contained onsite in appropriate containers for future analysis and appropriate disposal.

PPE (such as gloves, disposable clothing, and other disposable equipment) resulting from personnel cleaning procedures and soil sampling/handling activities will be placed in plastic bags. These bags will be transferred into appropriately labeled 55-gallon drums or a covered roll-off box for appropriate disposal.

Soil materials will be placed in sealed 55-gallon steel drums or covered roll-off boxes and stored in a secured area. Once full, the material will be analyzed to determine the appropriate disposal method.

VIII. Data Recording and Management

The supervising geologist or scientist will be responsible for documenting drilling

events using a bound field notebook and/or PDA to record all relevant information in a clear and concise format. The record of drilling events will include:

- start and finish dates of drilling;
- name and location of project;
- project number, client, and site location;
- sample number and depths;
- blow counts and recovery;
- depth to water;
- type of drilling method;
- drilling equipment specifications, including the diameter of drilling tools;
- documentation of any elevated organic vapor readings;
- names of drillers, inspectors, or other people onsite; and
- weather conditions.

IX. Quality Assurance

Equipment will be cleaned prior to use onsite, between each drilling location, and prior to leaving the site. Drilling equipment and associated tools, including augers, drill rods, sampling equipment, wrenches, and other equipment or tools that may have come in contact with soils and/or waste materials will be cleaned with high-pressure steam-cleaning equipment using a potable water source. The drilling equipment will be cleaned in an area designated by the supervising engineer or geologist that is located outside of the work zone. More elaborate cleaning procedures may be required for reusable soil samplers (split-spoons) when soil samples are obtained for laboratory analysis of chemical constituents.

X. References

American Society of Testing and Materials (ASTM) D 1586 - *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*.

Appendix B

Monitoring Well Installation SOP

ARCADIS
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Monitoring Well Installation

Rev. #: 3

Rev Date: February 2, 2011

Approval Signatures

Prepared by: _____ Date: 2/2/2011

Kevin Wilson
Senior Hydrogeologist

Reviewed by: _____ Date: 2/2/2011

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National Expert / Principal Geologist

I. Scope and Application

The procedures set out herein are designed to produce standard groundwater monitoring wells suitable for: (1) groundwater sampling, (2) water level measurement, (3) bulk hydraulic conductivity testing of formations adjacent to the open interval of the well.

Monitoring well boreholes in unconsolidated (overburden) materials are typically drilled using the hollow-stem auger drilling method. Other drilling methods that are also suitable for installing overburden monitoring wells, and are sometimes necessary due to site-specific geologic conditions, include: drive-and-wash, spun casing, Rotasonic, dual-rotary (Barber Rig), and fluid/mud rotary with core barrel or roller bit. Direct-push techniques (e.g., Geoprobe or cone penetrometer) and driven well points may also be used in some cases within the overburden. Monitoring wells within consolidated materials such as bedrock are commonly drilled using water-rotary (coring or tri-cone roller bit), air rotary or Rotasonic methods. The drilling method to be used at a given site will be selected based on site-specific consideration of anticipated drilling/well depths, site or regional geologic knowledge, type of monitoring to be conducted using the installed well, and cost.

No oils or grease will be used on equipment introduced into the boring (e.g., drill rod, casing, or sampling tools). No polyvinyl chloride (PVC) glue/cement will be used in constructing or retrofitting monitoring wells that will be used for water-quality monitoring. No coated bentonite pellets will be used in the well drilling or construction process. Specifications of materials to be installed in the well will be obtained prior to mobilizing onsite, including:

- well casing;
- bentonite;
- sand; and
- grout.

Well materials will be inspected and, if needed, cleaned prior to installation.

II. Personnel Qualifications

Monitoring well installation activities will be performed by persons who have been trained in proper well installation procedures under the guidance of an experienced field geologist, engineer, or technician. Where field sampling is performed for soil or

bedrock characterization, field personnel will have undergone in-field training in soil or bedrock description methods, as described in the appropriate SOP(s) for those activities.

III. Equipment List

The following materials will be available during soil boring and monitoring well installation activities, as required:

- Site Plan with proposed soil boring/well locations;
- Work Plan or Field Sampling Plan (FSP), and site Health and Safety Plan (HASP);
- personal protective equipment (PPE), as required by the HASP;
- traffic cones, delineators, caution tape, and/or fencing as appropriate for securing the work area, if such are not provided by drillers;
- appropriate soil sampling equipment (e.g., stainless steel spatulas, knife);
- soil and/or bedrock logging equipment as specified in the appropriate SOPs;
- appropriate sample containers and labels;
- drum labels as required for investigation derived waste handling;
- chain-of-custody forms;
- insulated coolers with ice, when collecting samples requiring preservation by chilling;
- photoionization detector (PID) or flame ionization detector (FID);
- ziplock style bags;
- water level or oil/water interface meter;
- locks and keys for securing the well after installation;
- decontamination equipment (bucket, distilled or deionized water, cleansers appropriate for removing expected chemicals of concern, paper towels);

- field notebook.

Prior to mobilizing to the site, ARCADIS personnel will contact the drilling subcontractor or in-house driller (as appropriate) to confirm that appropriate sampling and well installation equipment will be provided. Specifications of the sampling and well installation equipment are expected to vary by project, and so communication with the driller will be necessary to ensure that the materials provided will meet the project objectives. Equipment typically provided by the driller could include:

- drilling equipment required by the American Society of Testing and Materials (ASTM) D 1586, when performing split-spoon sampling;
- disposable plastic liners, when drilling with direct-push equipment;
- drums for investigation derived waste;
- drilling and sampling equipment decontamination materials;
- decontamination pad materials, if required; and
- well construction materials.

IV. Cautions

Prior to beginning field work, underground utilities in the vicinity of the drilling areas will be delineated by the drilling contractor or an independent underground utility locator service. See separate SOP for utility clearance.

Some regulatory agencies require a minimum annular space between the well or permanent casing and the borehole wall. When specified, the minimum clearance is typically 2 inches on all sides (e.g., a 2-inch diameter well requires a 6-inch diameter borehole). In addition, some regulatory agencies have specific requirements regarding grout mixtures. Determine whether the oversight agency has any such requirements prior to finalizing the drilling and well installation plan.

If dense non-aqueous phase liquids (DNAPL) are known or expected to exist at the site, refer to the DNAPL Contingency Plan SOP for additional details regarding drilling and well installation to reduce the potential for inadvertent DNAPL remobilization.

Similarly, if light non-aqueous phase liquids (LNAPLs) are known or expected to be present as “perched” layers above the water table, refer to the DNAPL Contingency

Plan. Follow the general provisions and concepts in the DNAPL contingency plan during drilling above the water table at known or expected LNAPL sites.

Avoid using drilling fluids or materials that could impact groundwater or soil quality, or could be incompatible with the subsurface conditions.

Similarly, consider the material compatibility between the well materials and the surrounding environment. For example, PVC well materials are not preferred when DNAPL is present. In addition, some groundwater conditions leach metals from stainless steel.

Water used for drilling and sampling of soil or bedrock, decontamination of drilling/sampling equipment, or grouting boreholes upon completion will be of a quality acceptable for project objectives. Testing of water supply should be considered.

Specifications of materials used for backfilling bore hole will be obtained, reviewed and approved to meet project quality objectives. Bentonite is not recommended where DNAPLs are likely to be present. In these situations, neat cement grout is preferred.

No coated bentonite pellets will be used in monitoring well construction, as the coating could impact the water quality in the completed well.

Monitoring wells may be installed with Schedule 40 polyvinyl chloride (PVC) to a maximum depth of 200 feet below ground surface (bgs). PVC monitoring wells between 200 and 400 feet total depth will be constructed using Schedule 80 PVC. Monitoring wells deeper than 400 feet will be constructed using steel.

V. Health and Safety Considerations

Field activities associated with monitoring well installation will be performed in accordance with a site-specific HASP, a copy of which will be present on site during such activities.

VI. Procedures

The procedures for installing groundwater monitoring wells are presented below:

Hollow-Stem Auger, Drive-and-Wash, Spun Casing, Fluid/Mud Rotary, Rotasonic, and Dual-Rotary Drilling Methods

1. Locate boring/well location, establish work zone, and set up sampling equipment decontamination area.

2. Advance boring to desired depth. Collect soil and/or bedrock samples at appropriate interval as specified in the Work Plan and/or FSP. Collect, document, and store samples for laboratory analysis as specified in the Work Plan and/or FSP. Decontaminate equipment between samples in accordance with the Work Plan and/or FSP. A common sampling method that produces high-quality soil samples with relatively little soil disturbance is the ASTM D 1586 - Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils. Split-spoon samples are obtained during drilling using hollow-stem auger, drive-and-wash, spun casing, and fluid/mud rotary. Rotasonic drilling produces large-diameter soil cores that tend to be more disturbed than split-spoon samples due to the vibratory action of the drill casing. Dual-rotary removes cuttings by compressed air and allows only a general assessment of geology. High-quality bedrock samples can be obtained by coring.

3. Describe each soil or bedrock sample as outlined in the appropriate SOP. Record descriptions in the field notebook and/or personal digital assistant (PDA). It should be noted that PDA logs must be electronically backed up and transferred to a location accessible to other project team members as soon as feasible to retain and protect the field data. During soil boring advancement, document all drilling events in field notebook, including blow counts (number of blows required to advance split-spoon sampler in 6-inch increments) and work stoppages. Blow counts will not be available if Rotasonic, dual-rotary, or direct-push methods are used. When drilling in bedrock, the rate of penetration (minutes per foot) is recorded.

4. If it is necessary to install a monitor well into a permeable zone below a confining layer, particularly if the deeper zone is believed to have water quality that differs significantly from the zone above the confining layer, then a telescopic well construction should be considered. In this case, the borehole is advanced approximately 3 to 5 feet into the top of the confining layer, and a permanent casing (typically PVC, black steel or stainless steel) is installed into the socket drilled into the top of the confining layer. The casing is then grouted in place. The preferred methods of grouting telescoping casings include: pressure-injection grouting using an inflatable packer installed temporarily into the base of the casing, such that grout is injected out the bottom of the casing until it is observed at ground surface outside the casing; displacement-method grouting (also known as the Halliburton method), which entails filling the casing with grout and displacing the grout out the bottom of the casing by pushing a drillable plug, typically made of wood to the bottom of the casing, following by tremie grouting the remainder of the annulus outside the casing; or tremie grouting the annulus surrounding the casing using a tremie pipe installed to the base of the borehole. In all three cases, the casing is grouted to the ground

surface, and the grout is allowed to set prior to drilling deeper through the casing. Site-specific criteria and work plans should be created for the completion of non-standard monitoring wells, including telescopic wells.

5. In consolidated formations such as competent bedrock, a monitoring well may be completed with an open borehole interval without a screen and sandpack. In these cases, the borehole is advanced to the targeted depth of the top of the open interval. A permanent casing is then grouted in place following the procedures described in Step 4 above. After the grout sets, the borehole is advanced by drilling through the permanent casing to the targeted bottom depth of the open interval, which then serves as the monitoring interval for the well. If open-borehole interval stability is found to be questionable or if a specific depth interval is later selected for monitoring, a screened monitoring well may later be installed within the open-borehole interval, depending on the annular space and well diameter requirements.

6. Before installing a screened well – or after drilling an open-bedrock well –, it is important to confirm that the borehole has been advanced into the saturated zone. This is particularly important for wells installed to monitor the water table and/or the shallow saturated zone, as the capillary fringe may cause soils above the water table to appear saturated. If one or more previously installed monitoring wells exist nearby, use the depth to water at such well(s) to estimate the water-table depth at the new borehole location.

   To verify that the borehole has been advanced into the saturated zone, it is necessary to measure the water level in the borehole. For boreholes drilled without using water (e.g., hollow-stem auger, cable-tool, air rotary, air hammer), verify the presence of groundwater (and /or LNAPL, if applicable) in the borehole using an electronic water level probe, oil-water interface probe, or a new or decontaminated bailer. For boreholes drilled using water (e.g., drive and wash, spun-casing with roller-bit wash, rotasonic, or water rotary with core or roller bit), monitor the water level in the borehole as it re-equilibrates to the static level. In low-permeability units like clay, fine-grained glacial tills, shale and other bedrock formations, it may be necessary to wait overnight to allow the water level to equilibrate. To the extent practicable, ensure that the depth of the well below the apparent water table is deep enough so that the installed well can monitor groundwater year-round, accounting for seasonal water-table fluctuations. In most cases, the well should be installed at least five feet below the water-table depth, determined as described above. When in doubt, err on the side of slightly deeper well installation.

If necessary, the borehole should be drilled deeper to ensure that the well may intersects the water table or a permeable water-bearing zone.

7. Upon completing the borehole to the desired depth, if a screened well construction is desired, install the monitoring well by lowering the screen and casing assembly with sump through the augers or casing. Monitoring wells typically will be constructed of 2-inch-diameter, flush-threaded PVC or stainless steel slotted well screen and blank riser casing. Smaller diameters may be used if wells are installed using direct-push methodology or if multiple wells are to be installed in a single borehole. The screen length will be specified in the Work Plan or FSP based on regulatory requirements and specific monitoring objectives. Monitoring well screens are usually 5 to 10 feet long, but may be up to 25 feet long in very low permeability, thick geologic formations. The screen length will depend on the purpose for the well and the objectives of the groundwater investigation. Typically, the slot size will be 0.010 inch and the sand pack will be 20-40, Morie No. 0, or equivalent. In very fine-grained formations where sample turbidity needs to be minimized, it may be preferred to use a 0.006-inch slot size and 30-65, Morie No. 00, or equivalent sand pack. Alternatively, where monitoring wells are installed in coarse-grained deposits and higher well yield is required, a 0.020-inch slot size and 10-20, Morie No. 1, or equivalent sand pack may be preferred. To the extent practicable, the slot size and sand pack gradation may be predetermined in the Work Plan or FSP based on site-specific grain-size analysis or other geologic considerations or monitoring objectives. A blank sump may be attached below the well screen if the well is being installed for DNAPL recovery/monitoring purposes. If so, the annular space around the sump will be backfilled with neat cement grout to the bottom of the well screen prior to placing the sand pack around the screen. A blank riser will extend from the top of the screen to approximately 2.5 feet above grade or, if necessary, just below grade where conditions warrant a flush-mounted monitoring well. For wells greater than 50 feet deep, centralizers may be desired to assist in centralizing the monitoring well in the borehole during construction.

8. When the monitoring well assembly has been set in place and the grout has been placed around the sump (if any), place a washed silica sand pack in the annular space from the bottom of the boring to a height of 1 to 2 feet above the top of the well screen. The sand pack is placed and drilling equipment extracted in increments until the top of the sand pack is at the appropriate depth. The sand pack will be consistent with the screen slot size and the soil particle size in the screened interval, as specified in the Work Plan or FSP. A hydrated bentonite seal (a minimum of 2 feet thick) will then be placed in the annular space above the sand pack. If non-hydrated bentonite is used, the bentonite

should be permitted to hydrate in place for a minimum of 30 minutes before proceeding. No coated bentonite pellets will be used in monitoring well drilling or construction. Potable water may be added to hydrate the bentonite if the seal is above the water table. Monitor the placement of the sand pack and bentonite with a weighted tape measure. During the extraction of the augers or casing, a cement/bentonite or neat cement grout will be placed in the annular space from the bentonite seal to a depth approximately 2 feet bgs.

9. Place a locking, steel protective casing (extended at least 1.5 feet below grade and 2 feet above grade) over the riser casing and secure with a neat cement seal. Alternatively, for flush-mount completions, place a steel curb box with a bolt-down lid over the riser casing and secure with a neat cement seal. In either case, the cement seal will extend approximately 1.5 to 2.0 feet below grade and laterally at least 1 foot in all directions from the protective casing, and should slope gently away to promote drainage away from the well. Monitoring wells will be labeled with the appropriate designation on both the inner and outer well casings or inside of the curb box lid.

   When an above-grade completion is used, the PVC riser will be sealed using an expandable locking plug and the top of the well will be vented by drilling a small-diameter (1/8 inch) hole near the top of the well casing or through the locking plug, or by cutting a vertical slot in the top of the well casing. When a flush-mount installation is used, the PVC riser will be sealed using an unvented, expandable locking plug.

10. During well installation, record construction details and actual measurements relayed by the drilling contractor and tabulate materials used (e.g., screen and riser footages; bags of bentonite, cement, and sand) in the field notebook.

11. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section VII below.

Direct-Push Method

The direct-push drilling method may also be used to complete soil borings and install monitoring wells. Examples of this technique include the Diedrich ESP vibratory probe system, GeoProbe®, or AMS Power Probe® dual-tube system. Environmental probe systems typically use a hydraulically operated percussion hammer. Depending on the equipment used, the hammer delivers 140- to 350-foot pounds of energy with each blow. The hammer provides the force needed to penetrate very stiff/medium dense soil formations. The hammer simultaneously advances an outer steel casing that contains a dual-tube liner for sampling soil. The outside diameter (OD) of the outer

casing ranges from 1.75 to 2.4 inches and the OD of the inner sampling tube ranges from 1.1 to 1.8 inches. The outer casing isolates shallow layers and permits the unit to continue to probe at depth. The double-rod system provides a borehole that may be tremie-grouted from the bottom up. Alternatively, the inside diameter (ID) of the steel casing provides clearance for the installation of small-diameter (e.g., 0.75- to 1-inch ID) micro-wells. The procedures for installing monitoring wells in soil using the direct-push method are described below.

1. Locate boring/well location, establish work zone, and set up sample equipment decontamination area.

2. Advance soil boring to designated depth, collecting samples at intervals specified in the Work Plan. Samples will be collected using dedicated, disposable, plastic liners. Describe samples in accordance with the procedures outlined in Step 3 above. Collect samples for laboratory analysis as specified in the Work Plan and/or FSP.

3. Upon advancing the borehole to the desired depth, install the micro-well through the inner drill casing. The micro-well will consist of approximately 1-inch ID PVC or stainless steel slotted screen and blank riser. The sand pack, bentonite seal, and cement/bentonite grout will be installed as described, where applicable, in Step 7 and 8 above.

4. Install protective steel casing or flush-mount, as appropriate, as described in Step 9 above. During well installation, record construction details and tabulate materials used.

5. After completing the well installation, lock the well, clean the area, and dispose of materials in accordance with the procedures outlined in Section VII below.

Driven Well Point Installation

Well points will be installed by pushing or driving using a drilling rig or direct-push rig, or hand-driven where possible. The well point construction materials will consist of a 1- to 2-inch-diameter threaded steel casing with either 0.010- or 0.020-inch slotted stainless steel screen. The screen length will vary depending on the hydrogeologic conditions of the site. The casings will be joined together with threaded couplings and the terminal end will consist of a steel well point. Because they are driven or pushed to the desired depth, well points do not have annular backfill materials such as sand pack or grout.

VII. Waste Management

Investigation-derived wastes (IDW), including soil cuttings and excess drilling fluids (if used), decontamination liquids, and disposable materials (well material packages, PPE, etc.), will be placed in clearly labeled, appropriate containers, or managed as otherwise specified in the Work Plan, FSP, and/or IDW management SOP.

VIII. Data Recording and Management

Drilling activities will be documented in a field notebook. Pertinent information will include personnel present on site, times of arrival and departure, significant weather conditions, timing of well installation activities, soil descriptions, well construction specifications (screen and riser material and diameter, sump length, screen length and slot size, riser length, sand pack type), and quantities of materials used. In addition, the locations of newly-installed wells will be documented photographically or in a site sketch. If appropriate, a measuring wheel or engineer's tape will be used to determine approximate distances between important site features.

The well or piezometer location, ground surface elevation, and inner and outer casing elevations will be surveyed using the method specified in the site Work Plan. Generally, a local baseline control will be set up. This local baseline control can then be tied into the appropriate vertical and horizontal datum, such as the National Geodetic Vertical Datum of 1929 or 1988 and the State Plane Coordinate System. At a minimum, the elevation of the top of the inner casing used for water-level measurements should be measured to the nearest 0.01 foot. Elevations will be established in relation to the National Geodetic Vertical Datum of 1929. A permanent mark will be placed on top of the inner casing to mark the point for water-level measurements.

IX. Quality Assurance

All drilling equipment and associated tools (including augers, drill rods, sampling equipment, wrenches, and any other equipment or tools) that may have come in contact with soil will be cleaned in accordance with the procedures outlined in the appropriate SOP. Well materials will also be cleaned prior to well installation.

X. References

American Society of Testing and Materials (ASTM) D 1586 - *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils*.

Appendix C

Monitoring Well Development SOP

United States Environmental Protection Agency | Office of Solid Waste and Emergency Response | April 1992

René

EPA

Ground Water Forum

MONITORING WELL DEVELOPMENT GUIDELINES FOR SUPERFUND PROJECT MANAGERS

Ruth Izraeli* Doug Yeskis, Mark Collins, Kathy Davies, Bernard Zavala

The Ground Water and Engineering Forums were established by EPA professionals in the ten EPA Regional Offices. The Forums are committed to the identification and resolution of scientific, technical and engineering issues impacting the remediation of Superfund and RCRA sites. The Forums are supported by and advise OSWER's Technical Support Project, which has established Technical Support Centers in laboratories operated by the Office of Research and Development, Office of Radiation Programs, and the Environmental Response Team. The Centers work closely with the Forums in providing state-of-the-science technical assistance to EPA project managers.

This document provides well development guidelines and recommended additional sources of information. It was developed by the Superfund Ground Water Forum and draws upon U.S. Army Corps of Engineers and draft RCRA SW-846 field protocols. Comments from ORD and Regional Superfund hydrogeologists have been incorporated. These guidelines are applicable to the great majority of sites. However, unusual, site-specific circumstances may require alternative approaches. In these instances, the appropriate Regional hydrogeologist should be contacted to establish alternative development protocols.

Introduction

The goal of ground-water sampling is to obtain water samples that best represent natural undisturbed hydrogeological conditions. Adequate well development is critical to minimize the introduction of biases into the sampling effort. Well development is necessary because every drilling method disturbs the geologic materials around the well bore to some extent. Development processes are used to try to ensure proper hydraulic connection between the well and the geologic materials in the vicinity of the well. This is done by stressing the formation around the screen so that mobile, artifact particulates are removed. This process is necessary to obtain a ground water sample which is as similar as possible to *in situ* conditions.

One of the major goals of well development is to produce a well capable of yielding ground-water samples of acceptably low turbidity. Excess turbidity may alter water quality and result in erroneous chemical analysis (particularly for unfiltered metals samples which require acid preservation).

Turbidity in ground-water samples is minimized by well development. Proper well development creates a graded filter pack around the well screen. When pumping is first initiated, natural materials in a wide range of grain sizes are drawn into the well, producing very turbid water. However, as pumping continues, the natural materials are drawn into the filter, producing an effective filter pack through a sorting process. This sorting process begins when the largest particles of natural materials are retained by the filter pack, resulting in a layer of coarse particles against the well screen. With continued development, this process produces progressively finer layers until an effective graded filter is produced, which then minimizes turbidity. Development is also necessary to remove any foreign materials introduced during drilling, such as drilling water and mud.

These guidelines are directed toward the development of relatively permeable (i.e., $K>10^{-6}$ cm/sec) aquifers. However, it is sometimes necessary to screen wells in water-bearing zones containing significant quantities of silt and clay, which would not normally be considered producing aquifers. Low-yielding wells located in marginal aquifers often cannot be developed using standard methods. For a discussion of the construction and development of wells in low-yielding forma-

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tions, see Aller et al. (1989), Gass (1989), and Paul et al. (1988).

Wells constructed in bedrock may require special protocols. For example, wells constructed as open boreholes (cased to monitored zone) generally should not be developed using a surge block due to the potential for damaging the borehole walls. Bedrock wells constructed with screens may be developed in two stages, before and after the screen is installed. Since bedrock wells may require special development protocols other than those described here for wells in unconsolidated aquifers, Regional hydrogeologists should be consulted when designing bedrock well development procedures.

Finally, it is important to note that there are some hydrogeologic environments, such as fine-grained "marginal" aquifers and karst terraines, where excess turbidity may still exist even after optimizing well construction (e.g., filter pack size and thickness, screen size, drilling technique) and development.

Development Methods

The common methods for developing wells are described by Aller et al. (1989) and Driscoll (1986) and include:

- Overpumping
- Backwashing
- Surging
- Bailing
- Jetting
- Airlift pumping
- Air surging

Well development procedures that have the potential to alter ground-water quality should not be used. Therefore, methods which involve adding water or other fluids to the well, or use air to accomplish development, are not recommended. Generally unsuitable methods for monitoring well development include jetting, airlift pumping, and air surging. However, air development techniques may be used if they offer site-specific advantages over other methods, and extreme care is taken to prevent air from contacting the screened interval. Air development techniques must only be implemented by an experienced operator.

Recommended monitoring well development methods include pumping, overpumping, bailing and backwashing, in combination with some form of surging. The most effective combination and timing of these methods must be determined through field testing, or from experience developing wells in similar hydrogeologic regimes.

Movement of ground water into the well in one direction generally results in bridging of the particles, and a means of inducing flow reversal is necessary to break down the bridging and produce a stable filter. Aller et al. (1989) state that one of the most effective and efficient methods to induce flow reversal is through careful use of a properly-constructed surge block. For a more detailed description of proper usage of a surge block and other methods of achieving flow reversal, see Aller et al.

One example of a well development field protocol is described below:

1. Record static water level and total well depth.

2. Set the pump and record pumping rate and turbidity. Pump until turbidity (as measured by a nephelometer) reaches desired level or stabilizes.

3. Discontinue pumping and surge the well.

4. Measure depth to the bottom of the well. If more than 10% of the screen is occluded by sediments, remove excess sediment by bailing.

5. Reset the pump, recording pumping rate and turbidity. Pump until turbidity reaches desired level or stabilizes. If the well has been properly designed, the amount of pumping required to achieve the desired turbidity level will be substantially less than required in the first pumping cycle.

6. Repeat surging and pumping until the well yields water of acceptable turbidity at the beginning of a pumping cycle. A good way to ensure that development is complete is to shut the pump off during the last anticipated pumping cycle, leaving the pump in place, and restart it some time later. The turbidity of the discharge water should remain low.

The pumping rate used during development must be greater than the highest rate expected to be used during subsequent purging and sampling. In fact, recent field experience suggests that extremely low (i.e., 100 to 500 ml/min) purging and sampling pumping rates may significantly reduce the turbidity of ground-water samples (Puls et al., 1990). The pump intake should be placed close to, or within, the well screen interval.

The development techniques listed above are most efficient in wells with screens having the greatest area open to the aquifer. Therefore, continuous slot, or wire wrapped screens are recommended for use in formations where adequate development is expected

to be difficult. The additional cost of continuous slot screen is typically more than compensated for by significantly less cost in development time and subsequent well purging times.

Development Criteria

Development should continue until clear, artifact-free, formation water is produced. Water quality parameters such as specific conductance, pH, temperature, and turbidity should be measured during development, and should stabilize before development is stopped. Turbidity measurements are the most critical development criteria. Other parameters should be used to provide supplemental information regarding aquifer conditions, and stabilization of these parameters is indicative of the presence of formation water. If water was added during well construction or development, two to three times the volume of water added must be removed. Finally, the well should be producing visually clear water before development is stopped.

Experience has shown that development may take from less than an hour to several days, depending on the formation, development procedures, and well characteristics or construction. In some marginal aquifers such as glacial tills and interbedded sands and clays, it may not be possible to attain the 5 NTUs turbidity target level used as guidance in RCRA. However, poor well construction practices, failure to emplace an adequate filter pack, poor selection of screen slot size and sand pack materials, as well as inadequate development may result in high turbidity levels. In these situations, the PRP or contractor must demonstrate that the well has been constructed properly and all reasonable efforts have been expended to develop the well. The determination of whether to abandon the well or address the turbidity problem during sampling and analysis should be made by the project manager in consultation with a Regional hydrogeologist.

After development is completed, wells should be allowed to stabilize and re-equilibrate before sampling. The time necessary for stabilization depends on the characteristics of the aquifer and the geochemistry of the parameters to be monitored. Generally, high permeability formations require less time (i.e., several days) than low permeability formations (i.e., several weeks).

Development Documentation

Monitoring well development must be thoroughly documented to verify that foreign materials have been removed, formation water is being sampled, and turbidity has reached acceptable levels or stabilized.

The following data should be recorded before and during well development:

1. Date and duration of development

2. Water level from the marked measuring point on the top of casing before and 24 hours after well development.

3. Depth from top of well casing to the top of any sediment present in the well, before, during, and after development.

4. Types and quantity of drilling fluids introduced during drilling and development.

5. Field measurements (e.g., turbidity, specific conductance, pH, dissolved oxygen, temperature) taken before, during, and after well development.

6. Volume and physical characteristics of developed water (e.g., odor, color, clarity, particulate matter).

7. Type and capacity of pump and/or bailer used and pumping rates.

8. Detailed description of all development methods used.

Glossary

Backwashing The surging effect or reversal of water flow in a well that removes fine-grained material from the formation surrounding the borehole. Only formation water is used during this process.

Jetting Bursts of high-velocity water injected into the well.

Overpumping Pumping at rates generally greater than those used during sampling or well purging. Commonly combined with surging of the well.

Surge Block A plunger-like tool, consisting of leather or rubber discs sandwiched between steel or wooden disks that may be soild or valved, that is used in well development.

Surging A well development technique where the surge block is alternately lifted and dropped within the borehole above or adjacent to the screen to create a strong inward and outward movement of the water through the well intake.

Turbidity Solids and organic matter suspended in water.

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Appendix B

Data Quality Objectives (DQOs)

Appendix B – Data Quality Objectives for Groundwater Monitoring

Step 1: State the Problem	Pursuant to Section III.D of the Administrative Order on Consent (AOC) Statement of Work (SOW), the Dairies shall establish a network of monitoring wells to measure the effectiveness of the nitrogen source reduction actions on water quality in the shallow, alluvial aquifer which serves as a groundwater source of drinking water. The goal of the AOC is to achieve drinking water quality that meets the EPA maximum contaminant level (MCL) for nitrate of 10 milligrams per liter (mg/L) in the drinking water aquifer beneath and downgradient of the Dairies.
Step 2: Identify the Decision	Primary Questions: · What is the baseline groundwater quality beneath and downgradient of the Dairies? · Are the actions taken to reduce nitrogen loading to the groundwater effective over time? · How does the environmental setting affect groundwater conditions including the hydrogeology of the aquifer, groundwater flow and hydraulic gradient?
Step 3: Identify Inputs to the Decision	· Location of monitoring wells with respect to upgradient and downgradient of Dairy facilities within the Dairy Facilities Boundary. · Subsurface characterization obtained during the drilling of monitoring wells. · Groundwater samples collected from Dairy monitoring wells on a quarterly basis for eight years and analyzed for nitrate, nitrite, ammonia, phosphorus, total Kjeldahl nitrogen, select inorganic anions and metals, and alkalinity. ·
Step 4: Define the Boundaries of the Study	· Spatial Boundary: Monitoring wells completed in the shallow and deep portions of the alluvial aquifer within the Dairy Facilities Boundary in Figures 3 and 4 of the QAPP. · Temporal Boundary: Pursuant to the AOC SOW, collection of groundwater samples from monitoring wells must commence within 60 days of approval of the QAPP and completed quarterly for eight years. · Media of Interest: Drinking water sourced from shallow groundwater.
Step 5: Develop a Decision Rule	Primary Decision Rule: Prior to termination of the AOC, if the Dairies can demonstrate to the EPA that nitrate levels in downgradient monitoring well(s) has remained below the MCL for eight quarters, upon notice form the EPA, the Dairies may cease to sample that well(s).
Step 6: Specify Tolerable Limits on Decision Errors	The Groundwater Monitoring was designed to provide a comprehensive characterization of groundwater conditions beneath and downgradient of Dairy facilities within the area of interest. Nitrate concentrations, as well as related analytes, will be measured in groundwater samples collected from Dairy monitoring wells within the area of interest. Precision, accuracy, and completeness criteria for analytical samples are shown in Table 3 of the QAPP. Data verification will be conducted by the laboratory prior to submission to the Project Coordinator. Data review, validation, and verification performed by the laboratory will comply with EPA requirements and laboratory SOPs for the EPA Methods specified in Section 2.5.2 of the QAPP
Step 7: Develop the Plan for Obtaining Data	1. Groundwater monitoring wells will be located within the area of interest and will be surveyed. 2. Groundwater monitoring wells will be drilled, installed, completed and developed under the direct supervision of a licensed geologist.

	3. A Groundwater Monitoring Well Installation Report will be prepared following well installation and development activities. This report, as well as subsequent Groundwater Monitoring Data Reports, will present a comprehensive discussion on the environmental setting in accordance with Section III.E. 1.a of the AOC SOW including geology and hydrogeology beneath the Dairies, hydrogeologic characteristics affecting groundwater flow and contaminant migration. The reports will present discussions on human influences, including off-site structures and conditions, that may affect the hydrogeology and migration of contaminants at or from the Dairies. The reports will present descriptions of surface water flow regimes, both regional and on/near the Dairies. 4. Groundwater samples will be collected from the monitoring wells using low-flow sampling methods. 5. Groundwater samples will be submitted to a state of Washington-certified analytical laboratory for the analysis of nitrate, nitrite, ammonia, phosphorus, total Kjeldahl nitrogen, select inorganic anions and metals, and alkalinity. 6. Analytical data will be compiled, validated and reported to EPA in quarterly Groundwater Monitoring Data Reports. The Groundwater Monitoring Data Reports will present the findings of the groundwater monitoring work at the Dairies. Each quarterly report will include figure(s) that depict, at a minimum, water level elevations and gradient and constituent concentrations and will include a cumulative presentation of all data collected to date. 7. Beginning in 2014, Annual Groundwater Monitoring Data Report will be prepared and submitted to EPA. These reports will contain a chart for each sample parameter at each well (e.g., time-concentration plots). The charts will include all historical data collected from each well.

Appendix C

Laboratory Certification

WASHINGTON STATE DEPARTMENT OF ECOLOGY

ENVIRONMENTAL LABORATORY ACCREDITATION PROGRAM

SCOPE OF ACCREDITATION

TestAmerica Spokane

Spokane Valley, WA

is accredited for the analytes listed below using the methods indicated. Full accreditation is granted unless stated otherwise in a note. Accreditation for U.S. Environmental Protection Agency (EPA) "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods" (SW-846) is for the latest version of the method. SM refers to EPA approved editions of “Standard Methods for the Examination of Water and Wastewater.” ASTM is the American Society for Testing and Materials. Other references are described in notes.

Matrix/Analyte	Method	Notes
Drinking Water		
Turbidity	EPA 180.1_2_1993	
Chloride	EPA 300.0_2.1_1993	
Fluoride	EPA 300.0_2.1_1993	
Nitrate	EPA 300.0_2.1_1993	
Nitrite	EPA 300.0_2.1_1993	
Sulfate	EPA 300.0_2.1_1993	
Color	SM 2120 B-01	
Alkalinity	SM 2320 B-97	
Hardness	SM 2340 B-97	
Specific Conductance	SM 2510 B-97	
Solids, Total Dissolved	SM 2540 C-97	
Aluminum	EPA 200.7_4.4_1994	
Barium	EPA 200.7_4.4_1994	
Beryllium	EPA 200.7_4.4_1994	
Cadmium	EPA 200.7_4.4_1994	
Calcium	EPA 200.7_4.4_1994	
Chromium	EPA 200.7_4.4_1994	
Copper	EPA 200.7_4.4_1994	
Iron	EPA 200.7_4.4_1994	
Magnesium	EPA 200.7_4.4_1994	
Manganese	EPA 200.7_4.4_1994	
Nickel	EPA 200.7_4.4_1994	

Matrix/Analyte	Method	Notes
Silver	EPA 200.7_4.4_1994	
Sodium	EPA 200.7_4.4_1994	
Zinc	EPA 200.7_4.4_1994	
Mercury	EPA 245.1_3_1994	
Total Coli/Ecoli - count	SM 9223 B (Colilert® QTray)	
Total Coli/Ecoli - detect	SM 9223 B Colilert	1
Non-Potable Water		
Specific Conductance	EPA 120.1_1982	
Turbidity	EPA 180.1_2_1993	
Chloride	EPA 300.0_2.1_1993	
Fluoride	EPA 300.0_2.1_1993	
Nitrate	EPA 300.0_2.1_1993	
Nitrite	EPA 300.0_2.1_1993	
Sulfate	EPA 300.0_2.1_1993	
Chemical Oxygen Demand (COD)	EPA 410.4_2_1993	
Color	SM 2120 B-01	
Alkalinity	SM 2320 B-97	
Hardness	SM 2340 B-97	
Specific Conductance	SM 2510 B-97	
Solids, Total Dissolved	SM 2540 C-97	
Solids, Total Suspended	SM 2540 D-97	
Dissolved Oxygen	SM 4500-O G-01	
Phosphorus, total	SM 4500-P E-99	
Biochemical Oxygen Demand (BOD)	SM 5210 B-01	
Aluminum	EPA 200.7_4.4_1994	
Antimony	EPA 200.7_4.4_1994	
Arsenic	EPA 200.7_4.4_1994	
Barium	EPA 200.7_4.4_1994	
Beryllium	EPA 200.7_4.4_1994	
Boron	EPA 200.7_4.4_1994	
Cadmium	EPA 200.7_4.4_1994	
Calcium	EPA 200.7_4.4_1994	
Chromium	EPA 200.7_4.4_1994	
Cobalt	EPA 200.7_4.4_1994	

Matrix/Analyte	Method	Notes
Copper	EPA 200.7_4.4_1994	
Iron	EPA 200.7_4.4_1994	
Lead	EPA 200.7_4.4_1994	
Magnesium	EPA 200.7_4.4_1994	
Manganese	EPA 200.7_4.4_1994	
Molybdenum	EPA 200.7_4.4_1994	
Nickel	EPA 200.7_4.4_1994	
Potassium	EPA 200.7_4.4_1994	
Selenium	EPA 200.7_4.4_1994	
Silver	EPA 200.7_4.4_1994	
Sodium	EPA 200.7_4.4_1994	
Thallium	EPA 200.7_4.4_1994	
Tin	EPA 200.7_4.4_1994	
Vanadium	EPA 200.7_4.4_1994	
Zinc	EPA 200.7_4.4_1994	
Mercury	EPA 245.1_3_1994	
Total Coli/Ecoli - count	SM 9223 B (Colilert® QTray)	
Solid and Chemical Materials		
pH	EPA 9045D_2002	
Aluminum	EPA 6010C_(2/07)	
Antimony	EPA 6010C_(2/07)	
Arsenic	EPA 6010C_(2/07)	
Barium	EPA 6010C_(2/07)	
Beryllium	EPA 6010C_(2/07)	
Boron	EPA 6010C_(2/07)	
Cadmium	EPA 6010C_(2/07)	
Calcium	EPA 6010C_(2/07)	
Chromium	EPA 6010C_(2/07)	
Cobalt	EPA 6010C_(2/07)	
Copper	EPA 6010C_(2/07)	
Iron	EPA 6010C_(2/07)	
Lead	EPA 6010C_(2/07)	
Magnesium	EPA 6010C_(2/07)	
Manganese	EPA 6010C_(2/07)	

Matrix/Analyte	Method	Notes
Molybdenum	EPA 6010C_(2/07)	
Nickel	EPA 6010C_(2/07)	
Potassium	EPA 6010C_(2/07)	
Selenium	EPA 6010C_(2/07)	
Silver	EPA 6010C_(2/07)	
Thallium	EPA 6010C_(2/07)	
Vanadium	EPA 6010C_(2/07)	
Zinc	EPA 6010C_(2/07)	
Mercury	EPA 7471B_(1/98)	
1,2-Dibromo-3-chloropropane (DBCP)	EPA 8011-94	
1,2-Dibromoethane (EDB, Ethylene dibromide)	EPA 8011-94	
Aroclor-1016 (PCB-1016)	EPA 8082A_(2/07)	
Aroclor-1221 (PCB-1221)	EPA 8082A_(2/07)	
Aroclor-1232 (PCB-1232)	EPA 8082A_(2/07)	
Aroclor-1242 (PCB-1242)	EPA 8082A_(2/07)	
Aroclor-1248 (PCB-1248)	EPA 8082A_(2/07)	
Aroclor-1254 (PCB-1254)	EPA 8082A_(2/07)	
Aroclor-1260 (PCB-1260)	EPA 8082A_(2/07)	
Total Pet Hydrocarbons - Diesel	WDOE NWTPH-Dx_(1997)	
Total Pet Hydrocarbons - Gasoline	WDOE NWTPH-Gx_(1997)	
1,1,1,2-Tetrachloroethane	EPA 8260C_(8/06)	
1,1,1-Trichloro-2,2,2-trifluoroethane	EPA 8260C_(8/06)	
1,1,1-Trichloro-2-propanone	EPA 8260C_(8/06)	
1,1,1-Trichloroethane	EPA 8260C_(8/06)	
1,1,2,2-Tetrachloroethane	EPA 8260C_(8/06)	
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	EPA 8260C_(8/06)	
1,1,2-Trichloroethane	EPA 8260C_(8/06)	
1,1,2-Trichlorofluoroethane	EPA 8260C_(8/06)	
1,1-Dichloro-1-fluoroethane	EPA 8260C_(8/06)	
1,1-Dichloroethane	EPA 8260C_(8/06)	
1,1-Dichloroethylene	EPA 8260C_(8/06)	
1,1-Dichloropropene	EPA 8260C_(8/06)	
1,2,3,4-Diepoxybutane	EPA 8260C_(8/06)	
1,2,3-Trichlorobenzene	EPA 8260C_(8/06)	

Matrix/Analyte	Method	Notes
1,2,3-Trichloropropane	EPA 8260C_(8/06)	
1,2,3-Trimethylbenzene	EPA 8260C_(8/06)	
1,2,4-Trichlorobenzene	EPA 8260C_(8/06)	
1,2,4-Trimethylbenzene	EPA 8260C_(8/06)	
1,2-Dibromo-3-chloropropane (DBCP)	EPA 8260C_(8/06)	
1,2-Dibromoethane (EDB, Ethylene dibromide)	EPA 8260C_(8/06)	
1,2-Dichloro-1,1,2,2-tetrafluoroethane (Freon 114)	EPA 8260C_(8/06)	
1,2-Dichloro-1,1,2-trifluoroethane	EPA 8260C_(8/06)	
1,2-Dichlorobenzene	EPA 8260C_(8/06)	
1,2-Dichloroethane (Ethylene dichloride)	EPA 8260C_(8/06)	
1,2-Dichloropropane	EPA 8260C_(8/06)	
1,2-Dimethoxyethane	EPA 8260C_(8/06)	
1,3,5-Trimethylbenzene	EPA 8260C_(8/06)	
1,3-Butanediol	EPA 8260C_(8/06)	
1,3-Dichloro-2-propanol	EPA 8260C_(8/06)	
1,3-Dichlorobenzene	EPA 8260C_(8/06)	
1,3-Dichloropropane	EPA 8260C_(8/06)	
1,3-Dichloropropene	EPA 8260C_(8/06)	
1,4-Butanediol	EPA 8260C_(8/06)	
1,4-Dichloro-2-butene	EPA 8260C_(8/06)	
1,4-Dichlorobenzene	EPA 8260C_(8/06)	
1,4-Difluorobenzene	EPA 8260C_(8/06)	
1,4-Dioxane (1,4- Diethyleneoxide)	EPA 8260C_(8/06)	
1-Butene	EPA 8260C_(8/06)	
1-Chloro-1,2,2-trifluoroethane (Freon 133)	EPA 8260C_(8/06)	
1-Chlorobutane	EPA 8260C_(8/06)	
1-Chlorohexane	EPA 8260C_(8/06)	
1-Heptene	EPA 8260C_(8/06)	
1-Hexene	EPA 8260C_(8/06)	
1-Methyl-2-n-propylbenzene	EPA 8260C_(8/06)	
1-Propene	EPA 8260C_(8/06)	
2,2,4-Trimethylpentane	EPA 8260C_(8/06)	
2,2-Dichloro-1,1,1-trifluoroethane (Freon 123)	EPA 8260C_(8/06)	
2,2-Dichloropropane	EPA 8260C_(8/06)	
2,2-Dimethylbutane	EPA 8260C_(8/06)	
2,2'-Oxybis(1-chloropropane)	EPA 8260C_(8/06)	

Matrix/Analyte	Method	Notes
2,3,4-Trimethylpentane	EPA 8260C_(8/06)	
2,3-Dichloropropene	EPA 8260C_(8/06)	
2,3-Dimethylbutane	EPA 8260C_(8/06)	
2,3-Dimethylpentane	EPA 8260C_(8/06)	
2,4-Dimethylpentane	EPA 8260C_(8/06)	
2-Bromofluorobenzene	EPA 8260C_(8/06)	
2-Butanone (Methyl ethyl ketone, MEK)	EPA 8260C_(8/06)	
2-Chloro-2-methybutane (tert-Amyl chloride)	EPA 8260C_(8/06)	
2-Chloroethanol	EPA 8260C_(8/06)	
2-Chloroethyl vinyl ether	EPA 8260C_(8/06)	
2-Chlorotoluene	EPA 8260C_(8/06)	
2-Ethylhexanol (2-Ethyl-1-hexanol)	EPA 8260C_(8/06)	
2-Ethyltoluene	EPA 8260C_(8/06)	
2-Hexanone	EPA 8260C_(8/06)	
2-Hexene	EPA 8260C_(8/06)	
2-Hydroxypropionitrile	EPA 8260C_(8/06)	
2-Methoxyethanol (Methyl cellosolve)	EPA 8260C_(8/06)	
2-Methyl-1,3-dioxolane	EPA 8260C_(8/06)	
2-Methyl-2-Butene	EPA 8260C_(8/06)	
2-Methylaniline (o-Toluidine)	EPA 8260C_(8/06)	
2-Methylbutadiene (Isoprene)	EPA 8260C_(8/06)	
2-Methylbutane (Isopentane)	EPA 8260C_(8/06)	
2-Methylheptane	EPA 8260C_(8/06)	
2-Methylhexane	EPA 8260C_(8/06)	
2-Methylpentane (Isohexane)	EPA 8260C_(8/06)	
2-methylpropane (Isobutane)	EPA 8260C_(8/06)	
2-Nitropropane	EPA 8260C_(8/06)	
2-Pentanone	EPA 8260C_(8/06)	
2-Picoline (2-Methylpyridine)	EPA 8260C_(8/06)	
3-Bromofluorobenzene	EPA 8260C_(8/06)	
3-Butene-1-ol	EPA 8260C_(8/06)	
3-Chloropropionitrile	EPA 8260C_(8/06)	
3-Ethyltoluene	EPA 8260C_(8/06)	
3-Methyl-1-Butene	EPA 8260C_(8/06)	
3-Methylheptane	EPA 8260C_(8/06)	
3-Methylhexane	EPA 8260C_(8/06)	

Matrix/Analyte	Method	Notes
3-Methylpentane	EPA 8260C_(8/06)	
4-Bromofluorobenzene	EPA 8260C_(8/06)	
4-Chlorotoluene	EPA 8260C_(8/06)	
4-Ethyltoluene	EPA 8260C_(8/06)	
4-Isopropyltoluene (p-Cymene)	EPA 8260C_(8/06)	
4-Methyl-1-Pentene	EPA 8260C_(8/06)	
4-Methyl-2-pentanone (MIBK)	EPA 8260C_(8/06)	
4-Methylaniline (p-Toluidine)	EPA 8260C_(8/06)	
Acetamide	EPA 8260C_(8/06)	
Acetone	EPA 8260C_(8/06)	
Acetonitrile	EPA 8260C_(8/06)	
Acetylene	EPA 8260C_(8/06)	
Acrolein (Propenal)	EPA 8260C_(8/06)	
Acrylamide	EPA 8260C_(8/06)	
Acrylic acid	EPA 8260C_(8/06)	
Acrylonitrile	EPA 8260C_(8/06)	
Adsorbable Organic Halides (AOX)	EPA 8260C_(8/06)	
Allyl alcohol	EPA 8260C_(8/06)	
Allyl chloride (3-Chloropropene)	EPA 8260C_(8/06)	
alpha-Methylstyrene	EPA 8260C_(8/06)	
Benzene	EPA 8260C_(8/06)	
beta-Propiolactone	EPA 8260C_(8/06)	
bis(2-Chloroethyl) sulfide	EPA 8260C_(8/06)	
bis(Chloromethyl)ether	EPA 8260C_(8/06)	
Bromoacetone	EPA 8260C_(8/06)	
Bromobenzene	EPA 8260C_(8/06)	
Bromochloromethane	EPA 8260C_(8/06)	
Bromodichloromethane	EPA 8260C_(8/06)	
Bromoethane (Ethyl Bromide)	EPA 8260C_(8/06)	
Bromoethene	EPA 8260C_(8/06)	
Bromoform	EPA 8260C_(8/06)	
Butyl acetate	EPA 8260C_(8/06)	
Carbon disulfide	EPA 8260C_(8/06)	
Carbon tetrachloride	EPA 8260C_(8/06)	
Chloral hydrate	EPA 8260C_(8/06)	
Chloroacetonitrile	EPA 8260C_(8/06)	

Matrix/Analyte	Method	Notes
Chlorobenzene	EPA 8260C_(8/06)	
Chlorodibromomethane	EPA 8260C_(8/06)	
Chlorodifluoromethane (Freon-22)	EPA 8260C_(8/06)	
Chloroethane (Ethyl chloride)	EPA 8260C_(8/06)	
Chloroform	EPA 8260C_(8/06)	
Chloromethyl methyl ether	EPA 8260C_(8/06)	
Chloroprene (2-Chloro-1,3-butadiene)	EPA 8260C_(8/06)	
cis & trans-1,2-Dichloroethene	EPA 8260C_(8/06)	
cis-1,2-Dichloroethylene	EPA 8260C_(8/06)	
cis-1,3-Dichloropropene	EPA 8260C_(8/06)	
cis-1,4-Dichloro-2-butene	EPA 8260C_(8/06)	
cis-2-Butene	EPA 8260C_(8/06)	
cis-2-Hexene	EPA 8260C_(8/06)	
cis-2-pentene	EPA 8260C_(8/06)	
Cycloate	EPA 8260C_(8/06)	
Cyclohexane	EPA 8260C_(8/06)	
Cyclohexanol	EPA 8260C_(8/06)	
Cyclohexanone	EPA 8260C_(8/06)	
Cyclopentane	EPA 8260C_(8/06)	
Cyclopentene	EPA 8260C_(8/06)	
Decanal	EPA 8260C_(8/06)	
Dibromochloropropane	EPA 8260C_(8/06)	
Dibromofluoromethane	EPA 8260C_(8/06)	
Dibromomethane (Methylene bromide)	EPA 8260C_(8/06)	
Dichlorodifluoromethane (Freon-12)	EPA 8260C_(8/06)	
Dichlorofluoromethane (Freon 21)	EPA 8260C_(8/06)	
Dichlorotetrafluoroethane	EPA 8260C_(8/06)	
Dicyclopentadiene	EPA 8260C_(8/06)	
Diethyl ether	EPA 8260C_(8/06)	
Diethylamine	EPA 8260C_(8/06)	
Diethylene glycol	EPA 8260C_(8/06)	
Dimethyl disulfide	EPA 8260C_(8/06)	
Dimethyl sulfoxide	EPA 8260C_(8/06)	
Epichlorohydrin (1-Chloro-2,3-epoxypropane)	EPA 8260C_(8/06)	
Ethane	EPA 8260C_(8/06)	
Ethanol	EPA 8260C_(8/06)	

Matrix/Analyte	Method	Notes
Ethene	EPA 8260C_(8/06)	
Ethyl acetate	EPA 8260C_(8/06)	
Ethyl acrylate	EPA 8260C_(8/06)	
Ethyl methacrylate	EPA 8260C_(8/06)	
Ethyl tert-Butyl alcohol	EPA 8260C_(8/06)	
Ethylbenzene	EPA 8260C_(8/06)	
Ethylene glycol	EPA 8260C_(8/06)	
Ethylene oxide	EPA 8260C_(8/06)	
Ethylene thiourea	EPA 8260C_(8/06)	
Ethyleneimine	EPA 8260C_(8/06)	
Ethyl-t-butylether (ETBE) (2-Ethoxy-2-methylpropan	EPA 8260C_(8/06)	
Fluorobenzene	EPA 8260C_(8/06)	
Fluoromethane (Freon 41)	EPA 8260C_(8/06)	
Heptanal	EPA 8260C_(8/06)	
Hexachlorobutadiene	EPA 8260C_(8/06)	
Hexachloroethane	EPA 8260C_(8/06)	
Iodomethane (Methyl iodide)	EPA 8260C_(8/06)	
Isobutyl alcohol (2-Methyl-1-propanol)	EPA 8260C_(8/06)	
Isopropyl acetate	EPA 8260C_(8/06)	
Isopropyl alcohol (2-Propanol, Isopropanol)	EPA 8260C_(8/06)	
Isopropylbenzene	EPA 8260C_(8/06)	
m+p-xylene	EPA 8260C_(8/06)	
Malononitrile	EPA 8260C_(8/06)	
Methacrylonitrile	EPA 8260C_(8/06)	
Methane	EPA 8260C_(8/06)	
Methanol	EPA 8260C_(8/06)	
Methyl acetate	EPA 8260C_(8/06)	
Methyl acrylate	EPA 8260C_(8/06)	
Methyl bromide (Bromomethane)	EPA 8260C_(8/06)	
Methyl chloride (Chloromethane)	EPA 8260C_(8/06)	
Methyl formate	EPA 8260C_(8/06)	
Methyl methacrylate	EPA 8260C_(8/06)	
Methyl tert-butyl ether (MTBE)	EPA 8260C_(8/06)	
Methylcyclohexane	EPA 8260C_(8/06)	
Methylcyclopentane	EPA 8260C_(8/06)	
Methylene chloride (Dichloromethane)	EPA 8260C_(8/06)	

Matrix/Analyte	Method	Notes
m-Xylene	EPA 8260C_(8/06)	
n, n-Dimethylformamide	EPA 8260C_(8/06)	
n-Amyl acetate	EPA 8260C_(8/06)	
n-Amyl alcohol	EPA 8260C_(8/06)	
Naphthalene	EPA 8260C_(8/06)	
n-Butane	EPA 8260C_(8/06)	
n-Butyl alcohol (1-Butanol, n-Butanol)	EPA 8260C_(8/06)	
n-Butylbenzene	EPA 8260C_(8/06)	
n-Butylcyclopentane	EPA 8260C_(8/06)	
n-Heptane	EPA 8260C_(8/06)	
n-Hexane	EPA 8260C_(8/06)	
Nitrobenzene	EPA 8260C_(8/06)	
n-Nitroso-di-n-butylamine	EPA 8260C_(8/06)	
n-Nonane	EPA 8260C_(8/06)	
n-Octane	EPA 8260C_(8/06)	
n-Pentane	EPA 8260C_(8/06)	
n-Propane	EPA 8260C_(8/06)	
n-Propanol (1-Propanol)	EPA 8260C_(8/06)	
n-Propylamine	EPA 8260C_(8/06)	
n-Propylbenzene	EPA 8260C_(8/06)	
o-Xylene	EPA 8260C_(8/06)	
p-Diethylbenzene	EPA 8260C_(8/06)	
Pentachloroethane	EPA 8260C_(8/06)	
Pentafluorobenzene	EPA 8260C_(8/06)	
Propargyl alcohol	EPA 8260C_(8/06)	
Propionitrile (Ethyl cyanide)	EPA 8260C_(8/06)	
Propyne	EPA 8260C_(8/06)	
Purgeable Organic Halides	EPA 8260C_(8/06)	
p-Xylene	EPA 8260C_(8/06)	
Pyridine	EPA 8260C_(8/06)	
Sec-Amyl Alcohol (2-Pentanol)	EPA 8260C_(8/06)	
sec-Butylbenzene	EPA 8260C_(8/06)	
S-Methyl thioacetate (S-Methyl etanethioate)	EPA 8260C_(8/06)	
Styrene	EPA 8260C_(8/06)	
tert-Amyl alcohol (TAA)	EPA 8260C_(8/06)	
tert-Amyl ethyl ether (TAEE)	EPA 8260C_(8/06)	

Matrix/Analyte	Method	Notes
tert-amylmethylether (TAME)	EPA 8260C_(8/06)	
tert-Butyl alcohol	EPA 8260C_(8/06)	
tert-Butylbenzene	EPA 8260C_(8/06)	
Tetrachloroethylene (Perchloroethylene)	EPA 8260C_(8/06)	
Tetrahydrofuran (THF)	EPA 8260C_(8/06)	
Toluene	EPA 8260C_(8/06)	
Total Trihalomethanes	EPA 8260C_(8/06)	
Total Volatile Petroleum Hydrocarbons (VPH)	EPA 8260C_(8/06)	
trans-1,2-Dichloroethylene	EPA 8260C_(8/06)	
trans-1,3-Dichloropropylene	EPA 8260C_(8/06)	
trans-1,4-Dichloro-2-butene	EPA 8260C_(8/06)	
trans-2-Butene	EPA 8260C_(8/06)	
trans-2-Hexene	EPA 8260C_(8/06)	
trans-2-pentene	EPA 8260C_(8/06)	
Trichloroethene (Trichloroethylene)	EPA 8260C_(8/06)	
Trichlorofluoromethane (Fluorotrichloromethane, Fr	EPA 8260C_(8/06)	
Triethylamine	EPA 8260C_(8/06)	
Trifluoromethane (Freon 23)	EPA 8260C_(8/06)	
Vinyl acetate	EPA 8260C_(8/06)	
Vinyl bromide	EPA 8260C_(8/06)	
Vinyl chloride	EPA 8260C_(8/06)	
Xylenes (total)	EPA 8260C_(8/06)	
2-Methylnaphthalene	EPA 8270D_(2/07)	
Acenaphthene	EPA 8270D_(2/07)	
Acenaphthylene	EPA 8270D_(2/07)	
Anthracene	EPA 8270D_(2/07)	
Benzo(a)anthracene	EPA 8270D_(2/07)	
Benzo(a)pyrene	EPA 8270D_(2/07)	
Benzo(g,h,i)perylene	EPA 8270D_(2/07)	
Benzo(k)fluoranthene	EPA 8270D_(2/07)	
Benzo[b]fluoranthene	EPA 8270D_(2/07)	
Biphenyl	EPA 8270D_(2/07)	
Chrysene	EPA 8270D_(2/07)	
Dibenz(a,h) acridine	EPA 8270D_(2/07)	
Dibenz(a,h) anthracene	EPA 8270D_(2/07)	
Dibenz(a,j) acridine	EPA 8270D_(2/07)	

Matrix/Analyte	Method	Notes
Dibenzo(a,e) pyrene	EPA 8270D_(2/07)	
Fluoranthene	EPA 8270D_(2/07)	
Fluorene	EPA 8270D_(2/07)	
Indeno(1,2,3-cd) pyrene	EPA 8270D_(2/07)	
Naphthalene	EPA 8270D_(2/07)	
Phenanthrene	EPA 8270D_(2/07)	
Pyrene	EPA 8270D_(2/07)	
Ignitability	EPA 1010A - 2004	

Accredited Parameter Note Detail

(1) Interim accreditation pending the successful completion of an on-site audit to verify method capabilities (WAC 173-50-100).

01/08/2013

Authentication Signature
Alan D. Rue, Lab Accreditation Unit Supervisor

Date

Appendix D

Field Forms

ARCADIS

MONITORING WELL LOG

WELL NO.	PROJECT NO.	LOCATION		SHEET OF
TIME START	PROJECT NAME	DRILLING CONTRACTOR	DRILLER	DATE
TIME STOP	DRILLING EQUIPMEMT	DRILLING METHOD	SAMPLING METHOD	FIRST WATER
TOTAL DEPTH	CASING	SCREEN		SCREEN LENGTH
PROJECT MGR.	FILTER PACK	SEAL		FINAL DTW

DEPTH BELOW SURFACE	PENETRATION RATE (IN./MIN.)	SAMPLER TYPE	INCHES DRIVEN/ RECOVERED	BLOWS PER 6 IN.	USCS	LOG OF MATERIAL	WELL CONSTRUCTION
1							
2							
3							
4							
5							
6							
7							
8							
9							
0							
1							
2							
3							
4							
5							
6							
7							
8							
9							

LOGGED BY: _____ OFFICE: _____ DATE: _____

WELL DEVELOPMENT RECORD

WELL NUMBER:

Project No:_____ Project Name:_____ PAGE ____ of: ____

Date(s): _____

Developed by: _____

Measuring Point (MP) of Well: _____

Screened Interval (ft. BGL): _____

Filter Pack Interval (ft. BGL): _____

Casing Stick-Up/Down (ft.): _____

Starting Water Level (ft. BMP): _____

Total Depth (ft. BMP): _____Water Column Height (ft.): _____

Casing Diameter (in. ID): ____ Multiplication Factor: _____

Casing Volume (gal.): _____

Water Level (ft. BMP) at End of Development: _____

Total Depth (ft. BMP) at End of Development: _____

QUALITY ASSURANCE

METHODS (describe):

Cleaning Equipment:_____

Development:_____

Disposal of Discharged Water:_____

INSTRUMENTS (indicate make, model, i.d.):

Water Level: _____ Thermometer: _____

pH Meter: _____ Field Calibration: _____

Conductivity Meter: _____ Field Calibration: _____

Other: Field Calibration:

DEVELOPMENT MEASUREMENTS

Date/ Time	Purge Characteristics		Water Quality Data				Appearance		Intake Depth (ft. BMP)	Remarks
	Cumul.Vol. (gal)	Water Level (ft. BGL)	Temp. (☐	pH	Specific Conductance (µmhos/cm) @ Field Temp.	Specific Conductance (µmhos/cm) @ 25 ☐	Color	Turbidity & Sediment		

Total Discharge (gallons): _____ Casing Volumes Removed: _____

Observations/Comments:

ABBREVIATIONS:
BMP - below measuring point
BGL - below ground level
Cumul. Vol. - Cumulative volume removed
ID - Inside Diameter
C - Celsius
gal. - gallons
gpm - gallons per minutes
in. – inches

Well Development Form Revision 8/00

ARCADIS U.S., INC.
695 N. Legacy Ridge Drive, Suite 200
LIBERTY LAKE, WA 99019
(509) 928-3369
FAX (509) 928-3075

GROUNDWATER SAMPLING RECORD

SAMPLE ID: PAGE:___of:___

Project No: Project Name: Date:

Sampling Location (well ID, etc.): _____

Sampled by: _____

Measuring Point (MP) of Well: Top of casing_____

Screened Interval (ft. BGL): _____

Filter Pack Interval (ft. BGL): _____

Casing Stickup (ft.): _____

Starting Water Level (ft.BMP):_____

Total Depth (ft. BMP): _____ Water Column Height (ft): ____

Casing Diameter (in ID): _____ Multiplication Factor: ____

Casing Volume (gal.): _____ 2X: _____ 3X _____ 4X ____

Water Level (ft. BMP) at End of Purge:_____

Total Depth (ft. BMP) at End of Purge:_____

QUALITY ASSURANCE

METHODS (describe):

Cleaning Equipment: _____

Purging: _____ Sampling: _____

Disposal of Discharged Water: _____

INSTRUMENTS (indicate make, model, i.d.):

Water Level: _____ Thermometer: _____

pH Meter: _____ Field Calibration: _____

Conductivity Meter:_____ Field Calibration: _____

Filtration:_____ Other:_____

SAMPLING MEASUREMENTS

Time	Purge Characteristics		Water Quality Data				Appearance		Remarks
	Cumul.Vol. (gal)	Purge Rate (gpm)	Temp. (☐C	pH	Specific Conductance (µmhos/cm) @ Field Temp.	Specific Conductance (µmhos/cm) @ 25 ☐	Color	Turbidity & Sediment	

Water Level (ft. BMP) at End of Purge: Sample Intake Depth (ft. BMP):

SAMPLE INVENTORY

Bottles Collected				Filtration (Y/N)	Preservation (type)	Remarks (quality control sample, other)
Time	Volume	Composition (glass, plastic)	Quantity			

Chain-of-Custody Record No.

_____

ABBREVIATIONS:

BMP - below measuring point
BGL - below ground level
Cumul. Vol. - Cumulative volume removed
ID - Inside Diameter
C - Celsius
gal. - gallons
gpm - gallons per minute
in. - inches

ARCADIS U.S., INC.
695 N. LEGACY RIDGE DRIVE, SUITE 200
LIBERTY LAKE, WA 99019
(509) 928-3369
FAX (509) 928-3075

TestAmerica Spokane
11922 E. 1st Ave.

Spokane, WA 99206
phone 509.924.9200 fax

Chain of Custody Record

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

Regulatory Program: ☐ DW ☐ NPDES ☐ RCRA ☐ Other:

TestAmerica Laboratories, Inc.

Client Contact	**Project Manager:**	**Site Contact:**	**Date:**	COC No:
Your Company Name here	**Tel/Fax:**	**Lab Contact:**	**Carrier:**	_____ of _____ COCs
Address	**Analysis Turnaround Time**			**For Lab Use Only:**
City/State/Zip	Calendar (C) or Work Days (W) _____			Walk-in Client:
(xxx) xxx-xxxx Phone	TAT if different from Below _____			Lab Sampling:
(xxx) xxx-xxxx FAX	☐ 2 weeks			
Project Name:	☐ 1 week			Job / SDG No.:
Site:	☐ 2 days			
P O #	☐ 1 day			Sampler:

Sample Identification	Sample Date	Sample Time	Sample Type	Matrix	# of Cont.	Filtered Sample (Y / N)	Composite = C / Grab = G																	Sample Specific Notes:

Preservation Used: 1= Ice, 2= HCl; 3= H2SO4; 4=HNO3; 5=NaOH; 6= Other _____

Possible Hazard Identification:
Are any samples from a listed EPA Hazardous Waste? Please List any EPA Waste Codes for the sample in the Comments Section if the lab is to dispose of the sample.

☐ Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison B ☐ Unknown

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)

☐ Return to Client ☐ Disposal by Lab ☐ Archive for_____ Months

Special Instructions/QC Requirements & Comments:

Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
Relinquished by:	Company:	Date/Time:	Received in Laboratory by:	Company:	Date/Time:

DAILY ACTIVITY REPORT

ARCADIS

DATE:____/____/20___

Page _1_ of_____

Project:	Work Period: to	Temp.:
	Total Hours:	Wind:
Project No.:	Field Activity:	Ground:
Client:		Misc.:
Location:		
Personnel:	Equipment:	Visitors:

Time	Field Notes
	Report By: // Review By: Date:

Appendix E

Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells SOP

ARCADIS
Infrastructure, environment, facilities

Imagine the result

Low-Flow Groundwater Purging and Sampling Procedures for Monitoring Wells

Rev. #: 4

Rev Date: February 2, 2011

Approval Signatures

Prepared by: _____ Date: 02/2/2011

David S. Lipson
Technical Expert

Reviewed by: _____ Date: 02/2/2011

Michael J. Gefell
National Expert / Principal Geologist

I. Scope and Application

Groundwater samples will be collected from monitoring wells to evaluate groundwater quality. The protocol presented in this standard operating procedure (SOP) describes the procedures to be used to purge monitoring wells and collect groundwater samples. This protocol has been developed in accordance with the United States Environmental Protection Agency (USEPA) Region I Low Stress (Low Flow) Purging and Sampling Procedures for the Collection of Groundwater Samples from Monitoring Wells (USEPA SOP No. GW0001; July 30, 1996). Both filtered and unfiltered groundwater samples may be collected using this low-flow sampling method. Filtered samples will be obtained using a 0.45-micron disposable filter. No wells will be sampled until well development has been performed in accordance with the procedures presented in the SOP titled Monitoring Well Development, unless that well has been sampled or developed within the prior 1-year time period. Groundwater samples will not be collected within 1 week following well development.

II. Personnel Qualifications

ARCADIS personnel directing, supervising, or leading groundwater sample collection activities should have a minimum of 2 years of previous groundwater sampling experience. ARCADIS personnel providing assistance to groundwater sample collection and associated activities should have a minimum of 6 months of related experience or an advanced degree in environmental sciences, engineering, hydrogeology, or geology.

The supervisor of the groundwater sampling team will have at least 1 year of previous supervised groundwater sampling experience.

Prior to mobilizing to the field, the groundwater sampling team should review and be thoroughly familiar with relevant site-specific documents including but not limited to the site work plan, field sampling plan, QAPP, HASP, and historical information. Additionally, the groundwater sampling team should review and be thoroughly familiar with documentation provided by equipment manufacturers for all equipment that will be used in the field prior to mobilization.

III. Equipment List

Specific to this activity, the following materials (or equivalent) will be available:

- Health and safety equipment (as required in the site Health and Safety Plan [HASP]).

- Site Plan, well construction records, prior groundwater sampling records (if available).
- Sampling pump, which may consist of one or more of the following:
  - submersible pump (e.g., Grundfos Redi-Flo 2);
  - peristaltic pump (e.g., ISCO Model 150); and/or
  - bladder pump (e.g., Marschalk System 1, QED Well Wizard, Geotech, etc.).
- Appropriate controller and power source for pump:
  - Submersible and peristaltic pumps require electric power from either a generator or a deep cell battery.
  - Submersible pumps such as Grundfos require a pump controller to run the pump
  - Bladder pumps require a pump controller and a gas source (e.g., air compressor or compressed N_2 or CO_2 gas cylinders).
- Teflon® tubing or Teflon®-lined polyethylene tubing of an appropriate size for the pump being used. For peristaltic pumps, dedicated Tygon® tubing (or other type as specified by the manufacturer) will also be used through the pump apparatus.
- Water-level probe (e.g., Solinist Model 101).
- Water-quality (temperature/pH/specific conductivity/ORP/turbidity/dissolved oxygen) meter and flow-through measurement cell. Several brands may be used, including:
  - YSI 6-Series Multi-Parameter Instrument;
  - Hydrolab Series 3 or Series 4a Multiprobe and Display; and/or
  - Horiba U-10 or U-22 Water Quality Monitoring System.
- Supplemental turbidity meter (e.g., Horiba U-10, Hach 2100P, LaMotte 2020). Turbidity measurements collected with multi-parameter meters have been shown to sometimes be unreliable due to fouling of the optic lens of the

turbidity meter within the flow-through cell. A supplemental turbidity meter will be used to verify turbidity data during purging if such fouling is suspected. Note that industry improvements may eliminate the need for these supplemental measurements in the future.

- Appropriate water sample containers (supplied by the laboratory).
- Appropriate blanks (trip blank supplied by the laboratory).
- 0.45-micron disposable filters (if field filtering is required).
- Large glass mixing container (if sampling with a bailer).
- Teflon® stirring rod (if sampling with a bailer).
- Cleaning equipment.
- Groundwater sampling log (attached) or bound field logbook.

Note that in the future, the client may acquire different makes/models of some of this equipment if the listed makes/models are no longer available, or as a result of general upgrades or additional equipment acquisitions. In the event that the client uses a different make/model of the equipment listed, the client will use an equivalent type of equipment (e.g., pumps, flow-through analytical cells) and note the specific make/model of the equipment used during a sampling event on the groundwater sampling log. In addition, should the client desire to change to a markedly different sampling methodology (e.g., discrete interval samplers, passive diffusion bags, or a yet to be developed technique), the client will submit a proposed SOP for the new methodology for USEPA approval prior to implementing such a change.

The maintenance requirements for the above equipment generally involve decontamination or periodic cleaning, battery charging, and proper storage, as specified by the manufacturer. For operational difficulties, the equipment will be serviced by a qualified technician.

IV. Cautions

If heavy precipitation occurs and no cover over the sampling area and monitoring well can be erected, sampling must be discontinued until adequate cover is provided. Rain water could contaminate groundwater samples.

Do not use permanent marker or felt-tip pens for labels on sample container or sample coolers – use indelible ink. The permanent markers could introduce volatile constituents into the samples.

It may be necessary to field filter some parameters (e.g., metals) prior to collection, depending on preservation, analytical method, and project quality objectives.

Store and/or stage empty and full sample containers and coolers out of direct sunlight.

To mitigate potential cross-contamination, groundwater samples are to be collected in a pre-determined order from least impacted to impacted based on previous analytical data. If no analytical data are available, samples are collected in order of upgradient, then furthest downgradient to source area locations.

Be careful not to over-tighten lids with Teflon liners or septa (e.g., 40 mL vials). Over-tightening can cause the glass to shatter or impair the integrity of the Teflon seal.

V. Health and Safety Considerations

Use caution and appropriate cut resistant gloves when tightening lids to 40 mL vials. These vials can break while tightening and can lacerate hand. Amber vials (thinner glass) are more prone to breakage.

If thunder or lighting is present, discontinue sampling and take cover until 30 minutes have passed after the last occurrence of thunder or lighting.

Use caution when removing well caps as well may be under pressure, cap can dislodge forcefully and cause injury.

Use caution when opening protective casing on stickup wells as wasps frequently nest inside the tops of the covers. Also watch for fire ant mounds near well pads when sampling in the south or western U.S.

VI. Procedure

Groundwater will be purged from the wells using an appropriate pump. Peristaltic pumps will initially be used to purge and sample all wells when applicable. If the depth to water is below the sampling range of a peristaltic pump (approximately 25 feet), submersible pumps or bladder pumps will be used provided the well is constructed with a casing diameter greater than or equal to 2 inches (the minimum well diameter capable of accommodating such pumps). Bladder pumps are preferred over peristaltic and submersible pumps if sampling of VOCs is required to prevent volatilization. For smaller diameter wells where the depth to water is below the sampling range of a

peristaltic pump, alternative sampling methods (i.e., bailing or small diameter bladder pumps) will be used to purge and sample the groundwater. Purge water will be collected and containerized.

1. Calibrate field instruments according to manufacturer procedures for calibration.

2. Measure initial depth to groundwater prior to placement of pumps.

3. Prepare and install pump in well: For submersible and non-dedicated bladder pumps, decontaminate pump according to site decontamination procedures. Non-dedicated bladder pumps will require a new Teflon® bladder and attachment of an air line, sample discharge line, and safety cable prior to placement in the well. Attach the air line tubing to the air port on the top of the bladder pump. Attach the sample discharge tubing to the water port on the top of the bladder pump. Care should be taken not to reverse the air and discharge tubing lines during bladder pump set-up as this could result in bladder failure or rupture. Attach and secure a safety cable to the eyebolt on the top of bladder pump (if present, depending on pump model used). Slowly lower pump, safety cable, tubing, and electrical lines into the well to a depth corresponding to the approximate center of the saturated screen section of the well. Take care to avoid twisting and tangling of safety cable, tubing, and electrical lines while lowering pump into well; twisted and tangled lines could result in the pump becoming stuck in the well casing. Also, make sure to keep tubing and lines from touching the ground or other surfaces while introducing them into the well as this could lead to well contamination. If a peristaltic pump is being used, slowly lower the sampling tubing into the well to a depth corresponding to the approximate center of the saturated screen section of the well. The pump intake or sampling tube must be kept at least 2 feet above the bottom of the well to prevent mobilization of any sediment present in the bottom of the well.

4. If using a bladder pump, connect the air line to the pump controller output port. The pump controller should then be connected to a supply line from an air compressor or compressed gas cylinder using an appropriate regulator and air hose. Take care to tighten the regulator connector onto the gas cylinder (if used) to prevent leaks. Teflon tape may be used on the threads of the cylinder to provide a tighter seal. Once the air compressor or gas cylinder is connected to the pump controller, turn on the compressor or open the valve on the cylinder to begin the gas flow. Turn on the pump controller if an on/off switch is present and verify that all batteries are charged and fully operating before beginning to pump.

5. Connect the pump discharge water line to the bottom inlet port on the flow-through cell connected to the water quality meter.

6. Measure the water level again with the pump in the well before starting the pump. Start pumping the well at 200 to 500 milliliters (mL) per minute (or at lower site-specific rate if specified). The pump rate should be adjusted to cause little or no water level drawdown in the well (less than 0.3 feet below the initial static depth to water measurement) and the water level should stabilize. The water level should be monitored every 3 to 5 minutes (or as appropriate, lower flow rates may require longer time between readings) during pumping if the well diameter is of sufficient size to allow such monitoring. Care should be taken not to break pump suction or cause entrainment of air in the sample. Record pumping rate adjustments and depths to water. If necessary, pumping rates should be reduced to the minimum capabilities of the pump to avoid pumping the well dry and/or to stabilize indicator parameters. A steady flow rate should be maintained to the extent practicable. Groundwater sampling records from previous sampling events (if available) should be reviewed prior to mobilization to estimate the optimum pumping rate and anticipated drawdown for the well in order to more efficiently reach a stabilized pumping condition.

   If the recharge rate of the well is very low, alternative purging techniques should be used, which will vary based on the well construction and screen position. For wells screened across the water table, the well should be pumped dry and sampling should commence as soon as the volume in the well has recovered sufficiently to permit collection of samples. For wells screened entirely below the water table, the well should be pumped until a stabilized level (which may be below the maximum displacement goal of 0.3 feet) can be maintained and monitoring for stabilization of field indicator parameters can commence. If a lower stabilization level cannot be maintained, the well should be pumped until the drawdown is at a level slightly higher than the bentonite seal above the well screen. Sampling should commence after one well volume has been removed and the well has recovered sufficiently to permit collection of samples.

   During purging, monitor the field indicator parameters (e.g., turbidity, temperature, specific conductance, pH, etc.) every 3 to 5 minutes (or as appropriate). Field indicator parameters will be measured using a flow-through analytical cell or a clean container such as a glass beaker. Record field indicator parameters on the groundwater sampling log. The well is considered stabilized and ready for sample collection when turbidity values remain within 10% (or within 1 NTU if the turbidity reading is less than 10 NTU), the specific conductance and temperature values remain within 3%, ORP readings remain within ± 10 mV and pH remains within 0.1 units for three consecutive readings collected at 3- to 5-minute intervals (or other appropriate interval, alternate stabilization goals may exist in different geographic regions, consult the site-specific Work Plan for stabilization criteria). If the field indicator parameters do not stabilize within 1 hour of the start of purging, but the groundwater turbidity is

below the goal of 50 NTU and the values for all other parameters are within 10%, the well can be sampled. If the parameters have stabilized but the turbidity is not in the range of the 50 NTU goal, the pump flow rate should be decreased to a minimum rate of 100 mL/min to reduce turbidity levels as low as possible. Dissolved oxygen is extremely susceptible to various external influences (including temperature or the presence of bubbles on the DO meter); care should be taken to minimize the agitation or other disturbance of water within the flow-through cell while collecting these measurements. If air bubbles are present on the DO probe or in the discharge tubing, remove them before taking a measurement. If dissolved oxygen values are not within acceptable range for the temperature of groundwater (Attachment 1), then again check for and remove air bubbles on probe before re-measuring. If the dissolved oxygen value is 0.00 or less, then the meter should be serviced and re-calibrated. If the dissolved oxygen values are above possible results, then the meter should be serviced and re-calibrated.

During extreme weather conditions, stabilization of field indicator parameters may be difficult to obtain. Modifications to the sampling procedures to alleviate these conditions (e.g., measuring the water temperature in the well adjacent to the pump intake) will be documented in the field notes. If other field conditions exist that preclude stabilization of certain parameters, an explanation of why the parameters did not stabilize will also be documented in the field logbook.

7. Complete the sample label(s) and cover the label(s) with clear packing tape to secure the label onto the container.

8. After the indicator parameters have stabilized, collect groundwater samples by diverting flow out of the unfiltered discharge tubing into the appropriate labeled sample container. If a flow-through analytical cell is being used to measure field parameters, the flow-through cell should be disconnected after stabilization of the field indicator parameters and prior to groundwater sample collection. Under no circumstances should analytical samples be collected from the discharge of the flow-through cell. When the container is full, tightly screw on the cap. Samples should be collected in the following order: VOCs, TOC, SVOCs, metals and cyanide, and others (or other order as defined in the site-specific Work Plan).

9. If sampling for total and filtered metals and/or PCBs, a filtered and unfiltered sample will be collected. Install an in-line, disposable 0.45-micron particle filter on the discharge tubing after the appropriate unfiltered groundwater sample has been collected. Continue to run the pump until an initial volume of “flush” water has been run through the filter in accordance with the manufacturer’s directions (generally 100 to 300 mL). Collect filtered groundwater sample by diverting flow

out of the filter into the appropriately labeled sample container. When the container is full, tightly screw on the cap.

10. Secure with packing material and store at 4°C in an insulated transport container provided by the laboratory.

11. Record on the groundwater sampling log or bound field logbook the time sampling procedures were completed, any pertinent observations of the sample (e.g., physical appearance, and the presence or lack of odors or sheens), and the values of the stabilized field indicator parameters as measured during the final reading during purging (Attachment 2 – Example Sampling Log).

12. Turn off the pump and air compressor or close the gas cylinder valve if using a bladder pump set-up. Slowly remove the pump, tubing, lines, and safety cable from the well. Do not allow the tubing or lines to touch the ground or any other surfaces which could contaminate them. .

13. If tubing is to be dedicated to a well, it should be folded to a length that will allow the well to be capped and also facilitate retrieval of the tubing during later sampling events. A length of rope or string should be used to tie the tubing to the well cap. Alternatively, if tubing and safety line are to be saved and reused for sampling the well at a later date they may be coiled neatly and placed in a clean plastic bag that is clearly labeled with the well ID. Make sure the bag is tightly sealed before placing it in storage.

14. Secure the well and properly dispose of personal protective equipment (PPE) and disposable equipment.

15. Complete the procedures for packaging, shipping, and handling with associated chain-of-custody.

16. Complete decontamination procedures for flow-through analytical cell and submersible or bladder pump, as appropriate.

17. At the end of the day, perform calibration check of field instruments.

If it is not technically feasible to use the low-flow sampling method, purging and sampling of monitoring wells may be conducted using the bailer method as outlined below:

1. Don appropriate PPE (as required by the HASP).

2. Place plastic sheeting around the well.

3. Clean sampling equipment.

4. Open the well cover while standing upwind of the well. Remove well cap and place on the plastic sheeting. Insert PID probe approximately 4 to 6 inches into the casing or the well headspace and cover with gloved hand. Record the PID reading in the field log. If the well headspace reading is less than 5 PID units, proceed; if the headspace reading is greater than 5 PID units, screen the air within the breathing zone. If the breathing zone reading is less than 5 PID units, proceed. If the PID reading in the breathing zone is above 5 PID units, move upwind from well for 5 minutes to allow the volatiles to dissipate. Repeat the breathing zone test. If the reading is still above 5 PID units, don appropriate respiratory protection in accordance with the requirements of the HASP. Record all PID readings. For wells that are part of the regular weekly monitoring program and prior PID measurements have not resulted in a breathing zone reading above 5 PID units, PID measurements will be taken monthly.

5. Measure the depth to water and determine depth of well by examining drilling log data or by direct measurement. Calculate the volume of water in the well (in gallons) by using the length of the water column (in feet), multiplying by 0.163 for a 2-inch well or by 0.653 for a 4-inch well. For other well diameters, use the formula:

   Volume (in gallons) = π TIMES well radius (in feet) squared TIMES length of water column (in feet) TIMES 7.481 (gallons per cubic foot)

6. Measure a length of rope or twine at least 10 feet greater than the total depth of the well. Secure one end of the rope to the well casing and secure the other end to the bailer. Test the knots and make sure the rope will not loosen. Check bailers so that all parts are intact and will not be lost in the well.

7. Lower bailer into well and remove one well volume of water. Contain all water in appropriate containers.

8. Monitor the field indicator parameters (e.g., turbidity, temperature, specific conductance, and pH). Measure field indicator parameters using a clean container such as a glass beaker or sampling cups provided with the instrument. Record field indicator parameters on the groundwater sampling log.

9. Repeat Steps 7 and 8 until three or four well volumes have been removed. Examine the field indicator parameter data to determine if the parameters have stabilized. The well is considered stabilized and ready for sample collection when turbidity values remain within 10% (or within 1 NTU if the turbidity reading is less than 10 NTU), the specific conductance and temperature values remain

within 3%, and pH remains within ˜0 .1 units for three consecutive readings collected once per well volume removed.

10. If the field indicator parameters have not stabilized, remove a maximum of five well volumes prior to sample collection. Alternatively, five well volumes may be removed without measuring the field indicator parameters.

11. If the recharge rate of the well is very low, wells screened across the water table may be bailed dry and sampling should commence as soon as the volume in the well has recovered sufficiently to permit collection of samples. For wells screened entirely below the water table, the well should only be bailed down to a level slightly higher than the bentonite seal above the well screen. The well should not be bailed completely dry, to maintain the integrity of the seal. Sampling should commence as soon as the well volume has recovered sufficiently to permit sample collection.

12. Following purging, allow water level in well to recharge to a sufficient level to permit sample collection.

13. Complete the sample label and cover the label with clear packing tape to secure the label onto the container.

14. Slowly lower the bailer into the screened portion of the well and carefully retrieve a filled bailer from the well causing minimal disturbance to the water and any sediment in the well.

15. The sample collection order (as appropriate) will be as follows:

    a. VOCs;

    b TOC;

    c. SVOCs;

    d. metals and cyanide; and

    e. others.

16. When sampling for volatiles, collect water samples directly from the bailer into 40-mL vials with Teflon®-lined septa.

17. For other analytical samples, remove the cap from the large glass mixing container and slowly empty the bailer into the large glass mixing container. The

sample for dissolved metals and/or filtered PCBs should either be placed directly from the bailer into a pressure filter apparatus or pumped directly from the bailer with a peristaltic pump, through an in-line filter, into the pre-preserved sample bottle.

18. Continue collecting samples until the mixing container contains a sufficient volume for all laboratory samples.

19. Mix the entire sample volume with the Teflon® stirring rod and transfer the appropriate volume into the laboratory jar(s). Secure the sample jar cap(s) tightly.

20. If sampling for total and filtered metals and/or PCBs, a filtered and unfiltered sample will be collected. Sample filtration for the filtered sample will be performed in the field using a peristaltic pump prior to preservation. Install new medical-grade silicone tubing in the pump head. Place new Teflon® tubing into the sample mixing container and attach to the intake side of pump tubing. Attach (clamp) a new 0.45-micron filter (note the filter flow direction). Turn the pump on and dispense the filtered liquid directly into the laboratory sample bottles.

21. Secure with packing material and store at 4°C in an insulated transport container provided by the laboratory.

22. After sample containers have been filled, remove one additional volume of groundwater. Measure the pH, temperature, turbidity, and conductivity. Record on the groundwater sampling log or bound field logbook the time sampling procedures were completed, any pertinent observations of the sample (e.g., physical appearance, and the presence or lack of odors or sheens), and the values of the field indicator parameters.

23. Remove bailer from well, secure well, and properly dispose of PPE and disposable equipment.

24. If a bailer is to be dedicated to a well, it should be secured inside the well above the water table, if possible. Dedicated bailers should be tied to the well cap so that inadvertent loss of the bailer will not occur when the well is opened.

25. Complete the procedures for packaging, shipping, and handling with associated chain-of-custody.

VII. Waste Management

Materials generated during groundwater sampling activities, including disposable equipment, will be placed in appropriate containers. Containerized waste will be disposed of by the client consistent with the procedures identified in the HASP.

VIII. Data Recording and Management

Initial field logs and chain-of-custody records will be transmitted to the ARCADIS PM at the end of each day unless otherwise directed by the PM. The groundwater team leader retains copies of the groundwater sampling logs.

IX. Quality Assurance

In addition to the quality control samples to be collected in accordance with this SOP, the following quality control procedures should be observed in the field:

- Collect samples from monitoring wells in order of increasing concentration, to the extent known based on review of historical site information if available.
- Equipment blanks should include the pump and tubing (if using disposable tubing) or the pump only (if using tubing dedicated to each well).
- Collect equipment blanks after wells with higher concentrations (if known) have been sampled.
- Operate all monitoring instrumentation in accordance with manufacturer's instructions and calibration procedures. Calibrate instruments at the beginning of each day and verify the calibration at the end of each day. Record all calibration activities in the field notebook.
- Clean all groundwater sampling equipment prior to use in the first well and after each subsequent well using procedures for equipment decontamination.

X. References

United States Environmental Protection Agency (USEPA). 1986. RCRA Groundwater Monitoring Technical Enforcement Guidance Document (September 1986).

USEPA Region II. 1998. *Ground Water Sampling Procedure Low Stress (Low Flow) Purging and Sampling*.

USEPA. 1991. Handbook Groundwater, Volume II Methodology, Office of Research and Development, Washington, DC. USEPN62S, /6-90/016b (July, 1991).

U.S. Geological Survey (USGS). 1977. National Handbook of Recommended Methods for Water-Data Acquisition: USGS Office of Water Data Coordination. Reston, Virginia.

Attachment 1

Groundwater Sampling Log

Attachment 2

Oxygen Solubility in Fresh Water

Temperature (degrees C)	**Dissolved Oxygen** (mg/L)
0	14.6
1	14.19
2	13.81
3	13.44
4	13.09
5	12.75
6	12.43
7	12.12
8	11.83
9	11.55
10	11.27
11	11.01
12	10.76
13	10.52
14	10.29
15	10.07
16	9.85
17	9.65
18	9.45
19	9.26
20	9.07
21	8.9
22	8.72
23	8.56
24	8.4
25	8.24
26	8.09
27	7.95
28	7.81
29	7.67
30	7.54
31	7.41
32	7.28
33	7.16
34	7.05
35	6.93

Reference: Vesilind, P.A., *Introduction to Environmental Engineering*, PWS Publishing Company, Boston, 468 pages (1996).

Appendix F

Field Equipment Decontamination SOP

ARCADIS
Infrastructure, environment, facilities

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Field Equipment Decontamination

Rev. #: 3

Rev Date: April 26, 2010

Approval Signatures

Prepared by: _____ Date: 4/26/2010
Keith Shepherd

Reviewed by: _____ Date: 4/26/2010
Richard Murphy (Technical Expert)

I. Scope and Application

Equipment decontamination is performed to ensure that sampling equipment that contacts a sample, or monitoring equipment that is brought into contact with environmental media to be sampled, is free from analytes of interest and/or constituents that would interfere with laboratory analysis for analytes of interest. Equipment must be cleaned prior to use for sampling or contact with environmental media to be sampled, and prior to shipment or storage. The effectiveness of the decontamination procedure should be verified by collecting and analyzing equipment blank samples.

The equipment cleaning procedures described herein includes pre-field, in the field, and post-field cleaning of sampling tools which will be conducted at an established equipment decontamination area (EDA) on site (as appropriate). Equipment that may require decontamination at a given site includes: soil sampling tools; groundwater, sediment, and surface-water sampling devices; water testing instruments; down-hole instruments; and other activity-specific sampling equipment. Non-disposable equipment will be cleaned before collecting each sample, between sampling events, and prior to leaving the site. Cleaning procedures for sampling equipment will be monitored by collecting equipment blank samples as specified in the applicable work plan or field sampling plan. Dedicated and/or disposable (not to be re-used) sampling equipment will not require decontamination.

II. Personnel Qualifications

ARCADIS field sampling personnel will have current health and safety training, including 40-hour HAZWOPER training, site supervisor training, and site-specific training, as needed. In addition, ARCADIS field sampling personnel will be versed in the relevant SOPs and possess the skills and experience necessary to successfully complete the desired fieldwork. The project HASP and other documents will identify any other training requirements such as site specific safety training or access control requirements.

III. Equipment List

- health and safety equipment, as required in the site Health and Safety Plan (HASP)
- distilled water

- Non-phosphate detergent such as Alconox or, if sampling for phosphorus phosphorus-containing compounds, Luminox (or equivalent).
- tap water
- rinsate collection plastic containers
- DOT-approved waste shipping container(s), as specified in the work plan or field sampling plan (if decontamination waste is to be shipped for disposal)
- brushes
- large heavy-duty garbage bags
- spray bottles
- (Optional) – Isoprophyl alcohol (free of ketones) or methanol
- Ziploc-type bags
- plastic sheeting

IV. Cautions

Rinse equipment thoroughly and allow the equipment to dry before re-use or storage to prevent introducing solvent into sample medium. If manual drying of equipment is required, use clean lint-free material to wipe the equipment dry.

Store decontaminated equipment in a clean, dry environment. Do not store near combustion engine exhausts.

If equipment is damaged to the extent that decontamination is uncertain due to cracks or dents, the equipment should not be used and should be discarded or submitted for repair prior to use for sample collection.

A proper shipping determination will be performed by a DOT-trained individual for cleaning materials shipped by ARCADIS.

V. Health and Safety Considerations

Review the material safety data sheets (MSDS) for the cleaning materials used in decontamination. If solvent is used during decontamination, work in a well-ventilated area and stand upwind while applying solvent to equipment. Apply solvent in a manner that minimizes potential for exposure to workers. Follow health and safety procedures outlined in the HASP.

VI. Procedure

A designated area will be established to clean sampling equipment in the field prior to sample collection. Equipment cleaning areas will be set up within or adjacent to the specific work area, but not at a location exposed to combustion engine exhaust. Detergent solutions will be prepared in clean containers for use in equipment decontamination.

Cleaning Sampling Equipment

1. Wash the equipment/pump with potable water.

2. Wash with detergent solution (Alconox, Liquinox or equivalent) to remove all visible particulate matter and any residual oils or grease.

3. If equipment is very dirty, precleaning with a brush and tap water may be necessary.

4. (Optional) – Flush with isopropyl alcohol (free of ketones) or with methanol. This step is optional but should be considered when sampling in highly impacted media such as non-aqueous phase liquids or if equipment blanks from previous sampling events showed the potential for cross contamination of organics.

5. Rinse with distilled/deionized water.

Decontaminating Submersible Pumps

Submersible pumps may be used during well development, groundwater sampling, or other investigative activities. The pumps will be cleaned and flushed before and between uses. This cleaning process will consist of an external detergent solution wash and tap water rinse, a flush of detergent solution through the pump, followed

by a flush of potable water through the pump. Flushing will be accomplished by using an appropriate container filled with detergent solution and another contained filled with potable water. The pump will run long enough to effectively flush the pump housing and hose (unless new, disposable hose is used). Caution should be exercised to avoid contact with the pump casing and water in the container while the pump is running (do not use metal drums or garbage cans) to avoid electric shock. Disconnect the pump from the power source before handling. The pump and hose should be placed on or in clean polyethylene sheeting to avoid contact with the ground surface.

VII. Waste Management

Equipment decontamination rinsate will be managed in conjunction with all other waste produced during the field sampling effort. Waste management procedures are outlined in the work plan or Waste Management Plan (WMP).

VIII. Data Recording and Management

Equipment cleaning and decontamination will be noted in the field notebook. Information will include the type of equipment cleaned, the decontamination location and any deviations from this SOP. Specific factors that should be noted include solvent used (if any), and source of water.

Any unusual field conditions should be noted if there is potential to impact the efficiency of the decontamination or subsequent sample collection.

An inventory of the solvents brought on site and used and removed from the site will be maintained in the files. Records will be maintained for any solvents used in decontamination, including lot number and expiration date.

Containers with decontamination fluids will be labeled.

IX. Quality Assurance

Equipment blanks should be collected to verify that the decontamination procedures are effective in minimizing potential for cross contamination. The equipment blank is prepared by pouring deionized water over the clean and dry tools and collecting the deionized water into appropriate sample containers. Equipment blanks should be analyzed for the same set of parameters that are performed on the field samples collected with the equipment that was cleaned. Equipment blanks are collected per equipment set, which represents all of the tools needed to collect a specific sample.

X. References

USEPA Region 9, Field Sampling Guidance #1230, Sampling Equipment Decontamination.

USEPA Region 1, Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells.

Appendix G

Chain-of-Custody, Handling, Packing and Shipping SOP

ARCADIS
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Chain-of-Custody, Handling, Packing and Shipping

Rev. #: 2

Rev Date: March 6, 2009

Approval Signatures

Prepared by: _____ Date: 3/6/09
Caron Koll

Reviewed by: _____ Date: 3/6/09
Jane Kennedy(Technical Expert)

I. Scope and Application

This Standard Operating Procedure (SOP) describes the chain-of-custody, handling, packing, and shipping procedures for the management of samples to decrease the potential for cross-contamination, tampering, mis-identification, and breakage, and to insure that samples are maintained in a controlled environment from the time of collection until receipt by the analytical laboratory.

II. Personnel Qualifications

ARCADIS field sampling personnel will have current health and safety training, including 40-hour HAZWOPER training, Department of Transportation (DOT) training, site supervisor training, and site-specific training, as needed. In addition, ARCADIS field sampling personnel will be versed in the relevant SOPs and possess the skills and experience necessary to successfully complete the desired field work.

III. Equipment List

The following list provides materials that may be required for each project. Project documents and sample collection requirements should be reviewed prior to initiating field operations:

- indelible ink pens (black or blue);
- polyethylene bags (resealable-type);
- clear packing tape, strapping tape, duct tape;
- chain of custody
- DOT shipping forms, as applicable
- custody seals or tape;
- appropriate sample containers and labels,;
- insulated coolers of adequate size for samples and sufficient ice to maintain 4°C during collection and transfer of samples;
- wet ice;
- cushioning and absorbent material (i.e., bubble wrap or bags);

- temperature blank
- sample return shipping papers and addresses; and
- field notebook.

IV. Cautions

Review project requirements and select appropriate supplies prior to field mobilization.

Insure that appropriate sample containers with applicable preservatives, coolers, and packing material have been supplied by the laboratory.

Understand the offsite transfer requirements for the facility at which samples are collected.

If overnight courier service is required schedule pick-up or know where the drop-off service center is located and the hours of operation. Prior to using air transportation, confirm air shipment is acceptable under DOT and International Air Transport Association (IATA) regulation

Schedule pick-up time for laboratory courier or know location of laboratory/service center and hours of operation.

Understand DOT and IATA shipping requirements and evaluate dangerous goods shipping regulations relative to the samples being collected (i.e. complete an ARCADIS shipping determination). Review the ARCADIS SOPs for shipping, packaging and labeling of dangerous goods. Potential samples requiring compliance with this DOT regulation include:

- Methanol preservation for Volatile Organic Compounds in soil samples
- Non-aqueous phase liquids (NAPL)

V. Health and Safety Considerations

Follow health and safety procedures outlined in the project/site Health and Safety Plan (HASP).

Use caution and appropriate cut resistant gloves when tightening lids to 40 mL vials. These vials can break while tightening and can lacerate hand. Amber vials (thinner glass) are more prone to breakage.

Some sample containers contain preservatives.

- The preservatives must be retained in the sample container and should in no instance be rinsed out.
- Preservatives may be corrosive and standard care should be exercised to reduce potential contact to personnel skin or clothing. Follow project safety procedures if spillage is observed.
- If sample container caps are broken discard the bottle. Do not use for sample collection.

VI. Procedure

Chain-of-Custody Procedures

1. Prior to collecting samples, complete the chain-of-custody record header information by filling in the project number, project name, and the name(s) of the sampling technician(s) and other relevant project information. Attachment 1 provides an example chain-o- custody record

2. Chain-of-custody information MUST be printed legibly using indelible ink (black or blue).

3. After sample collection, enter the individual sample information on the chain-of-custody:

    a. Sample Identification indicates the well number or soil location that the sample was collected from. Appropriate values for this field include well locations, grid points, or soil boring identification numbers (e.g., MW-3, X-20, SB-30). When the depth interval is included, the complete sample ID would be “SB-30 (0.5-1.0) where the depth interval is in feet. Please note it is very important that the use of hyphens in sample names and depth units (i.e., feet or inches) remain consistent for all samples entered on the chain-of-custody form. DO NOT use the apostrophe or quotes in the sample ID. Sample names may also use the abbreviations “FB,” “TB,” and “DUP” as prefixes or suffixes to indicate that the sample is a field blank, trip blank, or field duplicate, respectively. NOTE: The sample

nomenclature may be dictated by the project database and require unique identification for each sample collected for the project. Consult the project data management plan for additional information regarding sample identification.

b. List the date of sample collection. The date format to be followed should be mm/dd/yy (e.g., 03/07/09) or mm/dd/yyyy (e.g. 03/07/2009).

c. List the time that the sample was collected. The time value should be presented using military format. For example, 3:15 P.M. should be entered as 15:15.

d. The composite field should be checked if the sample is a composite over a period of time or from several different locations and mixed prior to placing in sample containers.

e. The “Grab”. field should be marked with an “X” if the sample was collected as an individual grab sample. (e.g. monitoring well sample or soil interval).

f. Any sample preservation should be noted.

g. The analytical parameters that the samples are being analyzed for should be written legibly on the diagonal lines. As much detail as possible should be presented to allow the analytical laboratory to properly analyze the samples. For example, polychlorinated biphenyl (PCB) analyses may be represented by entering “PCBs” or “Method 8082.” Multiple methods and/or analytical parameters may be combined for each column (e.g., PCBs/VOCs/SVOCs or 8082/8260/8270). These columns should also be used to present project-specific parameter lists (e.g., Appendix IX+3 target analyte list. Each sample that requires a particular parameter analysis will be identified by placing the number of containers in the appropriate analytical parameter column. For metals in particular, indicate which metals are required.

h. Number of containers for each method requested. This information may be included under the parameter or as a total for the sample based on the chain of custody form used.

i. Note which samples should be used for site specific matrix spikes.

j. Indicate any special project requirements.

k. Indicate turnaround time required.

l. Provide contact name and phone number in the event that problems are encountered when samples are received at the laboratory.

m. If available attach the Laboratory Task Order or Work Authorization forms

n. The remarks field should be used to communicate special analytical requirements to the laboratory. These requirements may be on a per sample basis such as “extract and hold sample until notified,” or may be used to inform the laboratory of special reporting requirements for the entire sample delivery group (SDG). Reporting requirements that should be specified in the remarks column include: 1) turnaround time; 2) contact and address where data reports should be sent; 3) name of laboratory project manager; and 4) type of sample preservation used.

o. The “Relinquished By” field should contain the signature of the sampling technician who relinquished custody of the samples to the shipping courier or the analytical laboratory.

p. The “Date” field following the signature block indicates the date the samples were relinquished. The date format should be mm/dd/yyyy (e.g., 03/07/2005).

q. The “Time” field following the signature block indicates the time that the samples were relinquished. The time value should be presented using military format. For example, 3:15 P.M. should be entered as 15:15.

r. The “Received By” section is signed by sample courier or laboratory representative who received the samples from the sampling technician or it is signed upon laboratory receipt from the overnight courier service.

3. Complete as many chain-of-custody forms as necessary to properly document the collection and transfer of the samples to the analytical laboratory.

4. Upon completing the chain-of-custody forms, forward two copies to the analytical laboratory and retain one copy for the field records.

5. If electronic chain-of-custody forms are utilized, sign the form and make 1 copy for ARCADIS internal records and forward the original with the samples to the laboratory.

Handling Procedures

1. After completing the sample collection procedures, record the following information in the field notebook with indelible ink:

   - project number and site name;
   - sample identification code and other sample identification information, if appropriate;
   - sampling method;
   - date;
   - name of sampler(s);
   - time;
   - location (project reference);
   - location of field duplicates and both sample identifications;
   - locations that field QC samples were collected including equipment blanks, field blanks and additional sample volume for matrix spikes; and
   - any comments.

2. Complete the sample label with the following information in indelible ink:

   - sample type (e.g., surface water);
   - sample identification code and other sample identification information, if applicable;
   - analysis required;
   - date;
   - time sampled; and
   - initials of sampling personnel;

- sample matrix; and
- preservative added, if applicable.

3. Cover the label with clear packing tape to secure the label onto the container and to protect the label from liquid.

4. Confirm that all caps on the sample containers are secure and tightly closed.

5. In some instances it may be necessary to wrap the sample container cap with clear packing tape to prevent it from becoming loose.

6. For some projects individual custody seals may be required. Custody seal evidence tape may be placed on the shipping container or they may be placed on each sample container such that the cooler or cap cannot be opened without breaking the custody seal. The custody seal should be initialed and dated prior to relinquishing the samples.

Packing Procedures

Following collection, samples must be placed on wet ice to initiate cooling to 4°C immediately. Retain samples on ice until ready to pack for shipment to the laboratory.

1. Secure the outside and inside of the drain plug at the bottom of the cooler being used for sample transport with “Duct” tape.

2. Place a new large heavy duty plastic garbage bag inside each cooler

3. Place each sample bottle wrapped in bubble wrap inside the garbage bag. VOC vials may be grouped by sample in individual resealable plastic bags). If a cooler temperature blank is supplied by the laboratory, it should be packaged following the same procedures as the samples. If the laboratory did not include a temperature blank, do not add one. Place 1 to 2 inches of cushioning material (i.e., vermiculite) at the bottom of the cooler.

4. Place the sealed sample containers upright in the cooler.

5. Package ice in large resealable plastic bags and place inside the large garbage bag in the cooler. Samples placed on ice will be cooled to and maintained at a temperature of approximately 4°C.

6. Fill the remaining space in the cooler with cushioning material such as bubble wrap. The cooler must be securely packed and cushioned in an upright position and be surrounded (Note: to comply with 49 CFR 173.4, filled cooler must not exceed 64 pounds).

7. Place the completed chain-of-custody record(s) in a large resealable bag and tape the bag to the inside of the cooler lid.

8. Close the lid of the cooler and fasten with packing tape.

9. Wrap strapping tape around both ends of the cooler.

10. Mark the cooler on the outside with the following information: shipping address, return address, “Fragile, Handle with Care” labels on the top and on one side, and arrows indicating “This Side Up” on two adjacent sides.

11. Place custody seal evidence tape over front right and back left of the cooler lid, initial and date, then cover with clear plastic tape.

Note: Procedure numbers 2, 3, 5, and 6 may be modified in cases where laboratories provide customized shipping coolers. These cooler types are designed so the sample bottles and ice packs fit snugly within preformed styrofoam cushioning and insulating packing material.

Shipping Procedures

1. All samples will be delivered by an express carrier within 48 hours of sample collection. Alternatively, samples may be delivered directly to the laboratory or laboratory service center or a laboratory courier may be used for sample pickup.

2. If parameters with short holding times are required (e.g., VOCs [EnCore™ Sampler], nitrate, nitrite, ortho-phosphate and BOD), sampling personnel will take precautions to ship or deliver samples to the laboratory so that the holding times will not be exceeded.

3. Samples must be maintained at 4°C±2°C until shipment and through receipt at the laboratory

4. All shipments must be in accordance with DOT regulations and ARCADIS dangerous goods shipping SOPs.

5. When the samples are received by the laboratory, laboratory personnel will complete the chain-of-custody by recording the date and time of receipt of samples, measuring and recording the internal temperature of the shipping container, and checking the sample identification numbers on the containers to ensure they correspond with the chain-of-custody forms.

Any deviations between the chain-of-custody and the sample containers, broken containers, or temperature excursions will be communicated to ARCADIS immediately by the laboratory.

VII. Waste Management

Not applicable

VIII. Data Recording and Management

Chain-of-custody records will be transmitted to the ARCADIS PM or designee at the end of each day unless otherwise directed by the ARCADIS PM. The sampling team leader retains copies of the chain-of-custody forms for filing in . the project file. Record retention shall be in accordance with project requirements.

IX. Quality Assurance

Chain-of-custody forms will be legibly completed in accordance with the applicable project documents such as Sampling and Analysis Plan (SAP), Quality Assurance Project Plan (QAPP), Work Plan, or other project guidance documents. A copy of the completed chain-of-custody form will be sent to the ARCADIS Project Manager or designee for review.

X. References

Not Applicable

Attachment 1

ARCADIS
Infrastructure, environment, facilities

ID#:

CHAIN OF CUSTODY & LABORATORY ANALYSIS REQUEST FORM

Page ___ of ___

Lab Work Order #

Send Results to:

Contact & Company Name: | Telephone:

Address: | Fax:

City | State | Zip | E-mail Address:

Project Name/Location (City, State): | Project #:

Sampler's Printed Name: | Sampler's Signature:

Preservative							
Filtered (✓)							
# of Containers							
Container Information							

PARAMETER ANALYSIS & METHOD

Keys

Preservation Key:
A. H_2SO_4
B. HCL
C. HNO_3
D. NaOH
E. None
F. Other: _____
G. Other: _____
H. Other: _____

Container Information Key:
1. 40 ml Vial
2. 1 L Amber
3. 250 ml Plastic
4. 500 ml Plastic
5. Encore
6. 2 oz. Glass
7. 4 oz. Glass
8. 8 oz. Glass
9. Other: _____
10. Other: _____

Matrix Key:
SO - Soil | SE - Sediment | NL - NAPL/Oil
W - Water | SL - Sludge | SW - Sample Wipe
T - Tissue | A - Air | Other: _____

Sample ID	Collection Date	Collection Time	Type (✓) Comp	Type (✓) Grab	Matrix								REMARKS

Special Instructions/Comments:

☐ **Special QA/QC Instructions(✓):**

Laboratory Information and Receipt		Relinquished By	Received By	Relinquished By	Laboratory Received By
Lab Name:	Cooler Custody Seal (✓)	Printed Name:	Printed Name:	Printed Name:	Printed Name:
☐ Cooler packed with ice (✓)	☐ Intact ☐ Not Intact	Signature:	Signature:	Signature:	Signature:
Specify Turnaround Requirements:	Sample Receipt:	Firm:	Firm/Courier:	Firm/Courier:	Firm:
Shipping Tracking #:	Condition/Cooler Temp: _____	Date/Time:	Date/Time:	Date/Time:	Date/Time:

20030826 CofC AR Form 01.12.2007

Distribution: **WHITE – Laboratory returns with results** **YELLOW – Lab copy** **PINK – Retained by BBL**

Appendix H

Field Log Book Entries SOP

ARCADIS
Infrastructure, environment, facilities

Imagine the result

Field Log Book Entries

Rev. #: 0

Rev Date: 11 August 2009

Approval Signatures

Prepared by: Andrew Kanik Date: 8/11/09

Reviewed by: Michael J. Heffell Date: 8/11/09
(Technical Expert)

I. Scope and Application

This ARCADIS Standard Operating Procedure covers the entries needed in a field log book for environmental investigations.

This SOP does not address all of the entries that may be needed for a specific project, and does not address health and safety, equipment decontamination, field parameter measurements, sample preservation, chain-of-custody, or laboratory analysis. For direction on requirements in these areas, refer to other ARCADIS SOPs, the project work plans including the quality assurance project plan, sampling plan, and health and safety plan, as appropriate.

II. Personnel Qualifications

ARCADIS personnel participating in fieldwork and making entries into the field log book should have a minimum of one (1) year of field experience (or be under the supervision and accompanied in the field by someone who does) and current health and safety training including 40-hour HAZWOPER training, site supervisor training, site-specific training, first aid, and CPR, as needed. Field personnel will also be compliant with client-specific training requirements. In addition, ARCADIS field sampling personnel will be versed in the relevant SOPs and posses the required skills and experience necessary to successfully complete the desired field work.

III. Equipment List

- Field Log Book
- Ball point (medium point) pen with blue or black ink (black preferred). A fine point Sharpie pen may be used if the ink does not bleed through the page and become visible on back side of the page. If weather conditions prevent the use of a pen, indicate so in the log and use an alternate writing instrument .
- Zip-lock baggie or other weather-proof container to protect the field log book from the elements.

IV. Cautions

All entries in the field log must be legible and archivable. Do not leave the field log book exposed to the elements or other conditions that might moisten the pages and smear/dissolve the entries. When not in the field, the log book should be stored in a location that is easily accessible to field crews.

V. Health and Safety Considerations

ARCADIS field personnel will be familiar and compliant with Client-specific health and safety requirements.

VI. Procedure

- Print legibly. Do not use cursive writing.
- The name of the project, project number and project location should be written in indelible ink on the outside of the field log book.
- On the inside of the front cover, write "If Found, Please Return to ARCADIS" and include the appropriate address and phone number, the name of the person to which the book is assigned, and the name of the project manager.
- Reserve the first page of the book for a Table of Contents.
- Reserve the last five (5) pages of the book for important contacts, notes, reminders, etc.
- Each day of field work, the following should be recorded in the field log book as applicable:

    a) Project Name

    b) Date and time arrived

    c) Work Site Location

    d) Names of people on-site related to the project including ARCADIS employees, visitors, subcontractor employees, agency personnel, client representative, etc.

    e) Describe the work to be performed briefly, and list the equipment on-site

    f) Indicate the health and safety (H&S) level to be used

    g) Record instrument calibrations and checks

    h) Record time and general content of H&S briefing

    i) Describe the weather conditions, including temperature, precipitation, and wind speed and direction

    j) List periodic time entries in the far left hand column of each page

    k) Minimize unused space on each page

- The tailgate meeting must be recorded in the log book and the tailgate form completed. If H&S monitoring is performed, record the time and results of initial and followup monitoring.

- Note factual observations including collection of QA/QC samples, delays, well damage, accidents, work plan deviations, instrument problems, and problem resolutions.

- Describe work performed and how documented such as photographs, sample core logs, water sampling logs, etc.

- Describe bases for field decisions including pertinent conversations with visitors, regulators, or project personnel.

- Note final instrument calibrations and checks.

- Sign the log book at the end of each day at a minimum. Draw a line to the end of the page to indicate no further entries on that page. Sign the bottom of each page if possible.

- If an entry to the log book is changed, strike out the deleted text or item with a single line such that the entry remains legible, and initial and date the change. Such changes should only be made by the same person that made the initial entry.

- Field log book entries must be made in the field at the site, not at a later time at a different location. Supplemental entries to the log book may be made at a later date. The supplemental entry must be clearly identified as such and the entry must be signed and dated as described in this SOP.

- Problems noted in the field log book must be brought to the attention of the project manager and task manager in a timely fashion. Problems may be reported in person, on the telephone, or in a written daily log form. If daily logs are prepared and you will not be able to personally give the daily log to the project manager, send the daily log via FAX or overnight courier to the project manager and task manager.

VII. Waste Management

Investigation-derived waste will be managed as described in the Investigation-Derived Waste Handling and Storage SOP. A drum/waste inventory should be maintained on a pre-designated page in the field log book.

VIII. Data Recording and Management

Each page of the field log book should be scanned for electronic/digital archiving at periodic intervals. This will ensure that copies of the field notes are available in the event the field book is lost or damaged, and that field data can be easily disseminated to others without the risk of physically sending the field log book. Field log books that are full should be archived with the project files, and readily retrievable.

IX. Quality Assurance

Be mindful that the field log book may be produced in court. All entries should be legible (as discussed above). Entries should also be in English, unless working in a country where English is not the predominant language or you are directed otherwise by the project manager.

X. References

Not Applicable

Appendix I

Calibration and Use of Horiba Water Quality Meter

Multi Water Quality Checker
U-50 Series

Instruction Manual

CODE:GZ0000144342C

Preface

This manual describes the operation of the Multi Water Quality Checker, U-50 Series.
Be sure to read this manual before using the product to ensure proper and safe operation of the instrument. Also safely store the manual so it is readily available whenever necessary.

Product specifications and appearance, as well as the contents of this manual are subject to change without notice.

■ Warranty and Responsibility

HORIBA warrants that the Product shall be free from defects in material and workmanship and agrees to repair or replace free of charge, at HORIBA's option, any malfunctioned or damaged Product attributable to HORIBA's responsibility for a period of one (1) year from the delivery unless otherwise agreed with a written agreement. In any one of the following cases, none of the warranties set forth herein shall be extended;

- Any malfunction or damage attributable to improper operation
- Any malfunction attributable to repair or modification by any person not authorized by HORIBA
- Any malfunction or damage attributable to the use in an environment not specified in this manual
- Any malfunction or damage attributable to violation of the instructions in this manual or operations in the manner not specified in this manual
- Any malfunction or damage attributable to any cause or causes beyond the reasonable control of HORIBA such as natural disasters
- Any deterioration in appearance attributable to corrosion, rust, and so on
- Replacement of consumables

HORIBA SHALL NOT BE LIABLE FOR ANY DAMAGES RESULTING FROM ANY MALFUNCTIONS OF THE PRODUCT, ANY ERASURE OF DATA, OR ANY OTHER USES OF THE PRODUCT.

■ Trademarks

Generally, company names and brand names are either registered trademarks or trademarks of the respective companies.

 © 2008 – 2009 HORIBA, Ltd.

Conformable Directive

This equipment conforms to the following directives and standards:

Directives: the EMC Directive 2004/108/EC

Standards: [the EMC Directive]
EN61326-1:2006 Class B, Portable test and measurement equipment

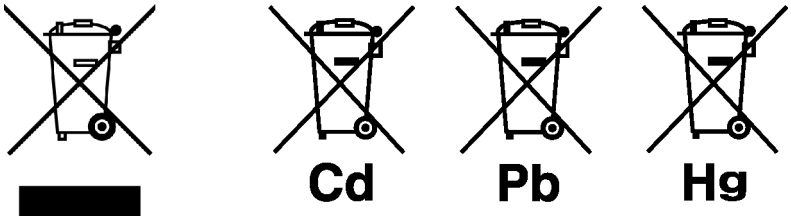
Information on Disposal of Electrical and Electronic Equipment and Disposal of Batteries and Accumulators

The crossed out wheeled bin symbol with underbar shown on the product or accompanying documents indicates the product requires appropriate treatment, collection and recycle for waste electrical and electronic equipment (WEEE) under the Directive 2002/96/EC, and/or waste batteries and accumulators under the Directive 2006/66/EC in the European Union.

The symbol might be put with one of the chemical symbols below. In this case, it satisfies the requirements of the Directive 2006/66/EC for the object chemical.

This product should not be disposed of as unsorted household waste.
Your correct disposal of WEEE, waste batteries and accumulators will contribute to reducing wasteful consumption of natural resources, and protecting human health and the environment from potential negative effects caused by hazardous substance in products.

Contact your supplier for information on applicable disposal methods.



FCC Rules

Any changes or modifications not expressly approved by the party responsible for compliance shall void the user's authority to operate the equipment.

WARNING

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications.
Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

For your safety

Warning messages are described in the following manner. Read the messages and follow the instructions carefully.

● Meaning of warning messages

⚠ DANGER	This indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations.
⚠ WARNING	This indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
⚠ CAUTION	This indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices. Without safety alert indication of hazardous situation which, if not avoided, could result in property damage.

● Symbols

❗	Description of what should be done, or what should be followed
⃠	Description of what should never be done, or what is prohibited

■ Safety Precautions

This section provides precautions to enable you to use the product safely and correctly and to prevent injury and damage. The terms of DANGER, WARNING, and CAUTION indicate the degree of imminency and hazardous situation. Read the precautions carefully as it contains important safety messages.

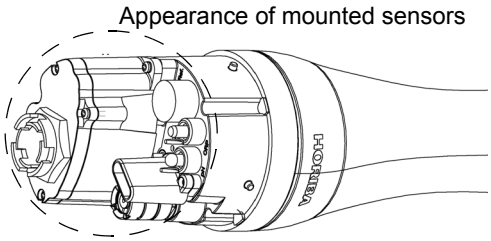
⚠ WARNING
Do not disassemble or modify the meter. May cause overheating or fire, resulting in accidents.

⚠ CAUTION
The pH and ORP sensors are made of glass. Handle them carefully to avoid breakage.
Do not ingest the DO, pH or ORP standard solutions. If it comes into contact with the eyes, rinse thoroughly with water. If swallowed, consult a physician.
Keep away from water when using USB communication. Improper use may result in fire or damage.

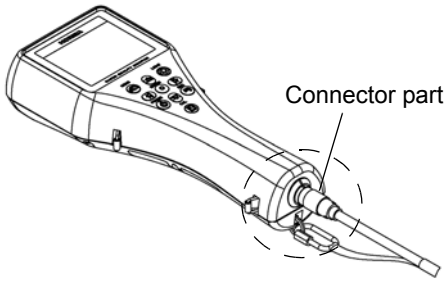
Points of concern

Use of the equipment in a manner not specified by the manufacturer may impair the protection provided by the equipment. It may also reduce equipment performance.

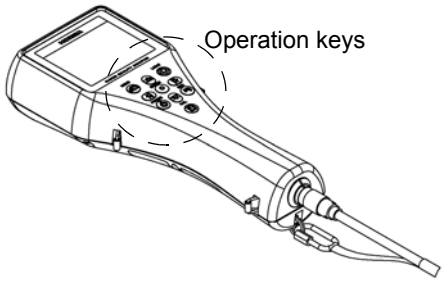
- **Sensor probe**
  - Do not immerse the sensor probe in seawater or other samples with high salinity. Doing so may erode metallic parts. After use, promptly wash the sensor probe thoroughly in water.
  - Do not immerse the sensor probe in alcohol, organic solvent, strong acid, strong alkaline, and other similar solutions.
  - Do not subject to strong shocks.
  - Do not perform measurement in environments of magnetic fields. Measurement errors may result.
  - The sensor probe is no longer waterproof when the sensors are not mounted.



  - Does not support measurement of samples containing fluorine.
  - To disconnect the sensor cable or interface cable, pull them out with holding the connector part. Do not pull the cable part; it may cause breakage.

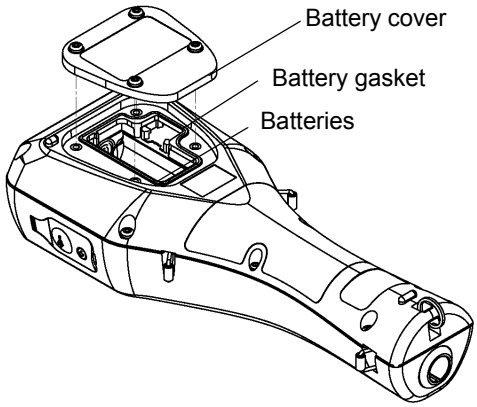


- **Control unit**
  - Do not subject to strong shocks.
  - The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.



  - The control unit is no longer waterproof when the USB cable is connected.
  - When operating the control unit only, protect the connector with the connector cap provided.

- Remove the batteries when not using the control unit for an extended period of time. Battery fluid leakage may cause equipment failure.
- Do not wipe the control unit with organic solvents or powder polish. The surface may deteriorate or its printing may disappear. If the display becomes dirty, wipe the dirt off with a soft cloth soaked in neutral detergent.
- Do not turn the power OFF or disconnect the cable during calibration or setting. Memory data may be erased.
- To perform measurement, connect the sensor probe cable before turning the power ON.
- Do not remove the battery gasket or twist it.
- When opening the battery case, make sure that no foreign matter is attached to the battery gasket.
- Do not use any unspecified batteries; it may cause breakage.



Measurement

- Do not pull the cable when lowering the sensor probe into the sample during measurement. Lower the sensor probe into the sample on a chain or string.
- Before lowering the sensor probe into the sample, do not connect the hook on the unit to a human body.
- The correct values are not displayed if the sensor is not mounted when the measurement display is activated.
- Perform DO measurement with no air bubbles in the internal solution.
- Do not reuse a membrane cap of DO sensor.
- Use the spanner for DO sensor provided to attach or remove the DO sensor.
- Avoid both U-53 and U-53G turbidity measurement in air, since the rubber wiper will quickly become damaged.
- Avoid turbidity measurement in direct sunlight, since the readout may be affected.

Calibration

During atmosphere calibration for the DO electrode with DO salinity compensation set to automatic, values are compensated based on electrical conductivity, but calibration is performed normally.

Location of use and storage

- Storage temperature: −10°C to 60°C
- Relative humidity: Under 80% and free from condensation

Store the meter in locations void of dust, strong vibrations, direct sunlight, corrosive gases, near air conditioners or windy areas.

Disposal of the product

When disposing of the product, follow the related laws and/or regulations of your country for disposal of the product.

Description in this manual

Note

This interprets the necessary points for correct operation and notifies the important points for handling the unit.

Reference

This indicates where to refer for information.

Tip

This indicates reference information.

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1 About this Unit

The U-50 Series Multi Water Quality Checker features an integrated control unit and sensors. It is capable of making a maximum of eleven simultaneous measurements for various parameters, and is perfect for use in the field. The U-50 Series is designed with on-site ease-of-use in mind, provides a wide variety of functions, and can be used for water quality measurements and inspections of river water, groundwater, and waste water.

2 Device Information

2.1 Measurement parameters

Parameters	Model				
	U-51	U-52	U-52G	U-53	U-53G
pH (pH)	✓	✓	✓	✓	✓
pH (mV)	✓	✓	✓	✓	✓
Oxidation reduction potential (ORP)	✓	✓	✓	✓	✓
Dissolved oxygen (DO)	✓	✓	✓	✓	✓
Electrical conductivity (COND)	✓	✓	✓	✓	✓
Salinity (SAL) [expressed as electrical conductivity]	✓	✓	✓	✓	✓
Total dissolved solids (TDS) [expressed as electrical conductivity]	✓	✓	✓	✓	✓
Seawater specific gravity (SG) [expressed as electrical conductivity]	✓	✓	✓	✓	✓
Water temperature (TEMP)	✓	✓	✓	✓	✓
Turbidity (TURB) [LED transmission/front 30° scattering method]	–	✓	✓	–	–
Turbidity (TURB) [tungsten lamp 90° transmission/scattering method] with wiper	–	–	–	✓	✓
Water depth (DEP)	–	–	✓	✓	✓
GPS	–	–	✓	–	✓

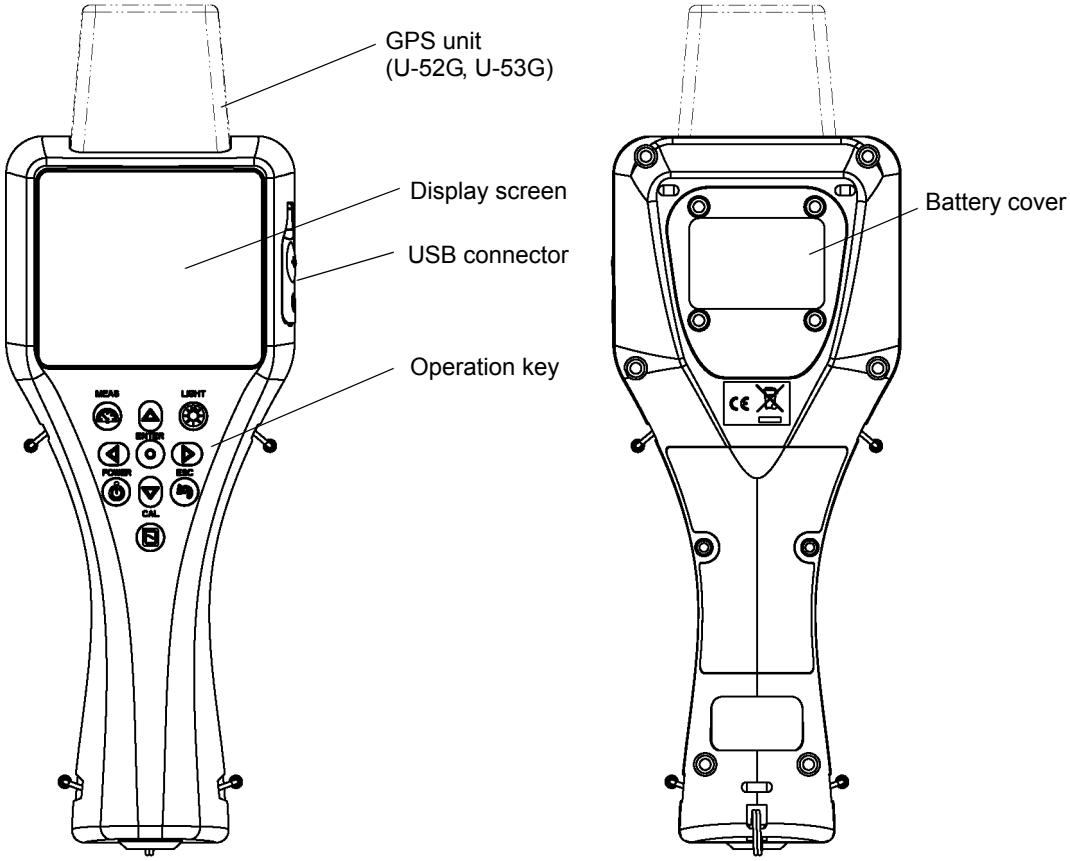
"✓" indicates a measurable parameter.

2.2 Packing list

Parts Name	Quantity	Note
Control unit	1	
Sensor probe	1	
pH sensor (#7112)	1	
ORP sensor (#7313)	1	
Reference electrode (#7210)	1	
DO sensor (#7543)	1	
Turbidity sensor (#7800)	1	With U-52/U-52G only. Attached to the sensor probe.
Turbidity sensor (#7801)	1	With U-53/U-53G only. Attached to the sensor probe.
pH 4 standard solution (#100-4)	1	500 mL
pH reference internal solution (#330)	1	250 mL
DO sensor internal solution set (#306)	1	Internal solution (50 mL), Sandpaper (#8000, #600), Syringe
DO Membrane spare parts set	1	
Spanner for DO sensor	1	
Cleaning brush	1	
calibration cup	1	transparent calibration cup, black calibration cup
Back pack	1	
Strap	1	
Alkaline batteries	4	LR14
Silicon grease	1	
Instruction manual	1	

2.3 Parts name and functions

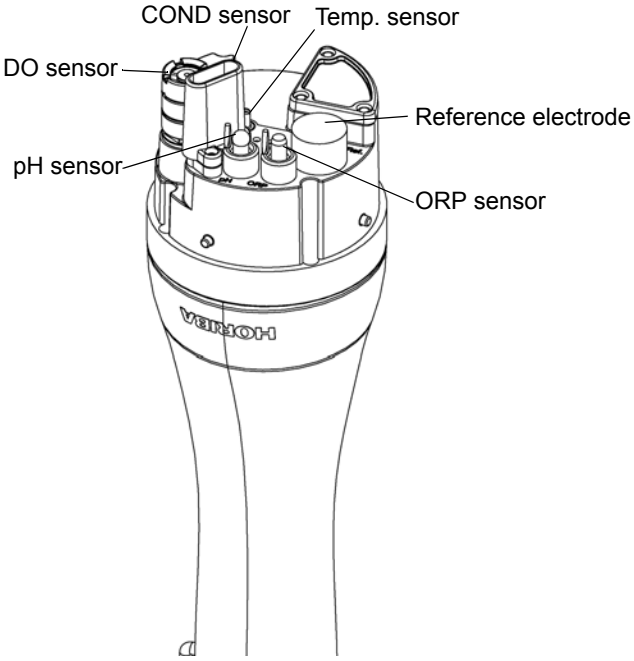
Display



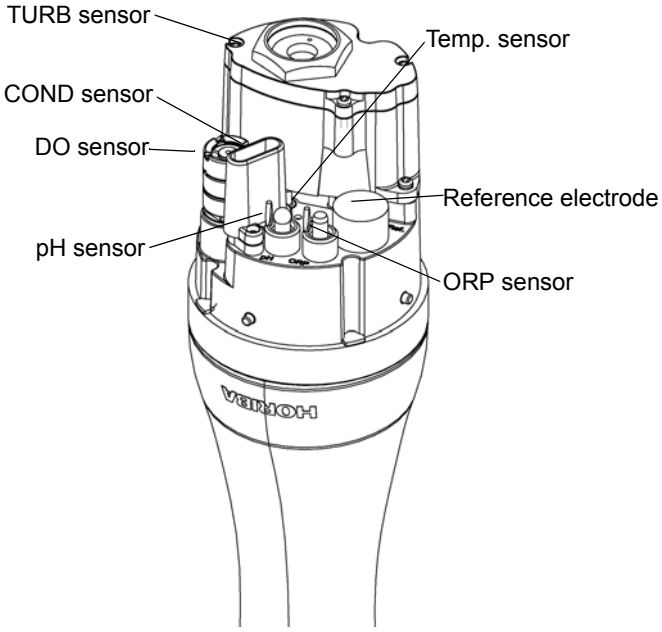
Front view

Back view

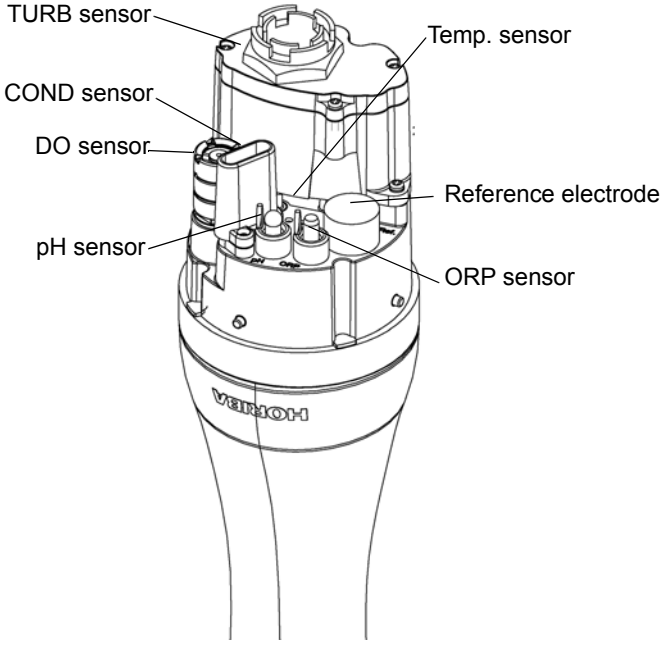
Sensor probe (U-51)



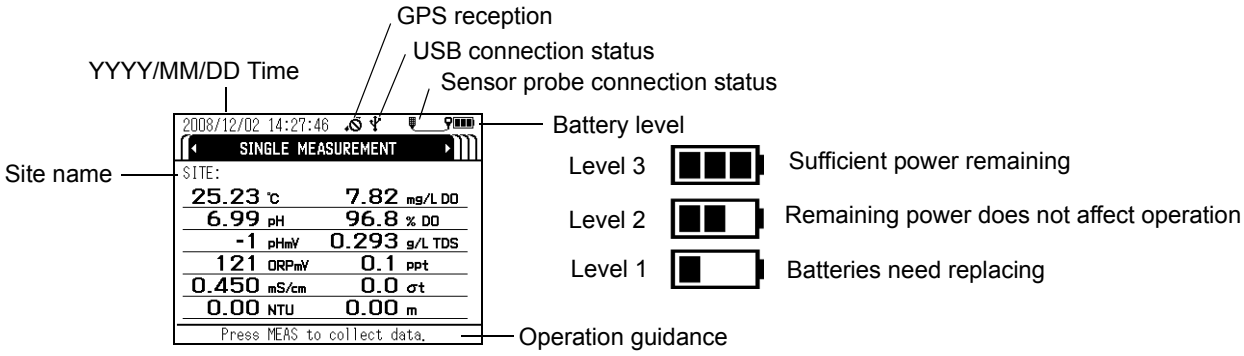
Sensor probe (U-52)



Sensor probe (U-53)



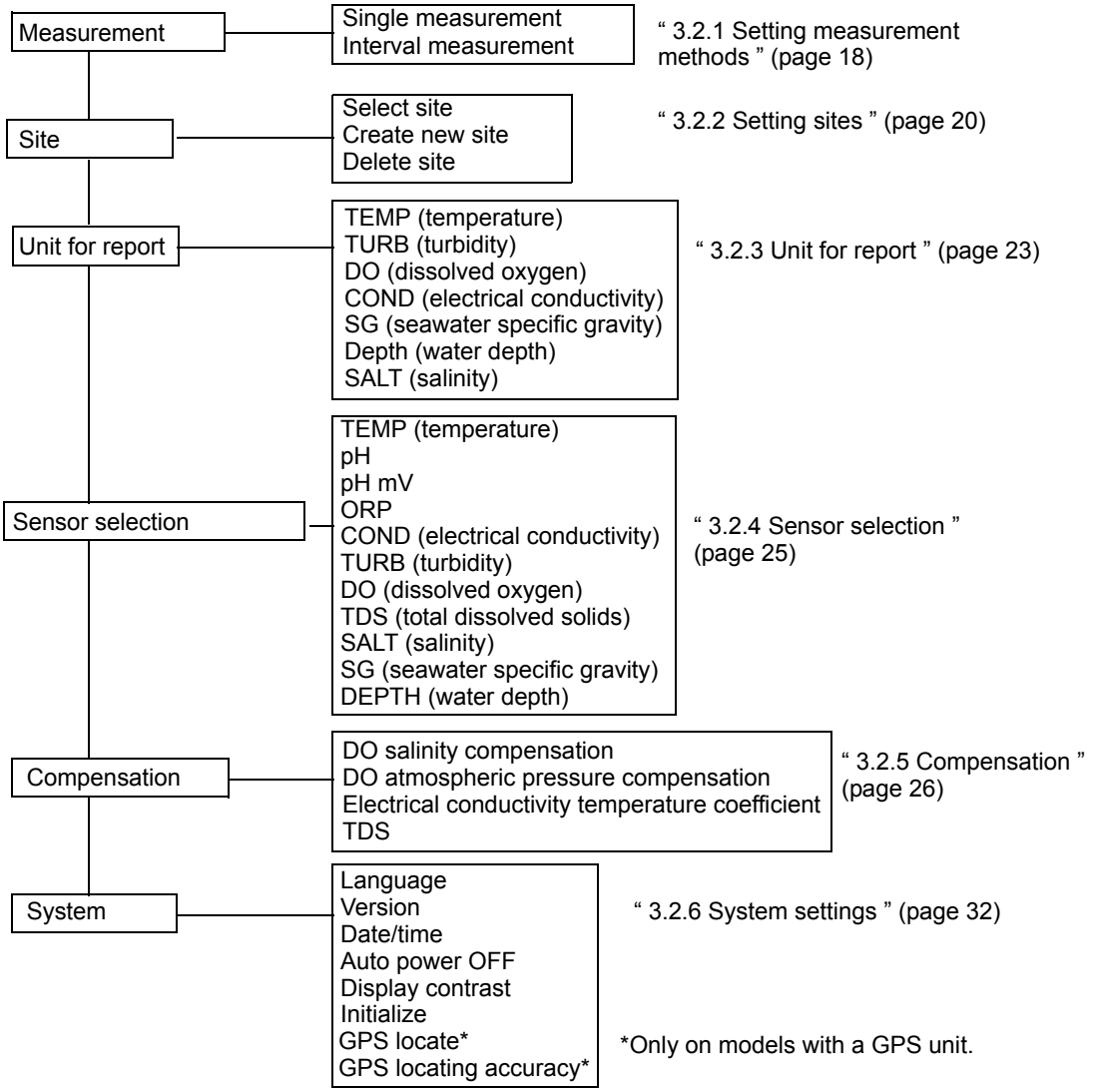
Display screen



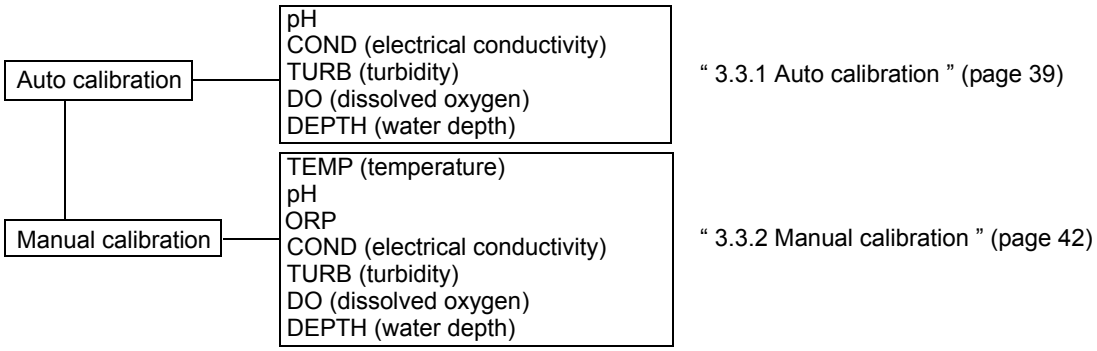
Operation key

	Key name	description
POWER	POWER key	Turns the system's power ON/OFF. The initial screen appears immediately after turning the power ON. Press and hold down the POWER key for about 3 seconds to turn the power ON and OFF.
MEAS	MEAS key	When pressed in the measurement screen, used to set the measurement values of all the measurement parameters. Measurement values flash until the data stabilizes.
		When pressed in the setting, calibration or data operation screen, returns to the measurement screen.
ENTER	ENTER key	Used to execute functions, set entered values or store data in memory.
CAL	CAL key	Switches to the calibration screen.
ESC	ESC key	Returns to the immediately preceding operation.
LIGHT	LIGHT key	Turns the backlight ON/OFF. ● Using the backlight shortens battery life. ● The backlight does not light for about 3 seconds after power ON. ● When the sensor probe is connected while the display's backlight is lit, the backlight goes out for about 3 seconds.
	Left key	Moves the cursor to the left.
	Right key	Moves the cursor to the right.
	Up key	Moves the cursor up.
	Down key	Moves the cursor down.

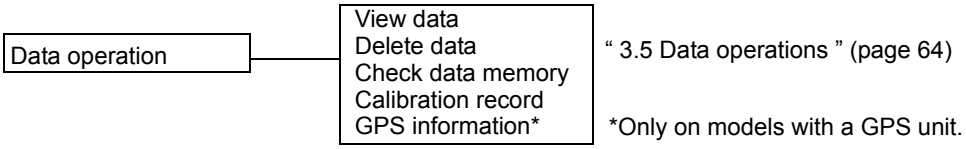
2.4 Setting menu items



2.5 Calibration menu items



2.6 Data operation menu items



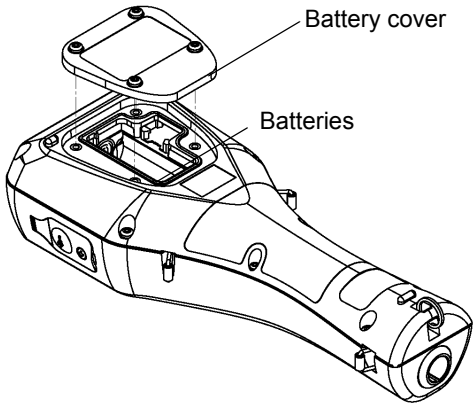
3 Basic Operation

3.1 System setup

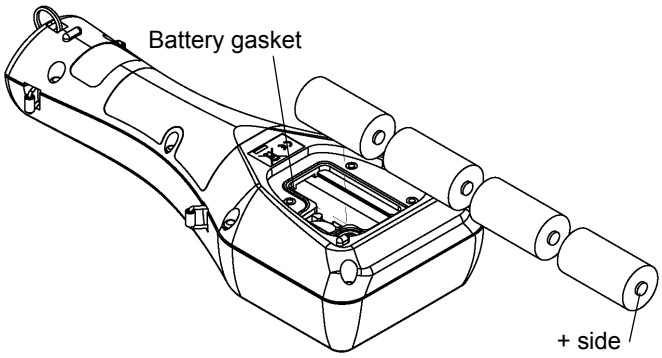
3.1.1 Inserting and replacing the batteries

The control unit is shipped without batteries. Follow the steps below to insert the batteries when using the system for the first time or replacing old batteries.

1. **Loosen the 4 screws on the battery cover by using No. 2 Phillips head screwdriver and remove the cover.**



2. **If replacing the batteries, discard the old batteries.**
3. **Insert new batteries in the control unit.**
   Check that the battery gasket is not dirty or twisted.



4. **Replace the battery cover and fasten it with the 4 screws.**
   Tighten the screws to less than 0.5 N·m.

Note

- **Data and settings will not be lost when the batteries are replaced.**
- **If dirty or twisted, the battery gasket will fail to keep the batteries dry. Check its condition before closing the cover.**
- **To ensure long service life, replacing the battery gasket periodically (once a year) is recommended.**

Precautions when using dry cell batteries

- **Batteries to use: LR14 alkaline dry cell batteries (C-size dry cell batteries) or rechargeable nickel-metal hydride dry cell batteries (C-size)**
  Do not use manganese batteries.
- **Dry cell batteries used incorrectly may leak or burst. Always observe the following**
  - Orient the batteries correctly (positive and negative ends in correct positions).
  - Do not combine new and used batteries, or batteries of different types.
  - Remove the batteries when not using the system for a prolonged period.
  - If batteries leak, have the system inspected at your nearest Horiba service station.

● Battery life

- The battery life for continuous operation when using C-size alkaline dry cell batteries is about 70 hours.
- Using the backlight consumes a proportionate amount of battery power, shortening battery life.
- Searching position information using the GPS unit consumes a proportionate amount of battery power, shortening battery life.
- Nickel-metal hydride secondary batteries can be used, but the battery life is not guaranteed since it will vary according to usage (number of times data is saved, number of charges and amount of each charge). In general, secondary batteries have one-half to one-third the life of C-size alkaline batteries.
- The 70-hour battery life figure applies to a control unit operating temperature of 20°C or more. The battery characteristics shorten the battery life at operating temperatures lower than 20°C, so check the remaining battery level, and replace the batteries before it reaches Level 1.
- The batteries packed with the system at the time of shipment are for checking operation. Their life is not guaranteed.
- The 70-hour battery life figure is the amount of operating time the batteries can provide until the system stops operating. The system may fail during operation if the remaining battery level is low, so it is a good idea to check the remaining battery level and replace the batteries with new ones well before the batteries run out completely.

U-51/52

Battery life: 70 hours (backlight off)

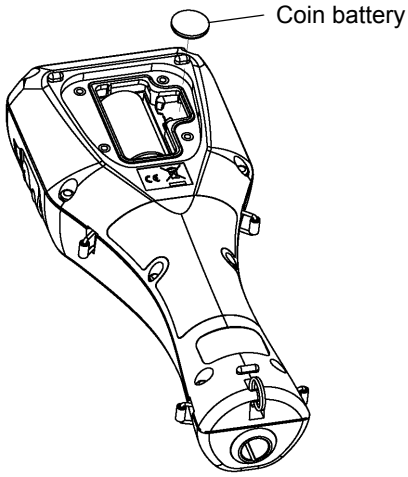
U-53

Battery life: 500 measurements (backlight off)

- Since U-53 is designed for turbidity measurement with wiper, its battery life is estimated in terms of the number of turbidity measurement sequences performed.
- Battery power is also consumed by measurement operations other than turbidity measurement.
- The battery life when turbidity measurement is not performed is about 70 hours.

3.1.2 Replacing the coin battery

- Coin battery to use: CR-2032
- The coin battery is only for the clock. It will provide problem-free operation for three years, but when using the clock continuously, it should be replaced every two years as a precaution.
- When replacing the coin battery for the clock, leave the control unit ON. If the coin battery is replaced when the control unit is turned OFF, the clock will be reset to the default settings.



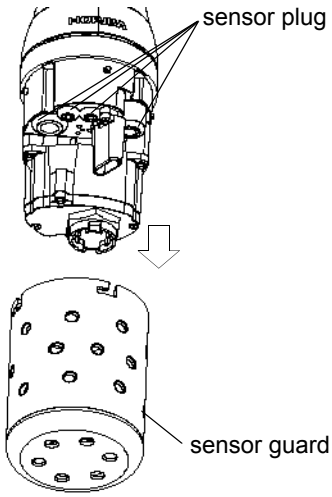
3.1.3 Attaching sensors

Note

- **When attaching or replacing a sensor, wipe any moisture off the sensor probe and sensor.**
- **Be sure to keep water out of sensor connectors. If moisture comes in contact with a sensor connector, blow-dry it with dry air.**
- **The sensor probe is not waterproof when the sensor is not mounted.**
- **Take care not to tighten the sensor too much.**

Attaching the pH sensor

1. **Remove the sensor guard.**

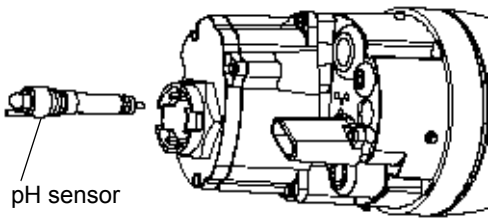


2. **Remove the sensor plug.**
3. **Coat the pH sensor O-ring with a thin layer of silicon grease (part No. 3014017718).**

Note

Be sure no grease from the O-ring gets on the sensor connector. If the sensor connector gets grease on it, wipe it off with a soft cloth soaked in alcohol.

4. **Make sure there is no moisture on the sensor probe's sensor connector (marked "pH").**
5. **Fasten the pH sensor securely by hand.**



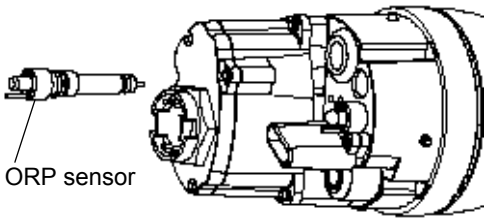
6. **Clean the sensor with an alcohol-soaked cloth.**

- **Attaching the ORP sensor**
  1. **Remove the sensor guard.**
  2. **Remove the sensor plug.**
  3. **Coat the ORP sensor O-ring with a thin layer of grease (part No. 3014017718).**

Note

Be sure no grease from the O-ring gets on the sensor connector. If the sensor connector gets grease on it, wipe it off with a soft cloth soaked in alcohol.

  4. **Make sure there is no moisture on the sensor probe's sensor connector (marked "ORP").**
  5. **Fasten the ORP sensor securely by hand.**



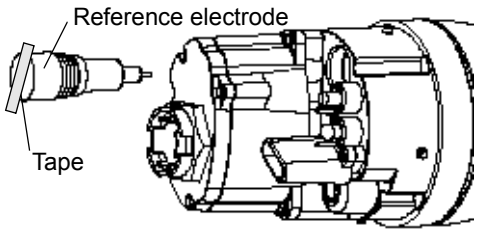
  6. **Clean the sensor with an alcohol-soaked cloth.**

- **Attaching the reference electrode**
  1. **Remove the sensor guard.**
  2. **Remove the sensor plug.**
  3. **Coat the reference electrode O-ring with a thin layer of grease (part No. 3014017718).**

Note

Be sure no grease from the O-ring gets on the sensor connector. If the sensor connector gets grease on it, wipe it off with a soft cloth soaked in alcohol.

  4. **Make sure there is no moisture on the sensor probe's sensor connector (marked "REF").**
  5. **Fasten the reference electrode securely by hand.**
  6. **Remove the tape from the liquid junction part of the reference electrode.**



Attaching the dissolved oxygen (DO) sensor

1. **Remove the membrane cap mounted on the DO sensor beforehand, and replace it with the new membrane cap provided. Replace the internal solution with fresh solution. The main component of the internal solution is potassium chloride (KCl), so the old solution can be disposed of down a sink or other drain.**

Reference

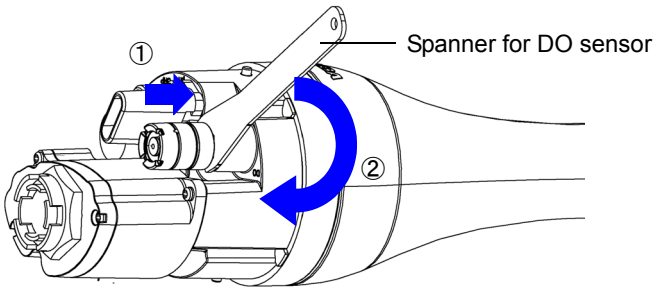
“ 4.5 Replacing the membrane cap ” (page 87)

2. **Screw in the DO sensor to attach it, allowing the internal solution to overflow slightly.**
3. **Use a soft cloth to wipe off the internal solution that overflowed onto the DO sensor.**
4. **Remove the sensor guard.**
5. **Remove the sensor plug.**
6. **Coat the DO sensor O-ring with a thin layer of grease (part No. 3014017718).**

Note

Be sure no grease from the O-ring gets on the sensor connector. If the sensor connector gets grease on it, wipe it off with a soft cloth soaked in alcohol.

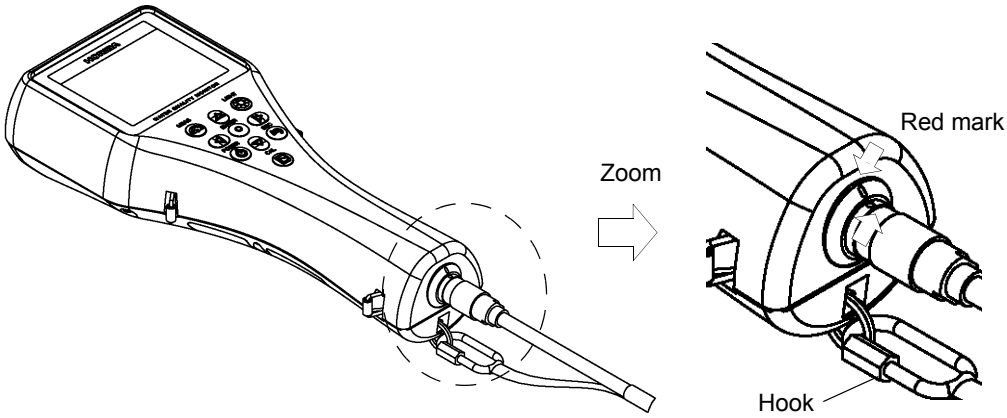
7. **Make sure there is no moisture on the sensor probe’s sensor connector (marked "DO").**
8. **Fasten the DO sensor securely using the spanner for DO sensor.**
   - Hold the DO sensor with the provided spanner for DO sensor and push the sensor down. (Step 1 in figure below)
   - Screw the DO sensor in place. (Step 2 in figure below)



3.1.4 Connecting the control unit and sensor probe

Note

Connect the control unit with its power OFF.

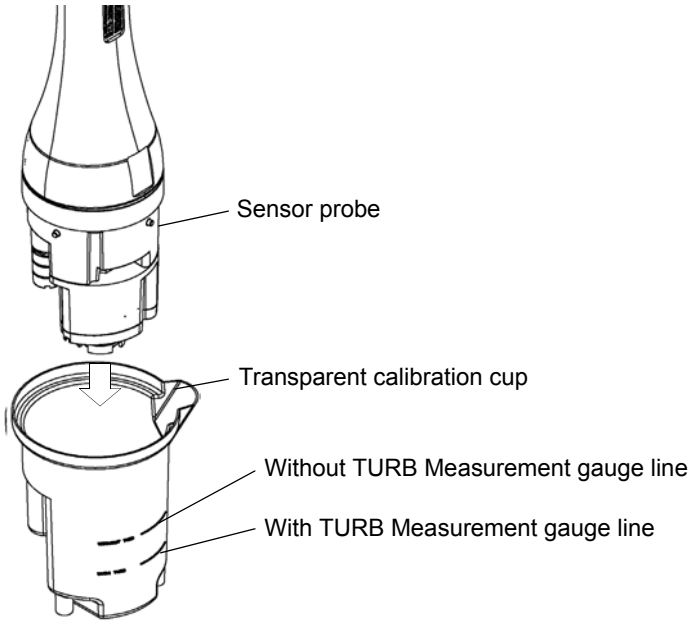


1. **Align the red mark on the connector, and press the connector in until you hear it click.**
2. **Connect the cable's hook to the display.**

3.1.5 Conditioning

Carry out the steps below when using the unit for the first time or when the system has not been used for 3 months or longer.

1. **Fill the transparent calibration cup to the line with pH 4 standard solution.**
   The transparent calibration cup has With TURB Measurement and Without TURB Measurement gauge lines.
2. **Insert the sensor probe in the transparent calibration cup.**



Note

Check that all sensors are attached.

3. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON. Leave the unit for at least 20 minutes to condition the sensors.**

Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

Tip

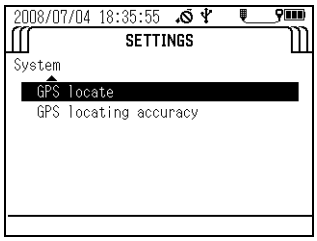
- **The procedure for immersing the sensor probe in the pH standard solution is the same as that described in " 3.3.1 Auto calibration " (page 39).**
  Auto calibration can be performed using the same pH 4 standard solution that was used in the conditioning procedure.
- **Immersing the sensor in the standard solution is generally required for sensor conditioning, but a voltage supply is required for DO sensor conditioning. Turning ON the power of the control unit is necessary during sensor conditioning.**

3.1.6 GPS (U-52G, U-53G)

The GPS position measurement precision is proportional to the GPS position measurement time. When the position measurement precision increases, the position measurement time also increases. See " ● GPS locating accuracy" (page 17) for how to set the position measurement precision. See " ● GPS locate" (page 15) below for how to check acquired GPS data.

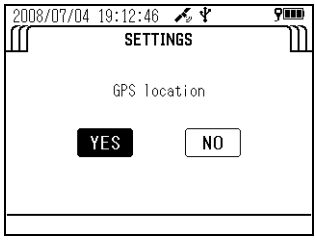
● **GPS locate**

1. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
2. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**
3. **Press the down (▽) key to move the cursor to "GPS locate", then press the ENTER key.**



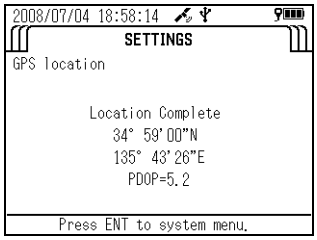
4. **The message "Press ENT key to start position measurement." appears. Press the ENTER key.**

5. **The message "Execute GPS position measurement?" appears. Move the cursor to "YES", then press the ENTER key.**

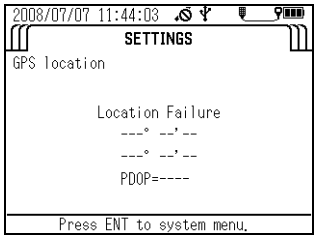


6. **The message "Warming up. Please wait." appears. Wait until the system has finished warming up (about 10 seconds).**

- Position measurement starts automatically when warmup has finished. Position measurement is performed up to 10 times.
- The GPS location complete screen appears after successful position measurement.

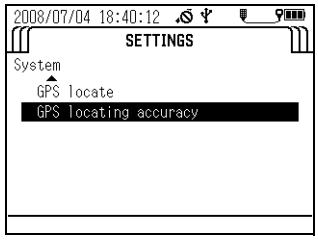


- The GPS location failure screen appears after position measurement has failed. Redo the measurement in a location free from obstacles, or wait for the meteorological conditions to improve before redoing the measurement.

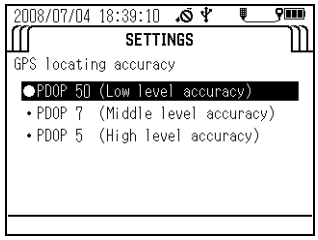


● GPS locating accuracy

1. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
2. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**
3. **Press the down (▽) key to move the cursor to "GPS locating accuracy", then press the ENTER key.**



4. **The screen below appears. Move the cursor to the locating accuracy, then press the ENTER key. The black circle (●) indicates the currently set precision.**



3.2 Settings

3.2.1 Setting measurement methods

This section describes how to set the measurement method.

Measurement methods

● U-51/U-52

Single measurement	Pressing the MEAS key acquires the 5-second average for the selected measurement parameter.
Interval measurement	Pressing the MEAS key acquires and saves the 5-second average for the selected measurement parameter in the set interval. The measurement interval can be set to any value between 10 seconds and 24 hours.

● U-53

The U-53 turbidity sensor uses a tungsten lamp. The lamp lights for about 10 seconds, and the average measurement value acquired during this interval is displayed.

Single measurement	Pressing the MEAS key acquires the 5-second average for the selected measurement parameter after wiper operation. The 10-second average is acquired when measuring turbidity.
Interval measurement	Pressing the MEAS key acquires and saves the 5-second average for the selected measurement parameter in the set interval. The 10-second average is acquired when measuring turbidity. The measurement interval can be set to any value between 10 seconds (final check of this value required; 30 seconds may be better for U-52) and 24 hour.

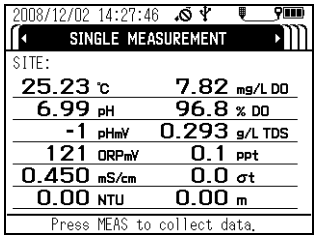
Reference

“ 3.4 Measurement ” (page 61)

Operation method

1. **Press and hold down the control unit’s POWER key for about 3 seconds to turn the power ON.**

The "MEASUREMENT" screen appears after about 10 seconds.

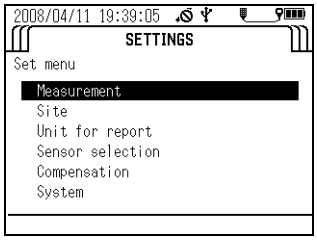


Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

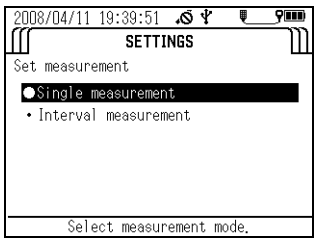
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

3. **Press the down (▽) key to move the cursor to "Measurement", then press the ENTER key.**



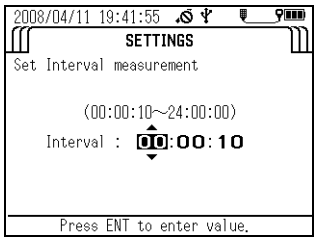
4. **Press the down (▽) key to move the cursor to the desired measurement mode. Press the ENTER key to save the setting.**

The black circle (●) indicates the currently selected measurement mode.



5. **If you selected "Interval measurement", the display switches to the screen used to set the measurement interval. Press the up (△) and down (▽) keys to set the measurement interval.**

The measurement interval can be set to any value between 10 seconds and 24 hours in the case of the U-51 and U-52, or between 30 seconds and 24 hours in the case of the U-53.



3.2.2 Setting sites

The site function allows position data to be connected to corresponding measurement data. Sites have the following specifications and features:

Site names: Text data consisting of up to 20 one-byte alphanumeric characters, spaces, etc.
Site names can be used for control unit searches and as labels for computer processing.
Site names allow measurement data to be saved with a name corresponding to the actual location where it was measured.

You can use site information as a search key when viewing data uploaded by a PC or data saved in the control unit (see “ 3.5 Data operations ” (page 64)).

- **Selecting sites**

  You can select previously created sites. The black circle (●) indicates the name of the currently selected site. No sites are created at new purchasing or after initialization. Select a site after first creating one from the "Create new site" menu.

- **Creating new sites**

  You can create and save new sites. Up to 20 site names can be registered.

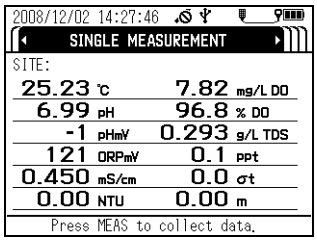
- **Deleting sites**

  You can select a previously created site and delete it.

● **Operation methods**

- **Selecting a site**

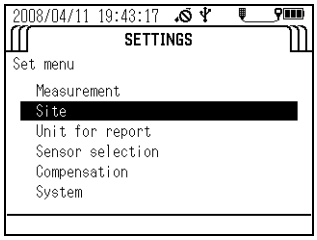
  1. **Press and hold down the control unit’s POWER key for about 3 seconds to turn the power ON.**
     The "MEASUREMENT" screen appears after about 10 seconds.



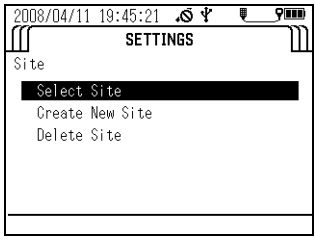
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

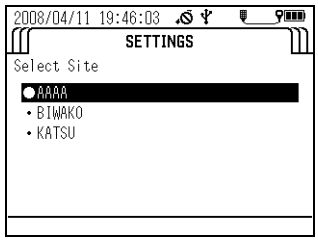
  2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
  3. **Press the down (▽) key to move the cursor to "Site", then press the ENTER key.**



4. **Press the down (▽) key to move the cursor to "Select Site", then press the ENTER key to display the names of the currently saved sites.**

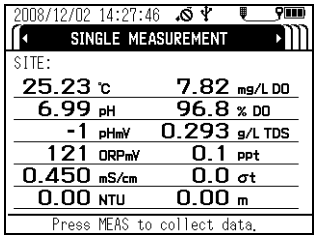


The black circle (●) indicates the currently selected site.



● **Creating a new site**

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
The "MEASUREMENT" screen appears after about 10 seconds.

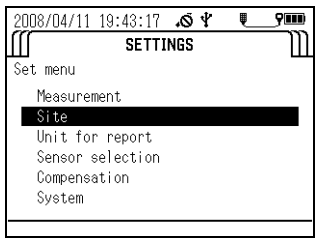


Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

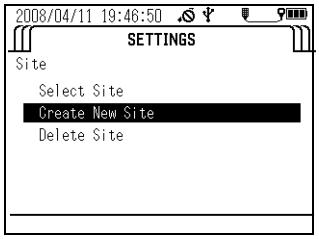
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

3. **Press the down (▽) key to move the cursor to "Site", then press the ENTER key.**

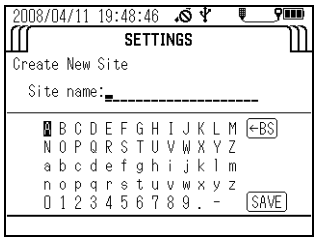


4. **Press the down (▽) key to move the cursor to "Create New Site", then press the ENTER key.**

Enter the desired site name (up to 20 alphanumeric non-Asian width characters).



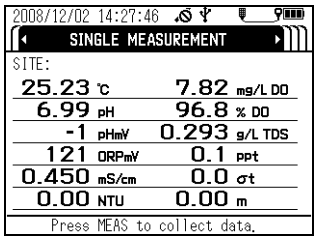
5. **Press the up (△), down (▽), right (▷), and left (◁) keys to move the cursor to each letter or number to use in the name, then press the ENTER key to confirm the entered characters. To delete incorrectly entered characters, move the cursor to "BS" and press the ENTER key to start deleting from the last character. When you have finished entering the name, save it by moving the cursor to "SAVE" and pressing the ENTER key.**



● **Deleting a site**

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**

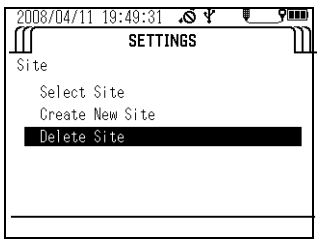
The "MEASUREMENT" screen appears after about 10 seconds.



Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

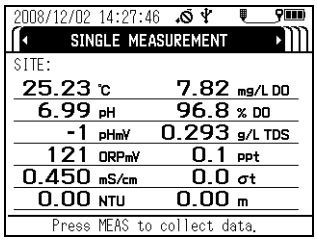
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**



3. **Press the down (▽) key to move the cursor to "Site", then press the ENTER key.**

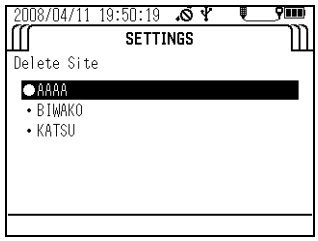
4. **Press the down (▽) key to move the cursor to "Delete Site", then press the ENTER key.**

A list of the currently saved sites appears. The black circle (●) indicates the currently selected site.



5. **Press the down (▽) key to move the cursor to the site to delete, then press the ENTER key to delete it.**

The currently selected site can be deleted after a different site has been selected from the site selection menu or after all unselected sites have been deleted. The same site name cannot be registered more than once.



3.2.3 Unit for report

Note

Units can only be selected when the sensor probe is connected.

Follow the steps below to set the measurement units of measurement parameters. No units are displayed if a measurement parameter has not been selected in the measurement parameter selection screen (see “ 3.2.4 Sensor selection ” (page 25)).

1. **Press and hold down the control unit’s POWER key for about 3 seconds to turn the power ON.**

The "MEASUREMENT" screen appears after about 10 seconds.

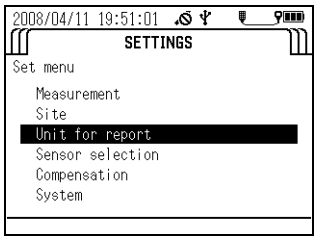
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

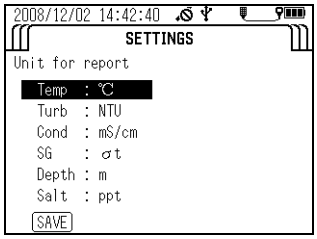
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

3. **Press the down (▽) key to move the cursor to "Unit for report", then press the ENTER key.**

A list of the currently selected measurement parameters and their units appears. Note that measurement parameters not selected (in the measurement parameter selection screen) are not displayed.

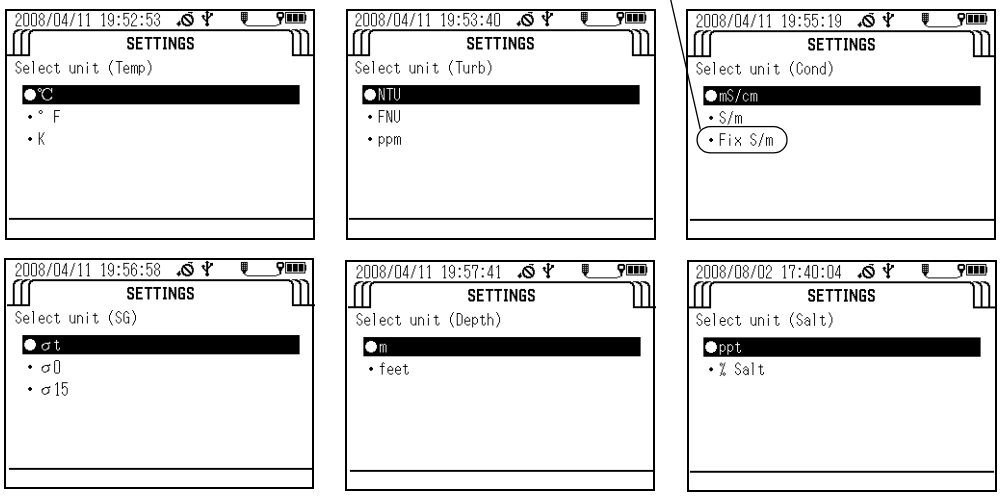


4. **Press the up (△) and down (▽) keys to move the cursor to the item to change, then press the ENTER key.**

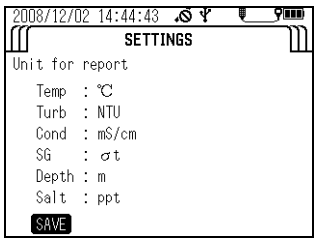


5. **A list of the units that can be selected appears. The black circle (●) indicates the currently selected unit. Press the up (△) and down (▽) keys to move the cursor to the desired unit, then press the ENTER key.**

Fix S/m: Fixes S/m with no auxiliary units for any measurement range.



6. **To save the changes, press the up (△) and down (▽) keys to move the cursor to SAVE, then press the ENTER key. If you do not want to save the changes, press the ESC key.**



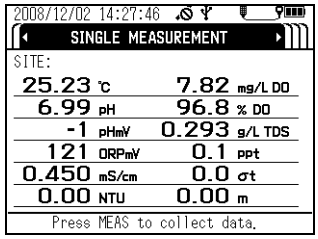
3.2.4 Sensor selection

Note

Measurement parameters can only be selected when the sensor probe is connected.

You can set between 1 and 11 measurement parameters to display in the control unit screen. Follow the steps below to select the desired measurement parameters.

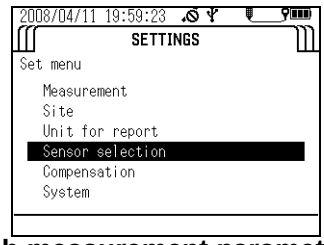
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



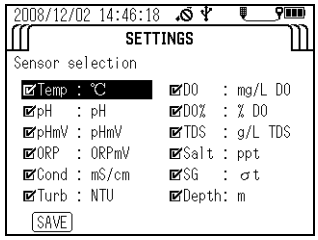
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
3. **Press the down (▽) key to move the cursor to "Sensor selection", then press the ENTER key.**
   A list of the measurement parameters that can be set and the currently set units are displayed.



4. **Move the cursor to each measurement parameter to change, then press the ENTER key.**
   A check in the check box of a measurement parameter indicates it will be displayed.
5. **To save the changes, press the up (△), down (▽), left (◁) and right (▷) keys to move the cursor to SAVE, then press the ENTER key. If you don't want to save the changes, press the ESC key.**



Note

Available measurement parameters differ according to product specifications.

3.2.5 Compensation

Note

Compensation settings can only be made when the sensor probe is connected.

U-50 series have following functions of compensation.

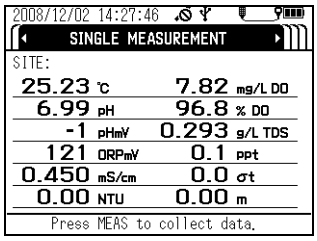
- Salinity compensation and atmospheric pressure compensation for dissolved oxygen (DO)
- Temperature compensation for conductivity (COND)
- Setting total dissolved solid (TDS) coefficient for TDS

● Salinity compensation (DO)

The dissolved oxygen (DO) value is presented higher than actual value if salinity compensation is not added, because the increase of salinity gives higher DO value. To obtain correct value salinity compensation is needed. The following modes are available for calculation of salinity compensation.

AUTO:	Salinity compensation is performed automatically with salinity converted from conductivity.
Value input:	Press the up (△) and down (▽) keys to enter a setting value when the salinity is known.

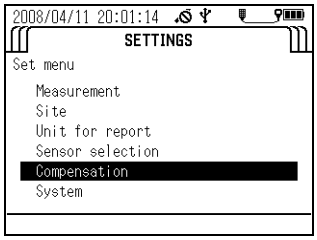
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



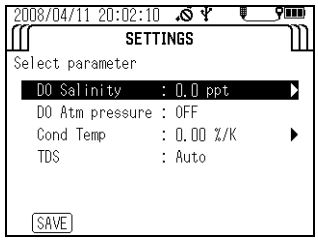
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

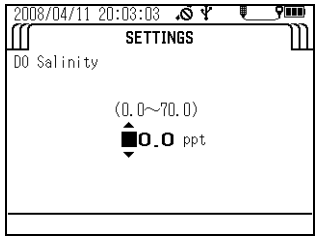
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
3. **Press the down (▽) key to move the cursor to "Compensation", then press the ENTER key.**



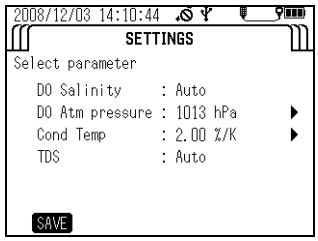
4. **Press the down (▽) key to move the cursor to "DO Salinity", then press the ENTER key to toggle the setting between "Auto" and "Input mode".**
Default: Auto



5. **If you selected "Input mode", press the right (▷) key to display the compensation value input screen. Press the up (△) and down (▽) keys to enter the desired value, then press the ENTER key to set it.**



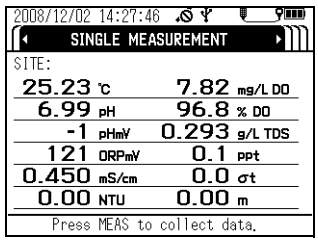
6. **To save the change, press the up (△) and down (▽) keys to move the cursor to SAVE, then press the ENTER key. If you don't want to save the change, press the ESC key.**



● **Atmospheric pressure compensation (DO)**

Differences in the atmospheric pressure of the measurement location influence the Dissolved Oxygen (DO) measurement. By setting (input) the actual atmospheric pressure of the measurement location into the control unit, it is possible to standardize the measured Dissolved Oxygen (DO) value to a value at the standard atmospheric pressure (1013 hPa).

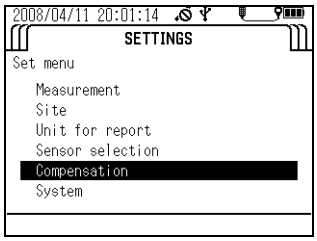
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
The "MEASUREMENT" screen appears after about 10 seconds.



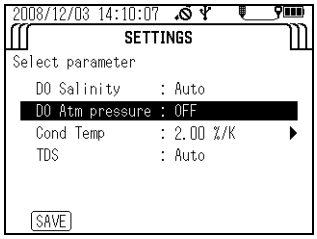
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

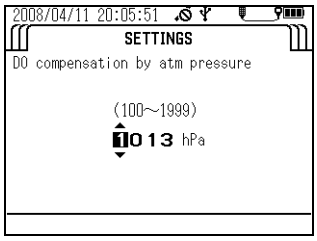
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
3. **Press the down (▽) key to move the cursor to "Compensation", then press the ENTER key.**



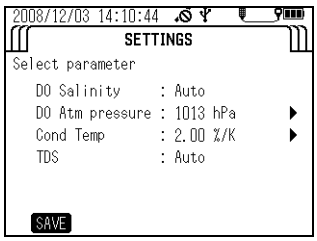
4. **Press the down (▽) key to move the cursor to "Cond Temp", then press the ENTER key to toggle the setting between "OFF" and "Input mode".**
   Default: OFF



5. **If you selected "Input mode", press the right (▷) key to display the compensation value input screen. Press the up (△) and down (▽) keys to enter the desired value, then press the ENTER key to set it.**



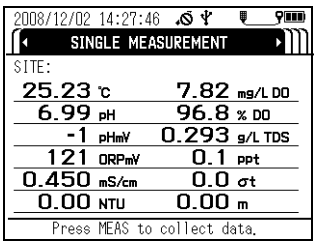
6. **To save the change, press the up (△) and down (▽) keys to move the cursor to SAVE, then press the ENTER key. If you don't want to save the change, press the ESC key.**



Temperature compensation for conductivity (COND)

Sample conductivity (COND) varies with temperature, and this control unit uses a temperature compensation coefficient to automatically standardize the conductivity (COND) at 25°C. The initial setting coefficient is 2%/K, which is the generally used.

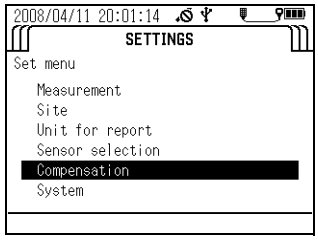
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



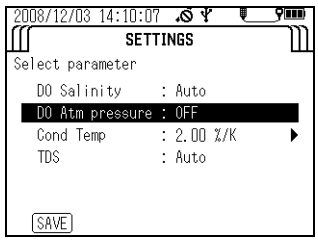
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

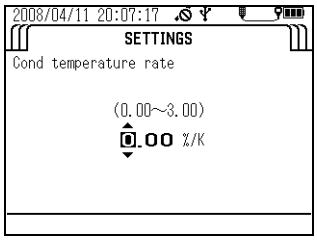
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
3. **Press the down (▽) key to move the cursor to "Compensation", then press the ENTER key.**



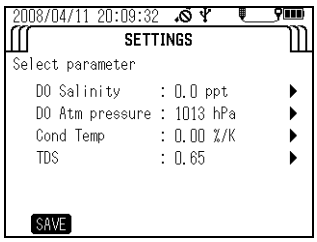
4. **Press the down (▽) key to move the cursor to "Cond Temp", then press the ENTER key to toggle the setting between "OFF" and "Input mode".**
   Default: 2.00%/K



5. **If you selected "Input mode", press the right (▷) key to display the compensation value input screen. Press the up (△) and down (▽) keys to enter the desired value, then press the ENTER key to set it.**



6. **To save the change, press the up (△) and down (▽) keys to move the cursor to SAVE, then press the ENTER key.**
If you don't want to save the change, press the ESC key.

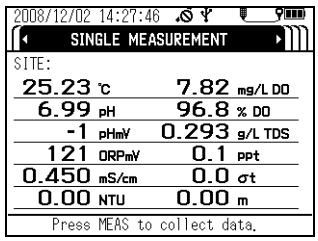


Setting a total dissolved solid (TDS) coefficient

The total dissolved solid amount (TDS) is a converted value obtained by multiplying the conductivity (COND) by a known coefficient. The coefficient initially set for the control unit is based on a conversion for KCl and $CaCO_3$ solutions and it depends on the conductivity (COND) value as shown below.

Conductivity (COND) (S/m)	Conversion coefficient
< 0.05	0.65
0.05 to 0.5	0.64
0.5 to 1	0.63
1 to 3	0.62
3 to 5	0.61
> 5	0.60

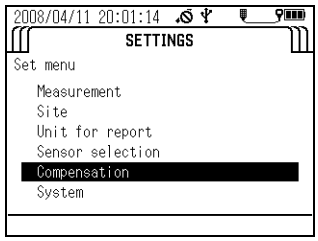
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



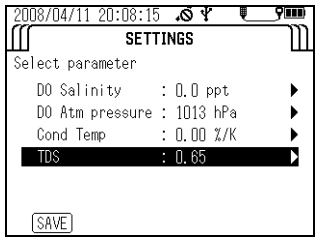
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

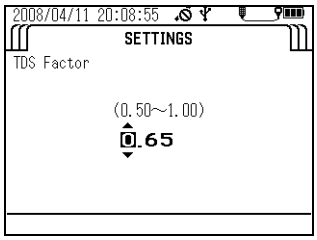
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
3. **Press the down (▽) key to move the cursor to "Compensation", then press the ENTER key.**



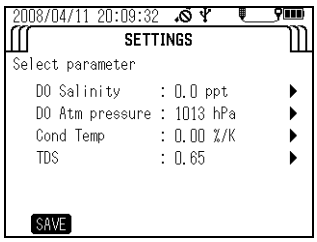
4. **Press the down (▽) key to move the cursor to "TDS", then press the ENTER key to toggle the setting between "AUTO" and "Input mode".**
   Default: Auto



5. **If you selected "Input mode", press the right (▷) key to display the compensation value input screen. Press the up (△) and down (▽) keys to enter the desired value, then press the ENTER key to set it.**



6. **To save the change, press the up (△) and down (▽) keys to move the cursor to SAVE, then press the ENTER key. If you don't want to save the change, press the ESC key.**



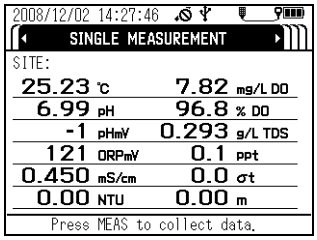
3.2.6 System settings

The system settings let you change the display language, check the system software version, set the date/time, set the auto power OFF time, set the display contrast, and initialize the settings.

● Display language

Follow the steps below to select either English or Japanese as the display language.

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
The "MEASUREMENT" screen appears after about 10 seconds.

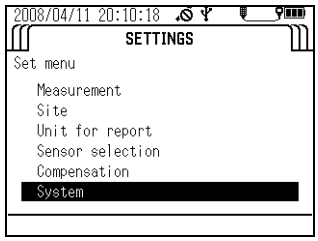


Note

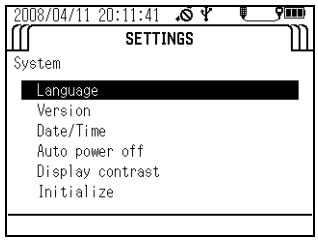
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

3. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**

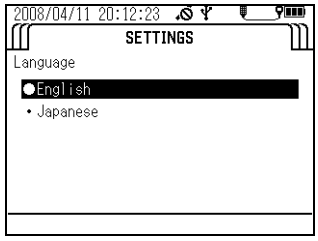


4. **Press the down (▽) key to move the cursor to "Language", then press the ENTER key.**



5. **A list of the supported display languages appears. Press the up (△) and down (▽) keys to move the cursor to the desired language, then press the ENTER key.**

The black circle (●) indicates the currently selected display language.



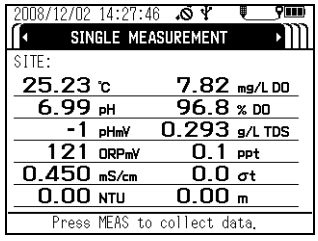
● Version

Follow the steps below to display the program No. and version of the control unit and sensor probe software.

The program No. and version of the sensor probe software will not be displayed if the sensor probe is not connected.

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**

The "MEASUREMENT" screen appears after about 10 seconds.

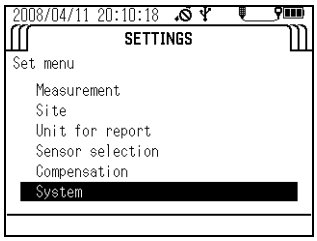


Note

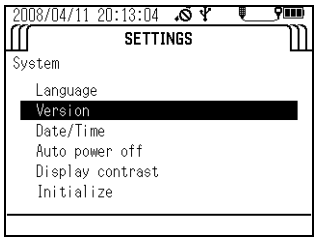
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

3. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**



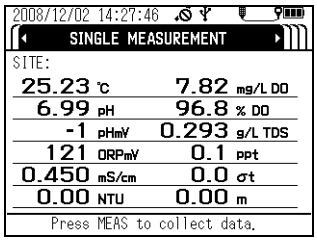
4. **Press the down (▽) key to move the cursor to "Version", then press the ENTER key.**
The program No. of the control unit and sensor probe software appears.



● Setting the date/time

Follow the steps below to set the date and time.

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
The "MEASUREMENT" screen appears after about 10 seconds.

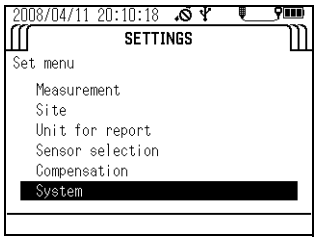


Note

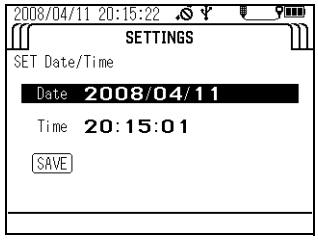
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

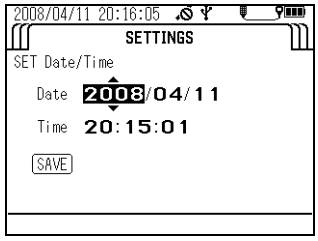
3. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**



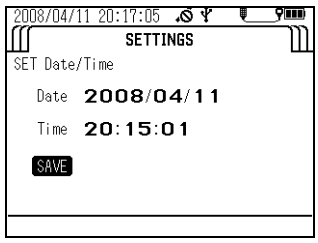
4. **Press the down (▽) key to move the cursor to "Date/time", then press the ENTER key.**



5. **Move the cursor to the date, then press the ENTER key.**
6. **Press the right (▷) key to move the cursor to the year, month, day, hour, minute and second, and press the up (△) and down (▽) keys to enter each value.**



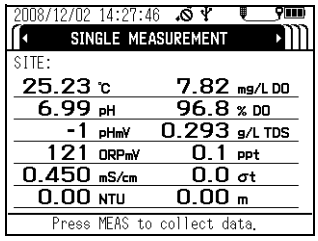
7. **When finished entering settings, press the ENTER key to move the cursor to SAVE, then press the ENTER key again to save the settings.**



● Setting the auto power OFF time

Follow the steps below to set the time for the auto power OFF function (which turns the power OFF automatically when no operation is performed for the preset amount of time).

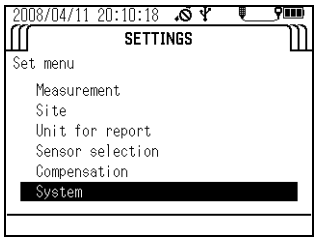
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



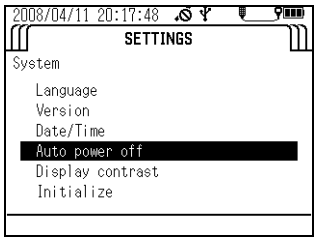
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

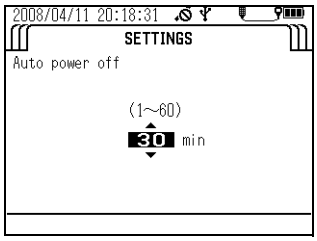
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
3. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**



4. **Press the down (▽) key to move the cursor to "Auto power off", then press the ENTER key.**



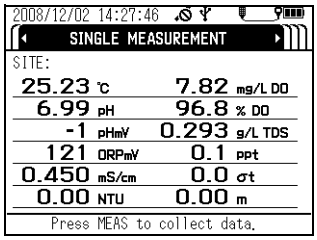
5. **Press the up (△) and down (▽) keys to select the desired time setting, then press the ENTER key.**
   You can select OFF, or settings of 1, 2, 5, 10, 20, 30 or 60 minutes.
   Default: 30 minutes



Display contrast

Follow the steps below to adjust the display's contrast.

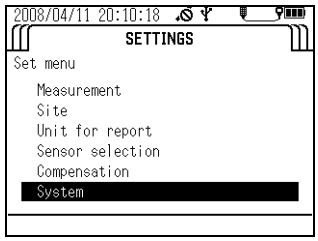
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



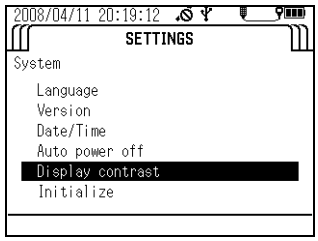
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

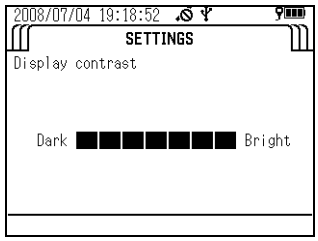
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
3. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**



4. **Press the down (▽) key to move the cursor to "Display contrast", then press the ENTER key.**



5. **Press the left (◁) and right (▷) keys to adjust the contrast.**
   Adjustment can be made in 26 steps.

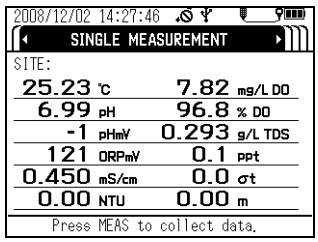


6. **Press the ENTER key.**

Initialization

Follow the steps below to restore all the settings except date/time to their factory defaults. Factory default calibration data for the electrical conductivity and turbidity sensors will also be deleted at the same time.

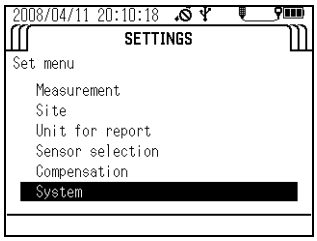
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



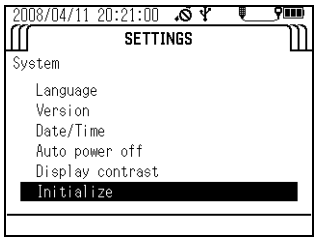
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

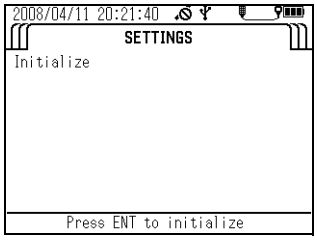
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
3. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**



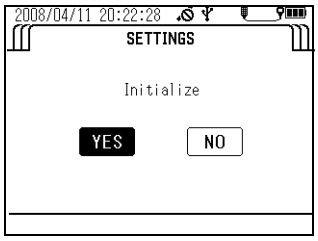
4. **Press the down (▽) key to move the cursor to "Initialize", then press the ENTER key.**



5. **Press the ENTER key again.**



6. **A confirmation message appears asking whether to execute initialization. Press the left (◁) key to move the cursor to YES, then press the ENTER key.**
   The message "Initialize Complete" appears to indicate the process has finished.



3.3 Calibration

To obtain correct measurement values, the sensors need to be calibrated using standard solution before measurement. You can select simultaneous auto calibration of the pH, COND and TURB sensors in pH4 standard solution and DO and DEP sensors simultaneously in air, or manual calibration of individual measurement parameters. You can check the result of the previous calibration using the procedure on “ 3.5.4 Checking the calibration record ” (page 70).

Note

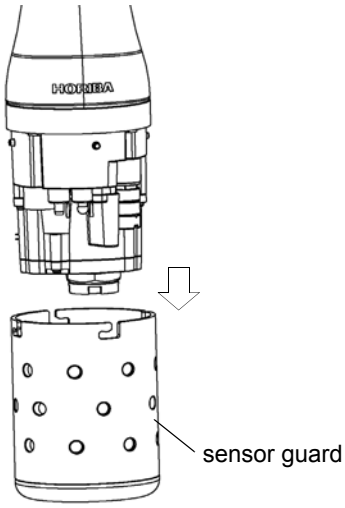
- **Wait at least 20 minutes after turning the system power ON before calibrating the DO sensor.**
- **Make the DO and COND compensation settings before calibration since these settings are applied during calibration.**
- **You can select only the desired parameters for calibration and calibrate just those parameters (see “ 3.2.4 Sensor selection ” (page 25)).**
- **Use about 200 mL of standard solution in the calibration cup.**
- **Calibration data is stored in the sensor probe.**

3.3.1 Auto calibration

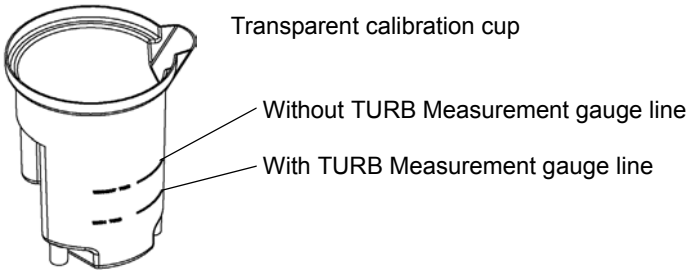
Tip

- **The following parameters are calibrated (at 25°C):**
  pH: Set to 4.01 (zero-point calibration); the span is adjusted to the factory default value.
  COND: 0.449 S/m (4.49 mS/cm, span calibration); the zero point is adjusted to the factory default value.
  TURB: 0 NTU (zero-point calibration); the span is adjusted to the factory default value.
  DO: 8.92 mg/L (span calibration); the zero point is adjusted to the factory default value.
  DEP: 0 m (zero-point calibration); the zero point is adjusted to the factory default value.
- **If the air temperature changes, the readout value may not be stable. Ensure that the ambient air temperature is the same temperature as the calibration solution, because the internal probe temperature sensor and external temperature sensor (in the calibration solution) are used for the auto calibration. Allow the probe and standard solution to equilibrate for 1 hour if a thermometer is not available to verify that these temperatures are the same.**
- **Do not hold the probe while performing the auto calibration. Body temperature may elevate the internal temperature sensor measurement creating DO calibration error.**

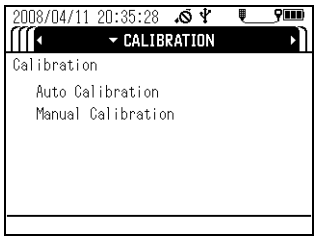
1. **Remove the sensor guard and wash the sensor probe 2 or 3 times with deionized water.**



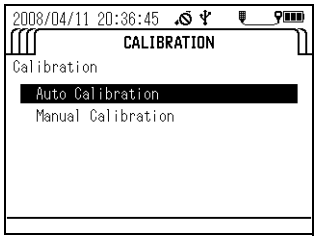
2. **Remove the transparent calibration cup.**
3. **Fill the transparent calibration cup to the line with pH 4 standard solution.**
   The transparent calibration cup has With TURB Measurement and Without TURB Measurement gauge lines.



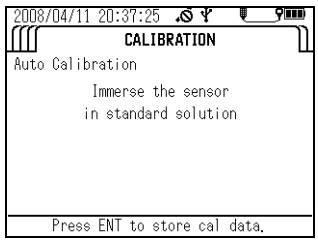
4. **Press the control unit's CAL key to set the calibration mode.**

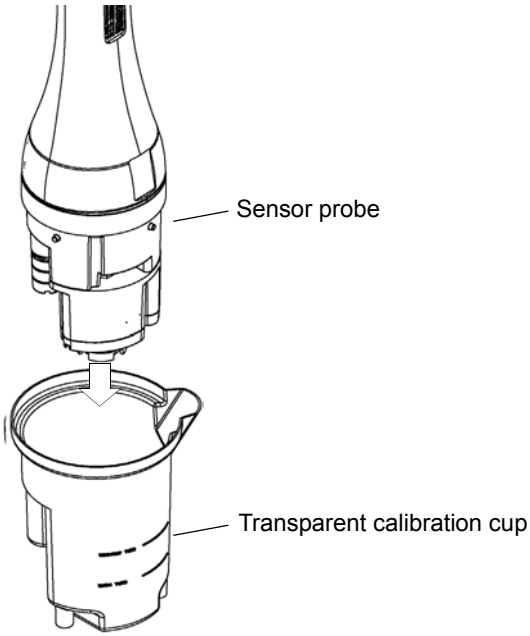


5. **Press the down (▽) key to move the cursor to "Auto Calibration", then press the ENTER key.**

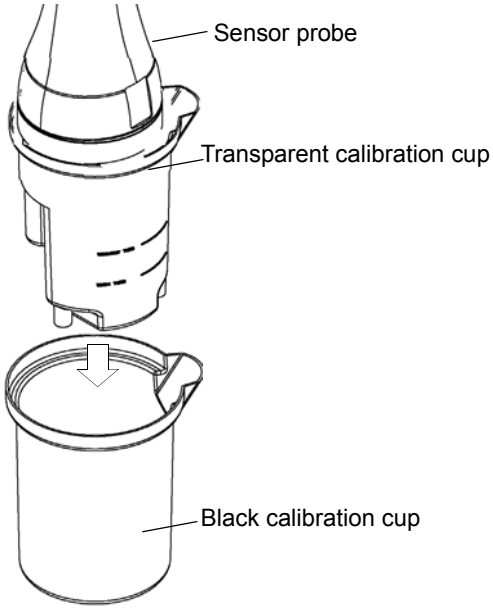


6. **Immerse the sensor probe in the transparent calibration cup.**
Check that the pH sensor, ORP sensor, reference electrode, COND sensor, TURB sensor and temperature sensor are submerged in the pH 4 standard solution and check that there are no air bubbles on the sensor.





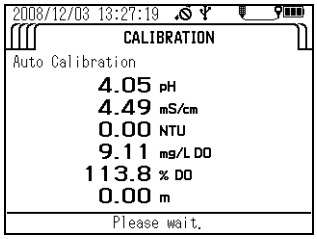
7. **With the sensor probe still in the transparent calibration cup, place the transparent calibration cup into the black calibration cup.**



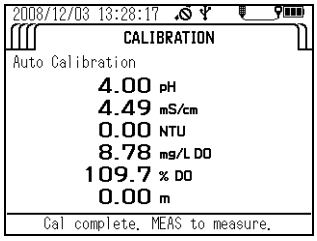
8. **When all the sensor values have stabilized, press the ENTER key to start calibration.**

Note

Do not remove the sensor probe from the calibration solution. U-53 turbidity data will display "----" until the calibration is completed.



Calibration is finished when the message "Cal complete. MEAS to measure." appears. Press the MEAS key to set the measurement screen, then start measurement.



If a calibration error occurs, start calibration after first resolving the issue according to the instructions in " 4.6 Troubleshooting " (page 89).

3.3.2 Manual calibration

The procedures below describe how to calibrate each sensor individually.

Note

The displayed units are the units set by selecting "Unit for report" in the "SETTINGS" screen.

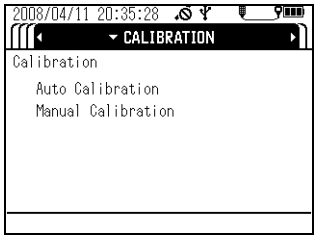
● **Temperature (TEMP) calibration**

1. **Fill a bucket or similar container with water of a known temperature, and insert the sensor probe in it.**

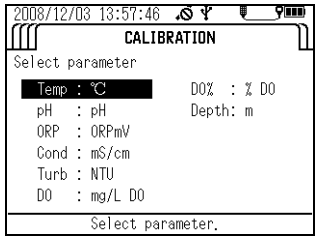
Wait 5 minutes before starting calibration to allow the sensor probe temperature to stabilize.

2. **Press the control unit's CAL key to set the calibration mode.**

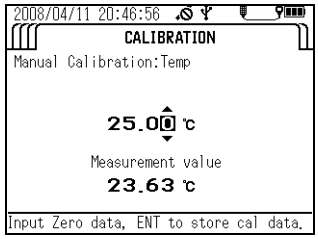
3. **Press the down (▽) key to move the cursor to "Manual Calibration", then press the ENTER key.**



4. **In the parameter selection screen, move the cursor to “Temp”, then press the ENTER key.**



5. **Press the up (△) and down (▽) keys to set the calibration value - the temperature of the water containing the submerged sensor probe.**



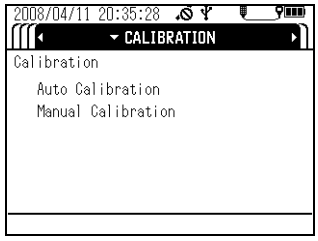
6. **Check that “Measurement value” has stabilized, then press the ENTER key to start calibration.**
   Calibration is finished when the message “Cal complete. CNT to measure.” appears.

● pH calibration

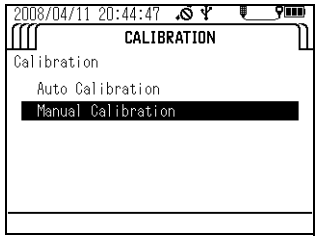
Note

You can select one calibration point (zero-point calibration) or two calibration points (zero-point calibration and span calibration). Carry out two calibration procedures to ensure good measurement precision throughout all measurement ranges.

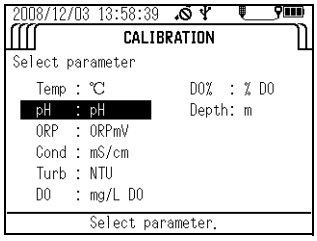
1. **Calibrate the zero point. Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with pH 7 standard solution.**
2. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**
3. **Press the control unit’s CAL key to set the calibration mode.**



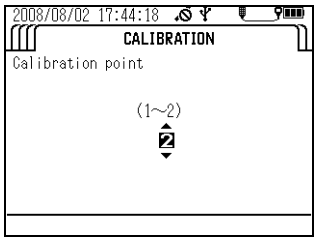
4. **Press the down (▽) key to move the cursor to "Manual Calibration", then press the ENTER key.**



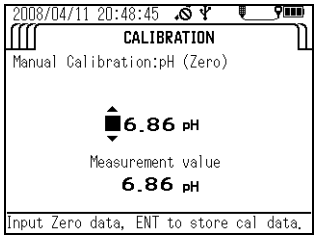
5. **In the parameter selection screen, move the cursor to "pH", then press the ENTER key.**



6. **Set the number of calibration points, then press the ENTER key.**



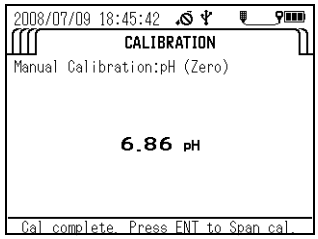
7. **Press the up (△) and down (▽) keys to set the pH value of the pH 7 standard solution containing the submerged sensor probe at the measurement temperature**



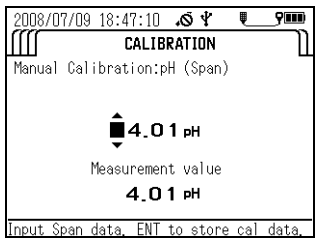
Temp. (°C)	pH 4 standard solution Phthalate	pH 7 standard solution Neutral phosphate	pH 9 standard solution Borate
0	4.01	6.98	9.46
5	4.01	6.95	9.39
10	4.00	6.92	9.33
15	4.00	6.90	9.27
20	4.00	6.88	9.22
25	4.01	6.86	9.18
30	4.01	6.85	9.14
35	4.02	6.84	9.10
40	4.03	6.84	9.07
45	4.04	6.84	9.04

8. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**

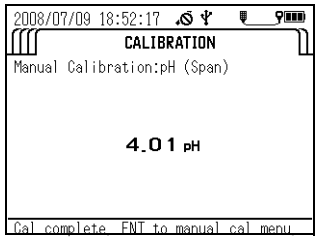
9. **Press the ENTER key to start the span calibration procedure when the message "Cal complete. Press ENT to Span cal." appears.**



10. **Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with pH 4 or pH 9 standard solution.**
11. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**
12. **Press the up (△) and down (▽) keys to set the pH value of the pH 4 or pH 9 standard solution containing the submerged sensor probe at the measurement temperature.**



13. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**
14. **Calibration is finished when the message "Cal complete. ENT to manual cal menu." appears. Press the ENTER key to return to the calibration parameter**

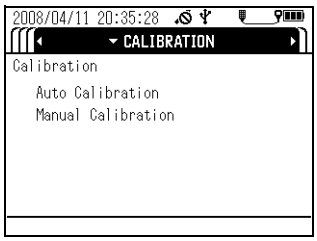


● ORP calibration

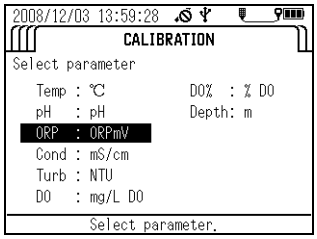
Note

- **If the prepared ORP standard solution is left in open air for one hour or more, the solution may be transformed. For this reason ORP standard solution cannot be stored.**
  Calibrate within one hour of preparing the solution.
- **When measuring sample with low concentrations of oxidants and reductants after conducting an operational check using a standard substance, the measured values may not stabilize or the results of measurement might not be repeatable. If this is the case, start the measurement after immersing the sensors in the sample water sufficiently.**
- **Note that when measuring the ORP of solution with extremely low concentrations of oxidants and reductants, such as tap water, well water, or water treated with purifying equipment, there may be less responsiveness, repeatability, and stability, in general.**
- **When alkaline ion water is left for 5 minutes, its ORP undergoes changes significantly. Always measure alkaline ion water promptly.**

1. **Fill a clean beaker with one bag of ORP standard powder No. 160-22 or No. 160-51. Add 250 mL of deionized water and agitate the solution thoroughly (there will be some excess quinhydrone (a black powder) that floats on the surface when agitating the solution). Fill the transparent calibration cup to the reference line with this standard solution.**
2. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**
3. **Press the control unit's CAL key to set the calibration mode.**
4. **Press the down (▽) key to move the cursor to "Manual Calibration", then press the ENTER key.**



5. **In the parameter selection screen, move the cursor to ORP, then press the ENTER key.**



6. **Press the up (△) and down (▽) keys to set the mV value of the ORP standard solution containing the submerged sensor probe at the measurement temperature.**

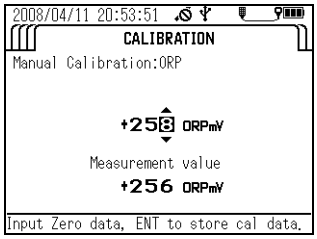


Table 1 Indicated value of ORP standard solution at various temperatures (mV)

Temperature	160-22	16051
5	+274	+112
10	+271	+107
15	+267	+101
20	+263	+95
25	+258	+89
30	+254	+83
35	+249	+76
40	+244	+69

7. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**
8. **Calibration is finished when the message "Cal complete. ENT to manual cal menu." appears. Press the ENTER key to return to the calibration parameter selection screen.**

Conductivity (COND) calibration

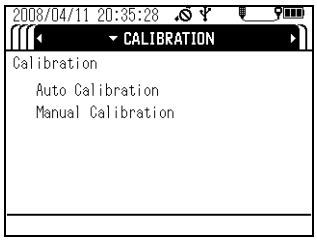
Note

- **To support a wide range of sample concentrations, electrical conductivity is divided into three measurement ranges: 0.0 mS/m to 99.9 mS/m, 0.090 S/m to 0.999 S/m, and 0.9 S/m to 9.99 S/m.**
- **When manually calibrating conductivity, you can select two calibration points (one zero-point calibration point and a span calibration point for one of the three measurement ranges) or four calibration points (one zero-point calibration point and span calibration points for all three measurement ranges). Carry out the four calibration points to ensure good measurement precision throughout all measurement ranges.**
- **Make the compensation setting before calibration since this setting is applied during calibration. (Refer to " 6.5.3 Temperature coefficient " (page 104)).**

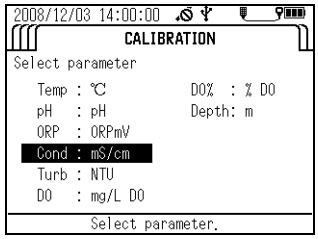
1. **Prepare the standard solution. Dry Potassium chloride (KCl) powder (high-grade commercially available) at 105°C for two hours, and leave it to cool in a desiccator.**
2. **Consult the following table and weigh potassium chloride (KCl), then prepare three standard potassium chloride (KCl) solutions following the procedure below.**

Potassium chloride (KCl) standard solution	Conductivity (COND) value	Potassium chloride (KCl) mass (g) at solution temperature of 25 °C	Calibration range
0.005 mol/L	71.8 mS/m (0.718 mS/cm)	0.373	0.0 mS/m to 99.9 mS/m (0.00 mS/cm to 0.999 mS/cm)
0.050 mol/L	0.667 S/m (6.67 mS/cm)	3.73	0.090 S/m to 0.999 S/m (1.00 mS/cm to 9.99 mS/cm)
0.500 mol/L	5.87 S/m (58.7 mS/cm)	37.2	0.9 S/m to 9.99 S/m (10.0 mS/cm to 99.9 mS/cm)

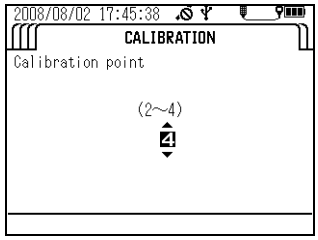
3. **Dissolve the weighed Potassium Chloride (KCl) in deionized water.**
4. **Put the dissolved Potassium Chloride (KCl) into a 1 L measuring flask, and fill to the 1 L mark with deionized water.**
5. **Calibrate the zero point. Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then remove all moisture from the sensor probe (it will be calibrated in air).**
6. **Press the control unit's CAL key to set the calibration mode.**
7. **Press the down (▽) key to move the cursor to "Manual Calibration", then press the ENTER key.**



8. **In the parameter selection screen, move the cursor to “Cond”, then press the ENTER key.**



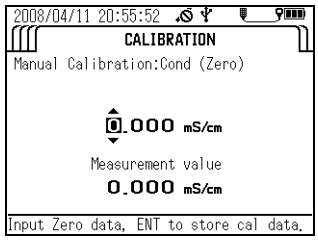
9. **Set the number of calibration points, then press the ENTER key.**



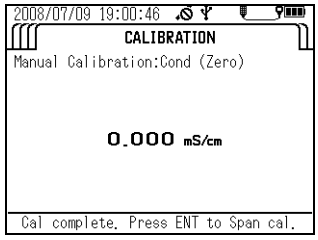
The instructions below assume that four calibration points have been set.

10. **Press the up (△) and down (▽) keys to set the "Cond" value to 0.0 mS/m (0.000 mS/cm).**

11. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**



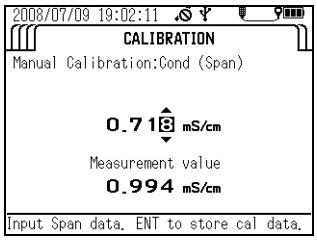
12. **When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the first span calibration procedure.**



13. **Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with 71.8 mS/m (0.718 mS/cm) standard solution.**

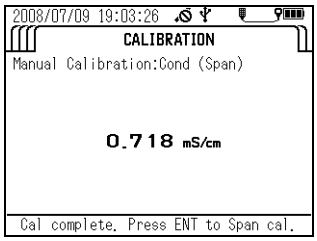
14. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**

15. **Press the up (△) and down (▽) keys to set the "Cond" value to 71.8 mS/m (0.718 mS/cm).**
Calibration range = 0 mS/m to 99.9 mS/m (0 mS/cm to 0.999 mS/cm)



16. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**

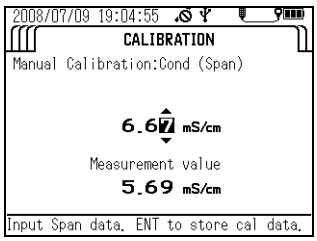
17. **When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the next span calibration procedure.**



18. **Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with 0.667 S/m (6.67 mS/cm) standard solution.**

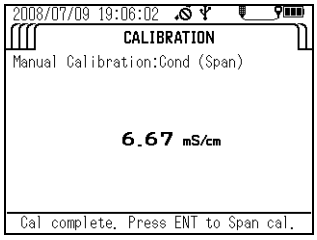
19. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**

20. **Press the up (△) and down (▽) keys to set the "Cond" value to 0.667 S/m (6.67 mS/cm).**
Calibration range = 0.100 S/m to 0.999 S/m (1.00 mS/cm to 9.99 mS/cm)



21. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**

22. **When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the next span calibration procedure.**

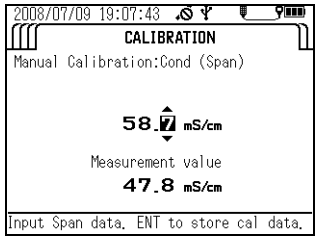


23. **Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with 5.87 S/m (58.7 mS/cm) standard solution.**

24. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**

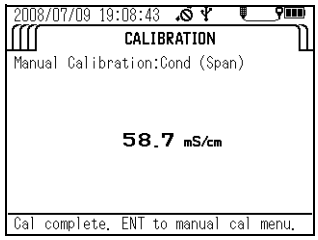
25. **Press the up (△) and down (▽) keys to set the "Cond" value to 5.87 S/m (58.7 mS/cm).**

Calibration range = 1.00 S/m to 10.00 S/m(10.0 mS/cm to 100.0 mS/cm)



26. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**

27. **Calibration is finished when the message "Cal complete. ENT to manual cal menu." appears. Press the ENTER key to return to the calibration parameter selection screen.**



Turbidity (TURB) calibration

Note

- **To support a wide range of sample concentrations, turbidity is divided into three measurement ranges: 0.0 to 9.9 NTU, 10 to 100 NTU, and over 100 NTU.**
- **When manually calibrating turbidity, you can select two calibration procedures (one zero-point calibration procedure and a span calibration procedure for one of the three measurement ranges), three calibration procedures (one zero-point calibration procedure and a span calibration procedure for two of the three measurement ranges) or four calibration procedures (one zero-point calibration procedure and span calibration procedures for all three measurement ranges). Carry out the four calibration procedures to ensure good measurement precision throughout all measurement ranges.**
- **Always use the calibration cup provided. Using other containers can create effects from ambient light that cause incorrect calibration.**

Preparing the standard solutions

1. **Weigh out 5.0 g of hydrazine sulfate (commercial special grade or above), and dissolve it in 400 mL of deionized water. Dissolve 50 g of hexamethylene tetramine (commercial special grade or above) in 400 mL of deionized water in anther flask.**
2. **Mix the two solutions and add deionized water until the total solution volume is 1000 mL, and mix well. Store this solution at a temperature of 25°C ±3°C for 48 hours.**
   The turbidity value (TURB) of this solution is equivalent to 4000 NTU.
3. **Dilute 4000 NTU-solution 5 times (use a pipette to measure 50 mL of the 4000 NTU solution and pour it into a 250 mL measuring flask, and fill up to 250 mL meniscus)**
   The turbidity value (TURB) of this solution is equivalent to 800 NTU.
4. **Dilute 800 NTU solution 10 times (use a pipette to measure 25 mL of the 800 NTU solution and pour it into a 250 mL measuring flask, and fill up to 250 mL meniscus)**
   The turbidity value (TURB) of this solution is equivalent to 80 NTU.
5. **Dilute 80 NTU solution 10 times (use a pipette to measure 25 mL of the 80 NTU solution and pour it into a 250 mL measuring flask, and fill up to 250 mL meniscus)**
   The turbidity value (TURB) of this solution is equivalent to 8 NTU.

Note

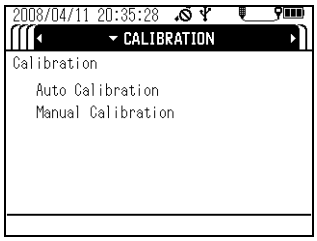
Instead of the standard solutions above, you can use other standard solutions of known concentration measured with other standard instruments.

U-52, U-53 turbidity calibration

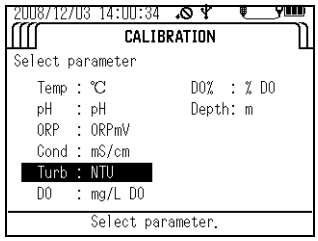
Set the number of calibration points.

You can set between 2 and 4 points.

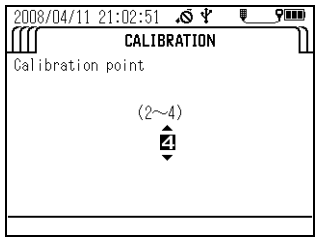
1. **Press the control unit's CAL key to set the calibration mode.**
2. **Press the down (▽) key to move the cursor to "Manual Calibration", then press the ENTER key.**



3. **In the parameter selection screen, move the cursor to "Turb", then press the ENTER key.**



4. **Press the up (△) and down (▽) keys to set the number of calibration points, then press the ENTER key.**

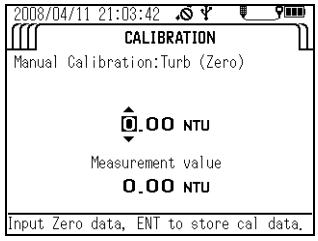


The instructions below assume that four calibration points have been set.

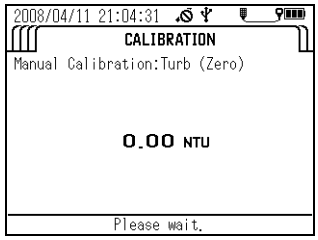
5. **Calibrate the zero point. Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with deionized water.**

6. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**

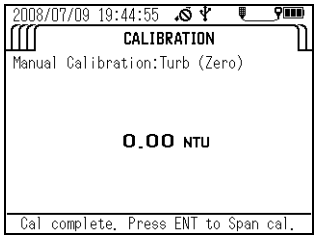
7. **Press the up (△) and down (▽) keys to set the "Turb" value to 0.0 NTU.**



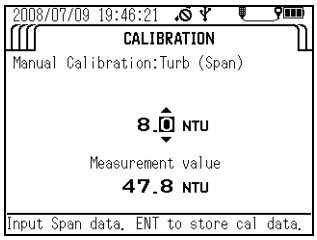
8. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**



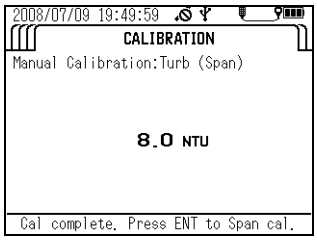
9. **When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the first span calibration procedure.**



10. **Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with 8 NTU standard solution, or a standard solution of known concentration between 0.1 and 10 NTU.**
11. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**
12. **Press the up (△) and down (▽) keys to set the "TURB" value to 8 NTU, or to the known concentration of the standard solution between 0.1 and 10 NTU. (Input range = 0 NTU to 9.9 NTU (U-51) or 0 NTU to 9.99 NTU (U-52))**

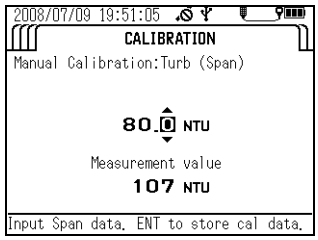


13. **Check that "Current measurement value" has stabilized, then press the ENTER key to start calibration.**
14. **When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the next span calibration procedure.**



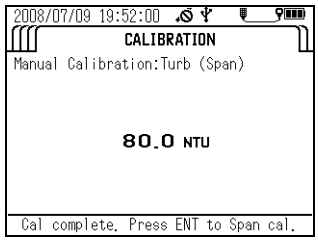
15. **Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with 80 NTU standard solution, or a standard solution of known concentration between 10 and 100 NTU.**
16. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**

17. **Press the up (△) and down (▽) keys to set the "Turb" value to 80 NTU, or to the known concentration of the standard solution between 10 and 100 NTU. (Input range = 10.0 NTU to 99.9 NTU)**



18. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**

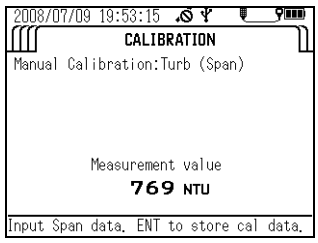
19. **When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the next span calibration procedure.**



20. **Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with 800 NTU standard solution, or a standard solution of known concentration 100 NTU above.**

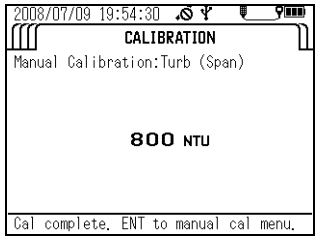
21. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**

22. **Press the up (△) and down (▽) keys to set the "TURB" value to 800 NTU, or to the known concentration of the standard solution 100 NTU above.**
(Input range = 100 NTU to 800 NTU (U-51), 100 NTU to 1000 NTU (U-52))



23. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**

24. **Calibration is finished when the message "Cal complete. ENT to manual cal menu." appears. Press the ENTER key to return to the calibration parameter selection screen.**

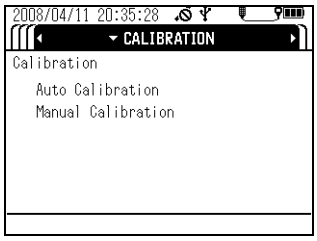


Dissolved oxygen (DO) calibration

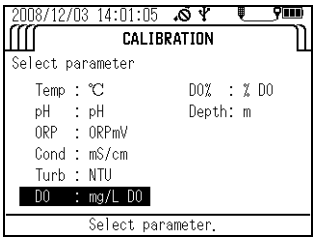
Note

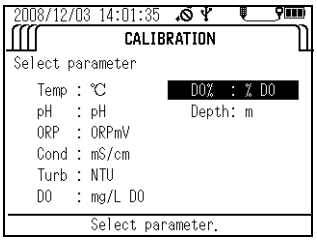
- **You can select one calibration procedure (span calibration) or two calibration procedures (zero-point calibration and span calibration). Carry out the two calibration procedures to ensure good measurement precision throughout all measurement ranges.**
- **It is necessary to prepare new solution before calibration of the Dissolved Oxygen (DO) sensor.**
- **The calibration cup (included) cannot be used to manually calibrate the DO sensor. Use a suitable bottle in which the DO sensor and the temperature sensor can be immersed.**
- **Wait at least 20 minutes after turning the system power ON before calibrating the DO sensor.**
- **Make the compensation setting before calibration since the setting is applied during calibration.**
- **The DO sensor is affected by flow. When performing span calibration with saturated dissolved oxygen water, move the cable slowly up and down (move the sensor probe at a rate of roughly 20 to 30 cm a second) or agitate the saturated dissolved oxygen water.**

1. **Prepare the standard solution.**
   - Add about 50 g of sodium sulfite to 1000 mL of water (either deionized water or tap water) and stir the mixture to dissolve the sodium sulfite in it.
   - Pour 1 to 2 liters of water into a suitable flask (either deionized water or tap water). Using a air pump, feed air into the water and aerate the solution until oxygen is saturated.
2. **First, calibrate the zero point. Press the control unit's CAL key to set the calibration mode.**
3. **Press the down (▽) key to move the cursor to "Manual Calibration", then press the ENTER key.**

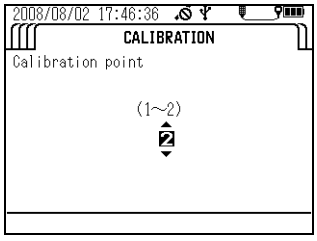


4. **In the parameter selection screen, move the cursor to DO or DO%, then press the ENTER key.**



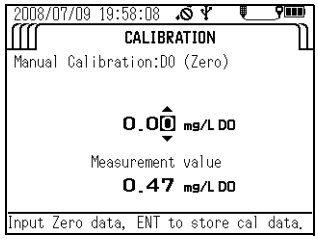


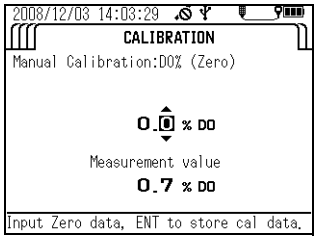
5. **Set the number of calibration procedures, then press the ENTER key.**



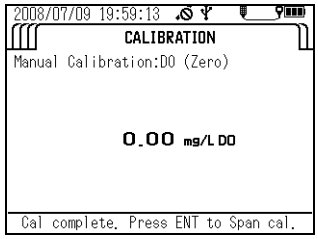
The instructions below assume that two calibration points have been set.

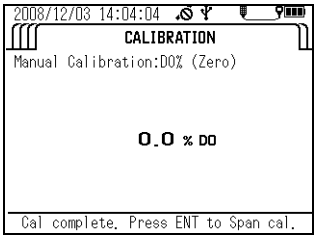
6. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the bottle.**
7. **Press the up (△) and down (▽) keys to set the DO value to 0.00 mg/L or 0.0%.**



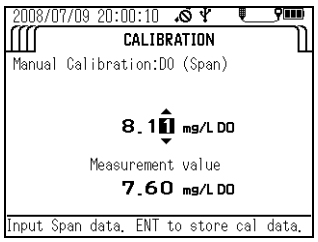


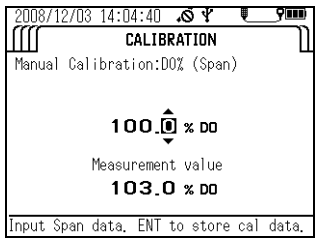
8. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**
9. **When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the span calibration procedure.**



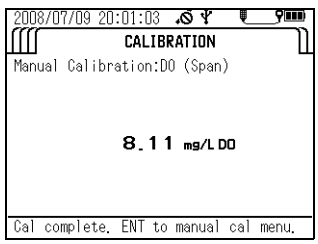


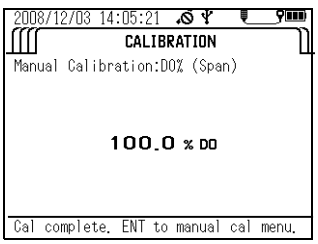
10. **Wash the sensor probe 2 or 3 times with deionized water to remove any dirt, then submerge the sensor probe in the container filled with the span solution.**
11. **Press the up (△) and down (▽) keys to set the DO value to the saturated dissolved oxygen value (mg/L) of the water at that temperature or the dissolved oxygen saturation ratio.**





12. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**
13. **Calibration is finished when the message "Cal complete. ENT to manual cal menu." appears. Press the ENTER key to return to the calibration parameter selection screen.**





Amounts of saturated dissolved oxygen in water at various temperatures (salinity=0.0%)

JIS K0101

Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)
0	14.16						
1	13.77	11	10.67	21	8.68	31	7.42
2	13.40	12	10.43	22	8.53	32	7.32
3	13.04	13	10.20	23	8.39	33	7.22
4	12.70	14	9.97	24	8.25	34	7.13
5	12.37	15	9.76	25	8.11	35	7.04
6	12.06	16	9.56	26	7.99	36	6.94
7	11.75	17	9.37	27	7.87	37	6.86
8	11.47	18	9.18	28	7.75	38	6.76
9	11.19	19	9.01	29	7.64	39	6.68
10	10.92	20	8.84	30	7.53	40	6.59

ISO5814

Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)
0	14.62				
1	14.22	11	11.03	21	8.91
2	13.83	12	10.78	22	8.74
3	13.46	13	10.54	23	8.58
4	13.11	14	10.31	24	8.42
5	12.77	15	10.08	25	8.26
6	12.45	16	9.87	26	8.11
7	12.14	17	9.66	27	7.97
8	11.84	18	9.47	28	7.83
9	11.56	19	9.28	29	7.69
10	11.29	20	9.09	30	7.56

● **Span setting values for calibration in air**

The software should display these values when auto calibration is performed.
Use this table to input values for manual span calibrations in air.

Tip

The DO measurement value of "air-saturated water" and air are different.
Due to the pressure difference against the membrane in air versus the membrane in water, the measurement value in air is about 10% higher than the value of air-saturated water on average.

Amounts of saturated dissolved oxygen in air at various temperatures

Following tables are applicable only to the air calibration of the U-50 DO sensor. Do not use them for other purpose.

Air calibration value in adopting evaluation based on JIS K0101

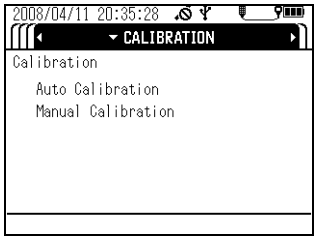
Temp (°C)	DO (mg/L)	Temp (°C)	DO (mg/L)	Temp (°C)	DO (mg/L)	Temp (°C)	DO (mg/L)
0	15.58						
1	15.15	11	11.74	21	9.55	31	8.16
2	14.74	12	11.47	22	9.38	32	8.05
3	14.34	13	11.22	23	9.23	33	7.94
4	13.97	14	10.97	24	9.08	34	7.84
5	13.61	15	10.74	25	8.92	35	7.74
6	13.27	16	10.52	26	8.79	36	7.63
7	12.93	17	10.31	27	8.66	37	7.55
8	12.62	18	10.10	28	8.53	38	7.44
9	12.31	19	9.91	29	8.40	39	7.35
10	12.01	20	9.72	30	8.28	40	7.25

Air calibration value in adopting evaluation based on ISO5814

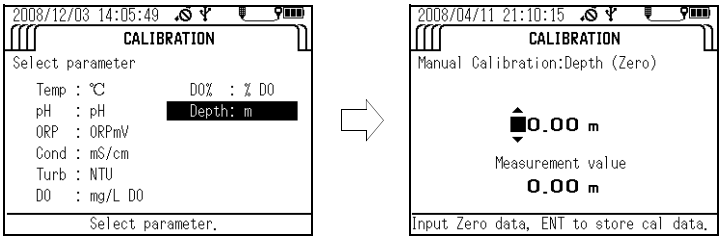
Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)
0	16.08				
1	15.64	11	12.13	21	9.80
2	15.21	12	11.86	22	9.61
3	14.81	13	11.59	23	9.44
4	14.42	14	11.34	24	9.26
5	14.05	15	11.09	25	9.09
6	13.70	16	10.86	26	8.92
7	13.35	17	10.63	27	8.77
8	13.02	18	10.42	28	8.61
9	12.72	19	10.21	29	8.46
10	12.42	20	10.00	30	8.32

Water depth (DEPTH) calibration

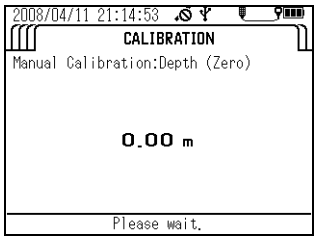
1. **Calibrate the zero point. Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then remove all moisture from the sensor probe (it will be calibrated in air).**
2. **Press the control unit's CAL key to set the calibration mode.**
3. **Press the down (▽) key to move the cursor to "Manual Calibration", then press the ENTER key.**



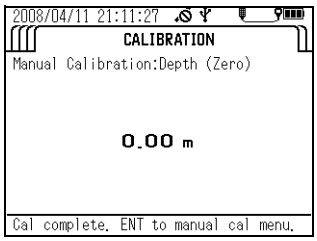
4. **In the parameter selection screen, move the cursor to "Depth", then press the ENTER key.**



5. **Press the up (△) and down (▽) keys to set the "Depth" value to 0.00 m.**
6. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**



7. **Calibration is finished when the message "Cal complete. ENT to manual cal menu." appears. Press the ENTER key to return to the calibration parameter selection screen.**



3.4 Measurement

You can perform measurement by either of the methods below.

- Storing data in memory manually with reference to the measurement value (single measurement)
- Having data stored in memory automatically and continuously
  U-51/U-52: Interval measurement (minimum memory interval of 10 seconds)
  U-53: Interval measurement (minimum memory interval of 30 seconds)

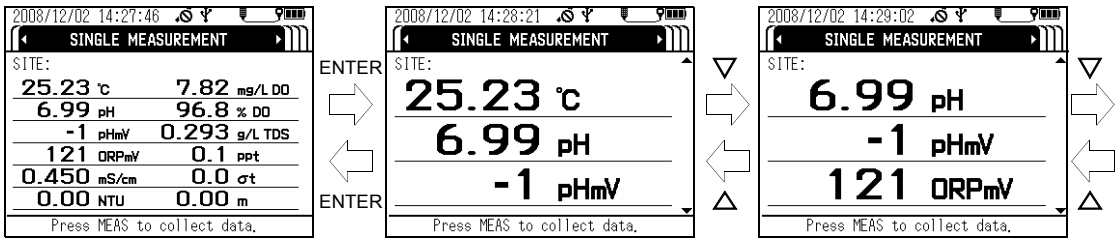
Select the measurement method that meets your requirements.

Note

- **Lower sensor probe slowly when submerging them in samples.**
- **Sensors may break if sensor probe are dropped from a height of 1 meter or more.**
- **Do not submerge sensor probe in water depths of over 30 meters. Sensor probe are only resistant to water pressure of up to 30 meters.**
- **After turning the power ON, check that the DO readout value has stabilized before starting measurement (takes around 20 minutes).**

Tip

- **When on the measurement screen, pressing the ENTER key enlarges the display and shows three measured values at a time.**
- **Pressing the up (△) and down (▽) keys scrolls through the measured values one item at a time.**
- **Pressing the ENTER key again reverts to the normal measurement screen display.**



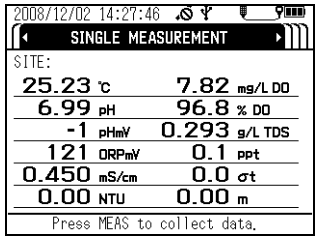
Measurement screen Normal Enlarged

3.4.1 Storing data in memory manually

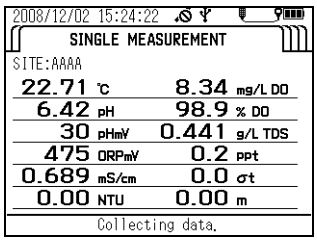
Follow the steps below to manually store data in memory while referring to the measurement value to check the readout value is stable.

● **U-51/U-52**

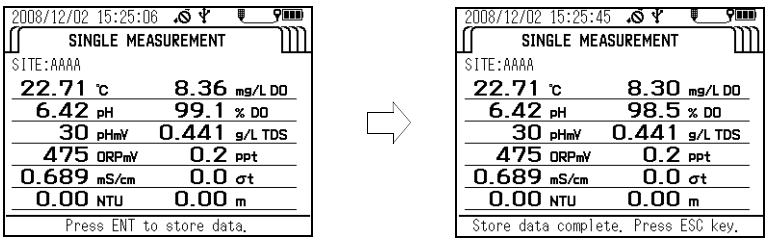
1. **Check that each sensor and sensor guard is mounted.**
2. **Check that "SINGLE MEASUREMENT" has been selected in the measurement screen.**



3. **Submerge the sensor probe in the sample, gently shaking them in the sample to remove any air bubbles from the sensors.**
   If the sample is non-flowing, move the cable slowly up and down (move the sensor probe at a rate of roughly 20 to 30 cm a second) to ensure that fresh sample is continuously supplied to the DO sensor.
4. **When the measurement values are stable, press the MEAS key to acquire the 5-second average.**



5. **Press the ENTER key to save the held measurement values, or press the ESC key to cancel the operation.**

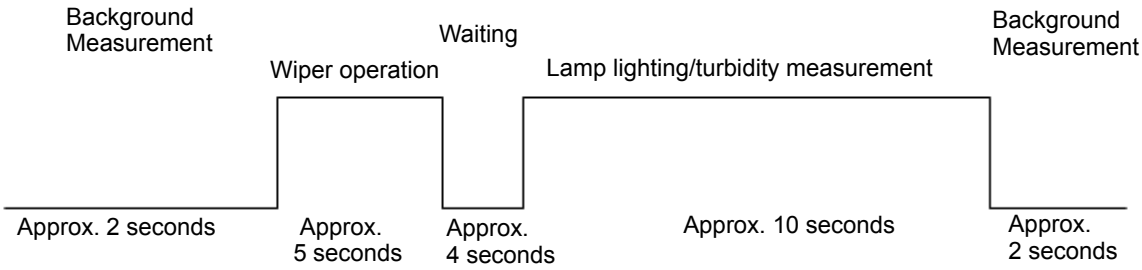


● U-53

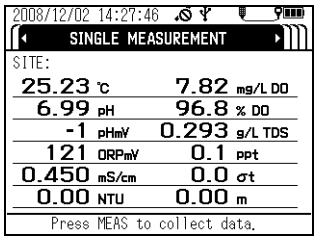
Note

Do not perform turbidity measurement in air as it may damage the wiper.

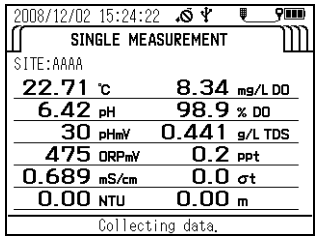
U-53 turbidity measurement follows the sequence below. The measurement values are held after each sequence.



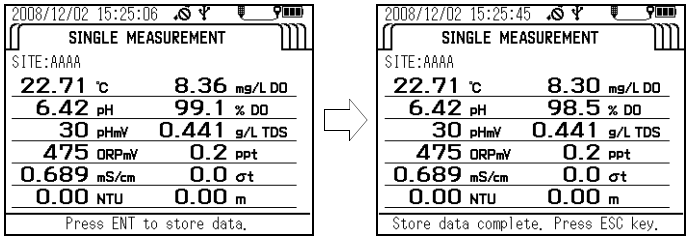
1. **Check that each sensor and sensor guard is mounted.**
2. **Check that "SINGLE MEASUREMENT" has been selected in the measurement screen.**



3. **Submerge the sensor probe in the sample, gently shaking them in the sample to remove any air bubbles from the sensors.**
   If the sample is non-flowing, move the cable slowly up and down (move the sensor probe at a rate of roughly 20 to 30 cm a second) to ensure that fresh sample is continuously supplied to the DO sensor.
4. **When the non-turbidity meter measurement values are stable, press the MEAS key to start the sequence above.**



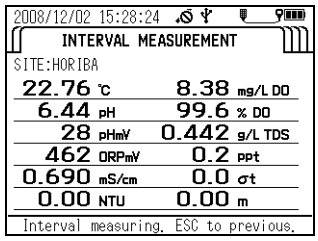
5. **When the sequence has finished, hold the measurement values. Press the ENTER key to store the held measurement values, or press the ESC key to cancel the operation.**



3.4.2 Automatic, continuous measurement

● **Interval measurement**

1. **Select the "Interval measurement" measurement setting (see “ 3.2.1 Setting measurement methods ” (page 18)).**
2. **Press the up (△) and down (▽) keys to set the interval value to the desired value (U-51/U-52: minimum interval: 10 seconds, U-53: minimum interval: 30 seconds), then press the ENTER key.**
   The measurement screen appears automatically, and the system becomes ready for measurement.
3. **Check that each sensor and sensor guard is mounted.**
4. **Submerge the sensor probe in the sample, gently shaking them in the sample to remove any air bubbles from the sensors.**
   If the sample is non-flowing, move the cable slowly up and down (move the sensor probe at a rate of roughly 20 to 30 cm a second) to ensure that fresh sample is continuously supplied to the DO sensor.
5. **Press the ENTER key to start measurement.**



3.5 Data operations

Use the procedures below to retrieve data stored in memory, delete all the data, check the remaining data memory capacity, and check the calibration record.

3.5.1 Displaying data

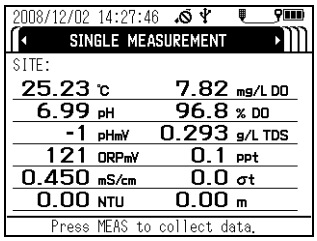
For maximum efficiency, there are 3 methods of displaying data.

- Displaying the data for a specified site
- Displaying the data for a specified date/time
- Displaying all the data

Use the method that best suits your requirements.

● **Displaying the data for a specified site**

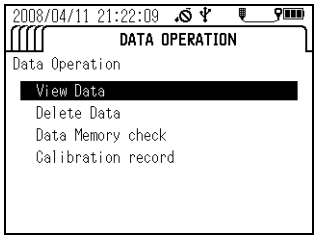
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



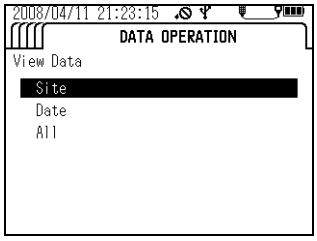
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key 3 times to display the "DATA OPERATION" screen.**
3. **Press the down (▽) key to move the cursor to "View Data", then press the ENTER key.**

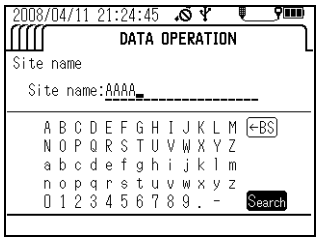


4. **Move the cursor to "Site", then press the ENTER key.**



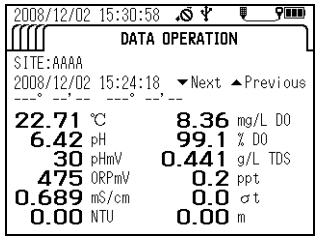
5. **Press the up (△), down (▽), left (◁) and right (▷) keys to enter the site to retrieve.**

6. **Move the cursor to "Search", then press the ENTER key.**



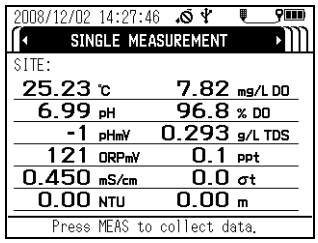
All site names that begin with the entered text are displayed.
The most recently measured data for the entered site is displayed.

7. **Press the up (△) and down (▽) keys to display earlier data.**



● Displaying the data for a specified date/time

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
The "MEASUREMENT" screen appears after about 10 seconds.

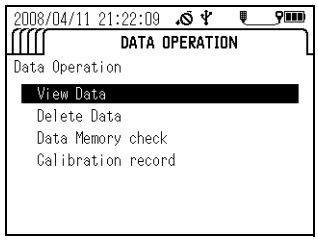


Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

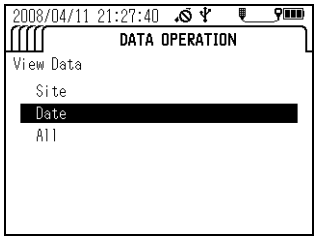
2. **Press the right (▷) key 3 times to display the "DATA OPERATION" screen.**

3. **Press the down (▽) key to move the cursor to "View Data", then press the ENTER key.**



4. **Move the cursor to "Date", then press the ENTER key.**

5. **With the cursor on the Date, press the ENTER key.**



6. **Press the up (△), down (▽), left (◁) and right (▷) keys to enter the desired date/ time, then press the ENTER key to apply the setting.**

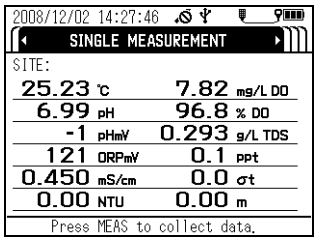
7. **The cursor moves to "Search". Press the ENTER key to start the search.**

8. **Press the up (△) and down (▽) keys to display earlier data.**

● Displaying all the data

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**

The "MEASUREMENT" screen appears after about 10 seconds.

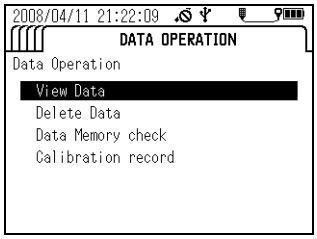


Note

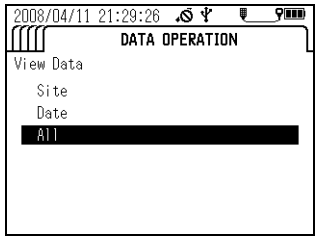
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key 3 times to display the "DATA OPERATION" screen.**

3. **Press the down (▽) key to move the cursor to "View Data", then press the ENTER key.**



4. **Move the cursor to "All", then press the ENTER key.**
The most recently measured data is displayed.

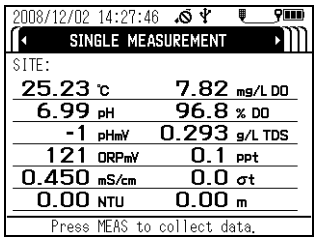


5. **Press the up (△) and down (▽) keys to display earlier data.**

3.5.2 Deleting data

Follow the steps below to delete all the data stored in memory.

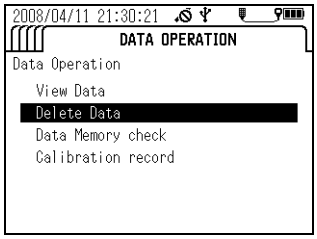
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



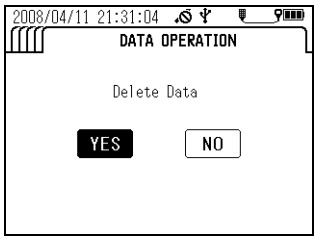
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key 3 times to display the "DATA OPERATION" screen.**
3. **Press the down (▽) key to move the cursor to "Delete Data", then press the ENTER key.**



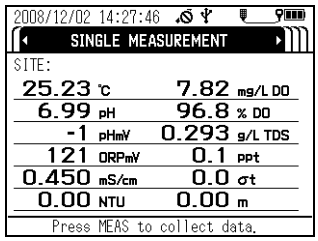
4. **Press the left (◁) key to move the cursor to YES, then press the ENTER key.**
   All the data has been deleted when the indicator appears along with the message "No data exists".



3.5.3 Checking the data memory

You can check the used data capacity and the remaining data capacity.

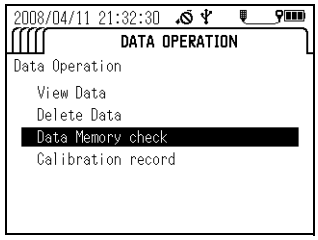
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



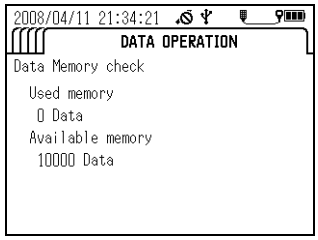
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key 3 times to display the "DATA OPERATION" screen.**
3. **Press the down (▽) key to move the cursor to "Data Memory Check", then press the ENTER key.**



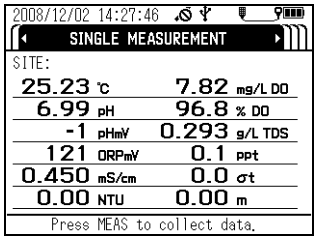
The amount of memory in use and amount of available memory are displayed.



3.5.4 Checking the calibration record

Follow the steps below to check the latest calibration history.

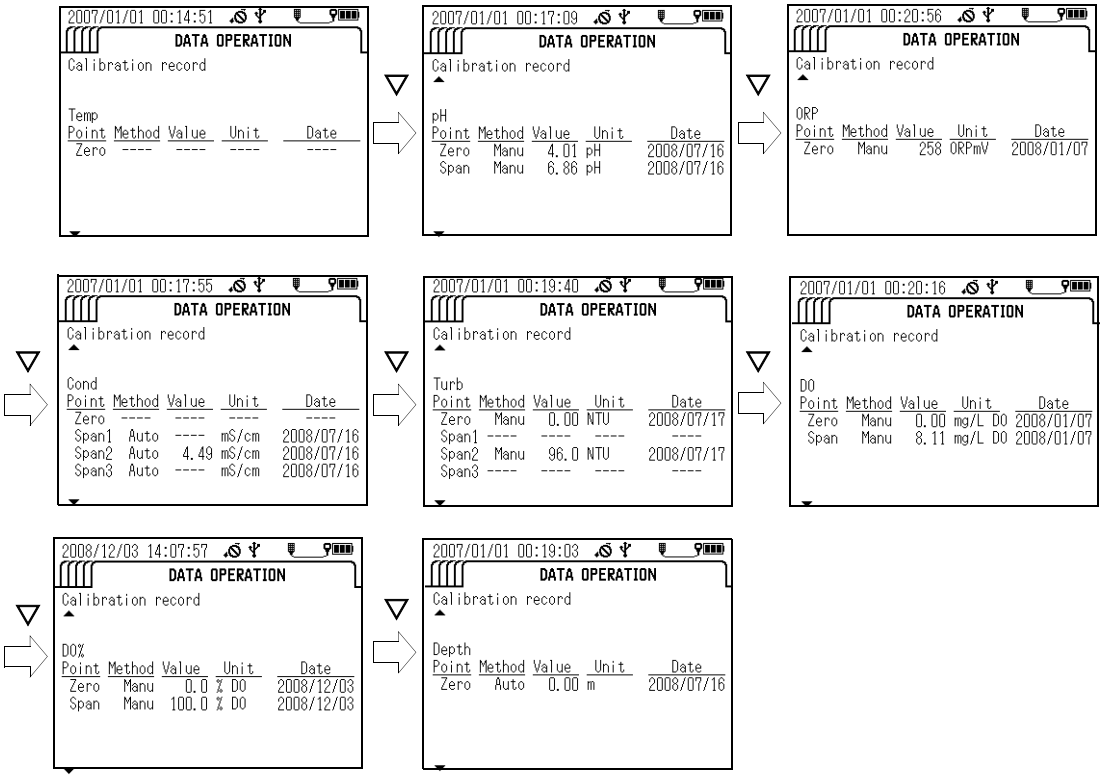
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key 3 times to display the "DATA OPERATION" screen.**
3. **Press the down (▽) key to move the cursor to "Calibration record", then press the ENTER key.**
   The latest calibration record is displayed.



3.5.5 GPS data operations

The menu for GPS data operations appears on the display to which the GPS unit is mounted.

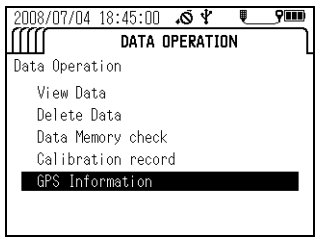
● GPS information

Follow the steps below to display acquired GPS information.

Note

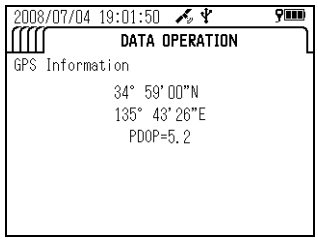
Turning the power OFF erases the GPS information.

1. **Press the right (▷) key to switch the display to the "DATA OPERATION" screen.**
2. **the down (▽) key to move the cursor to "GPS Information", then press the ENTER key.**

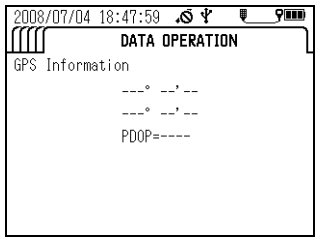


The last GPS information acquired is displayed.

● When received data exists

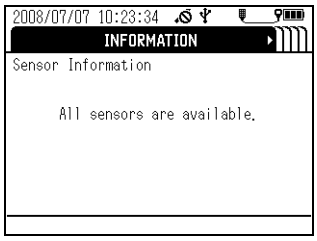


● When no received data exists

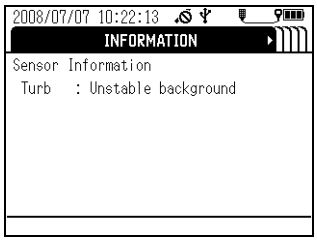


3.6 Sensor information

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.
2. **Press the left (◁) key once to display the "INFORMATION" screen.**
   The "Sensor Information" screen displays the sensor probe's status.
   - When the sensor probe is normal, the display below appears.



   - When there is a sensor probe problem, individual measurement parameters generate messages such as the one shown below. Follow the troubleshooting information to remove the problem before continuing to operate the system.

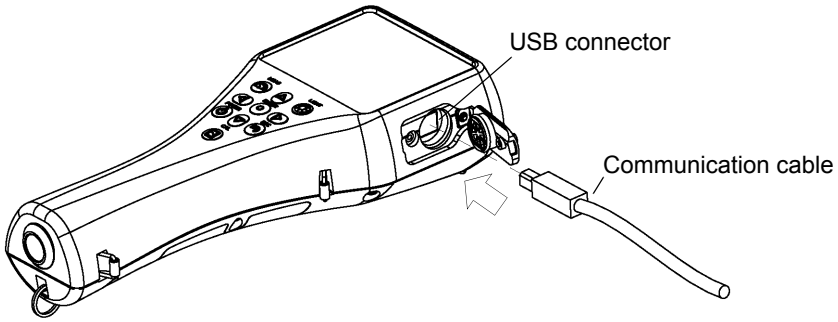


3.7 USB communication

The separately-sold, dedicated PC connection cable comes with data collection software. This software allows data to be downloaded from the control unit in CSV format.

This section contains instructions for communication commands used for USB communication.

● Connecting the cable



Dedicated cable

Part name: Communication cable (with data collection software)

Part no.: 3200174823

● Cautions when using USB communication

Take care to observe the following when using USB communication.

- Use the dedicated cable (with data collection software) or a commercially-available USB cable (A-B type) to connect to a PC.
- Be sure to match the transmission format on the control unit and the computer.
  The control unit uses the following transmission format:

Baud rate:	19200 bps
Number of stop bits:	1 bit
Data bit length:	8 bits
Parity:	None
Flow control:	None

Tip

If the transmission formats do not match, a communication error occurs and USB communication will not function normally. After changing the transmission format, restart the control unit and the computer.

- If received data is not sent back or an error occurs after a data request has been sent, adjust the program configuration so that it allows a little waiting time before a data request is sent again. This will enable more stable communication.
- The unit does not use DCD, CTS, or DSR signals. Take care of this when creating programs.

3.7.1 Communication settings

Baud rate:	19200 bps
Number of stop bits:	1 bit
Data bit length:	8 bits
Parity:	None
Flow control:	None

3.7.2 Commands

● Instant data requests

● Request command format

#	RD	@	XX	[CR]	[LF]
1	2	3	4		

1	Header	1 character
2	Command	2 characters
3	Delimiter character	1 character
4	Frame check sequence (FCS)	2 characters

The two ASCII-code characters created by converting the 8 bits of data created by successively combining the value of each character from # through @ in an exclusive OR (XOR) operation with the value of the next character.

Example: #RD@

(1)	0	XOR	35	(ASCII code of # symbol)	⇒	35
(2)	35	XOR	82	(ASCII code of R)	⇒	113
(3)	113	XOR	68	(ASCII code of D)	⇒	53
(4)	53	XOR	64	(ASCII code of @ symbol)	⇒	117 (decimal)
						↓
						75 (hex)
						↓
						Sets "75".

Example: 35 XOR 82 operation

35 in binary	⇒	0	0	1	0	0	0	1	1	
82 in binary	⇒	0	1	0	1	0	0	1	0	
XOR result		0	1	1	1	0	0	0	1	⇒ 113 (decimal)

Note: Set "XX" if you do not want to test for communication frame errors with FCS.

● Response format

#	RD	AAAAAAAAAAAAAAAAAAAA	X	X	XXXX	XX	X	X	XXXXX	X
1	2	3	4	5	6	7	8	9	10	11

XX	X	X	XXXXX	X	XX	X	X	XXXXX	X	XX	X	X	XXXXX	X
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

XX	X	X	XXXXX	X	XX	X	X	XXXXX	X	XX	X	X	XXXXX	X
27	28	29	30	31	32	33	34	35	36	37	38	39	40	41

XX	X	X	XXXXX	X	XX	X	X	XXXXX	X	XX	X	X	XXXXX	X
42	43	44	45	46	47	48	49	50	51	52	53	54	55	56

```
XX   X   X   XXXXX  X   XX   X   X   XXXXX  X   XX   X   X   XXXXX  X
57   58  59  60       61  62   63  64  65       66  67   68  69  70       71

XX  XX  XX  XX  XX  XX  XX  XX  XX  X   X   XXX  XX  XX  X   X   @   XX  [CR]  [LF]
72  73  74  75  76  77  78  79  80  81  82  83   84  85  86  87  88  89
```

1	Header		1 character
2	Command		2 characters
3	Site name	Upper- and lowercase letters, numbers, periods (.) hyphens (-) and spaces ( )	20 characters
4	Probe status	(3) Status code	1 character
5	Probe error	(4) Status error code	1 character
6	Unused		4 characters
7	Parameter 1 code	(1) Parameter code	2 characters
8	Parameter 1 status	(5) Parameter status code	1 character
9	Parameter 1 error	(6) Parameter error code	1 character
10	Parameter 1 data	5 characters including decimal point, right-justified with blanks filled	5 characters
11	Parameter 1 unit	(2) Unit code	1 character
12	Parameter 2 code	(1) Parameter code	2 characters
13	Parameter 2 status	(5) Parameter status code	1 character
14	Parameter 2 error	(6) Parameter error code	1 character
15	Parameter 2 data	5 characters including decimal point, right-justified with blanks filled	5 characters
16	Parameter 2 unit	(2) Unit code	1 character
17	Parameter 3 code	(1) Parameter code	2 characters
18	Parameter 3 status	(5) Parameter status code	1 character
19	Parameter 3 error	(6) Parameter error code	1 character
20	Parameter 3 data	5 characters including decimal point, right-justified with blanks filled	5 characters
21	Parameter 3 unit	(2) Unit code	1 character
22	Parameter 4 code	(1) Parameter code	2 characters
23	Parameter 4 status	(5) Parameter status code	1 character
24	Parameter 4 error	(6) Parameter error code	1 character
25	Parameter 4 data	5 characters including decimal point, right-justified with blanks filled	5 characters
26	Parameter 4 unit	(2) Unit code	1 character
27	Parameter 5 code	(1) Parameter code	2 characters
28	Parameter 5 status	(5) Parameter status code	1 character
29	Parameter 5 error	(6) Parameter error code	1 character
30	Parameter 5 data	5 characters including decimal point, right-justified with blanks filled	5 characters
31	Parameter 5 unit	(2) Unit code	1 character
32	Parameter 6 code	(1) Parameter code	2 characters
33	Parameter 6 status	(5) Parameter status code	1 character
34	Parameter 6 error	(6) Parameter error code	1 character

35	Parameter 6 data	5 characters including decimal point, right-justified with blanks filled	5 characters
36	Parameter 6 unit	(2) Unit code	1 character
37	Parameter 7 code	(1) Parameter code	2 characters
38	Parameter 7 status	(5) Parameter status code	1 character
39	Parameter 7 error	(6) Parameter error code	1 character
40	Parameter 7 data	5 characters including decimal point, right-justified with blanks filled	5 characters
41	Parameter 7 unit	(2) Unit code	1 character
42	Parameter 8 code	(1) Parameter code	2 characters
43	Parameter 8 status	(5) Parameter status code	1 character
44	Parameter 8 error	(6) Parameter error code	1 character
45	Parameter 8 data	5 characters including decimal point, right-justified with blanks filled	5 characters
46	Parameter 8 unit	(2) Unit code	1 character
47	Parameter 9 code	(1) Parameter code	2 characters
48	Parameter 9 status	(5) Parameter status code	1 character
49	Parameter 9 error	(6) Parameter error code	1 character
50	Parameter 9 data	5 characters including decimal point, right-justified with blanks filled	5 characters
51	Parameter 9 unit	(2) Unit code	1 character
52	Parameter 10 code	(1) Parameter code	2 characters
53	Parameter 10 status	(5) Parameter status code	1 character
54	Parameter 10 error	(6) Parameter error code	1 character
55	Parameter 10 data	5 characters including decimal point, right-justified with blanks filled	5 characters
56	Parameter 10 unit	(2) Unit code	1 character
57	Parameter 11 code	(1) Parameter code	2 characters
58	Parameter 11 status	(5) Parameter status code	1 character
59	Parameter 11 error	(6) Parameter error code	1 character
60	Parameter 11 data	5 characters including decimal point, right-justified with blanks filled	5 characters
61	Parameter 11 unit	(2) Unit code	1 character
62	Parameter 12 code	(1) Parameter code	2 characters
63	Parameter 12 status	(5) Parameter status code	1 character
64	Parameter 12 error	(6) Parameter error code	1 character
65	Parameter 12 data	5 characters including decimal point, right-justified with blanks filled	5 characters
66	Parameter 12 unit	(2) Unit code (6) Parameter error code	1 character
67	Parameter 13 code	(1) Parameter code	2 characters
68	Parameter 13 status	(5) Parameter status code	1 character
69	Parameter 13 error	(6) Parameter error code	1 character
70	Parameter 13 data	5 characters including decimal point, right-justified with blanks filled	5 characters
71	Parameter 13 unit	(2) Unit code	1 character
72	Year	00 to 99	2 characters

73	Month	01 to 12	2 characters
74	Day	01 to 31	2 characters
75	Hour	00 to 23	2 characters
76	Minute	00 to 59	2 characters
77	Second	00 to 59	2 characters
78	Longitude (degrees)	00 to 90 or "--" (no GPS data)	2 characters
79	Longitude (minutes)	00 to 59 or "--" (no GPS data)	2 characters
80	Longitude (seconds)	00 to 59 or "--" (no GPS data)	2 characters
81	Unused	1 character	1 character
82	North latitude/South latitude	N: North; S: South	1 character
83	Latitude (degrees)	000 to 180 or "---" (no GPS data)	3 characters
84	Latitude (minutes)	00 to 59 or "--" (no GPS data)	2 characters
85	Latitude (seconds)	00 to 59 or "--" (no GPS data)	2 characters
86	Unused		1 character
87	East longitude/West longitude	E: East; W: West	1 character
88	Delimiter character		1 character
89	Frame check sequence (FCS)		2 characters

● Memory data requests

● Request command format

#	RM	X	X	AAAAAAAAAAAAAAAAAAAA	XX	XX	XX	@	XX	[CR]	[LF]
1	2	3	4	5	6	7	8	9	10		

1	Header		1 character
2	Command		2 characters
3	Data specification*1	0: Start search; 1: Next data item; 2: Previous data item; 3: Request same data again	1 character
4	Search method specification	0: All data; 1: Site search; 2: Date search	1 character
5	Search site*2	Upper- and lowercase letters, numbers, periods (.) hyphens (-) and spaces ( )	20 characters
6	Search year*3	00 to 99	2 characters
7	Search month*3	01 to 12	2 characters
8	Search day*3	01 to 31	2 characters
9	Delimiter character		1 character
10	Frame check sequence (FCS)		2 characters

*1: When sending the RM command, first send 0 [Start search], then 1 [Next data item], 2 [Previous data item] or 3 [Request same data again].

*2: [Search site] is only needed when [Site search] is specified as the search method. If another search method is specified, fill this field with spaces.

*3: [Search year], [Search month] and [Search day] are only needed when [Date search] is specified as the search method. If another search method is specified, fill this field with spaces.

● **Response format**

(when data exists)

```
#   RM  AAAAAAAAAAAAAAAAAAAA   XX  X   X   XXXXX  X
1   2   3                      4   5   6   7      8

XX  X   X   XXXXX  X   XX  X   X   XXXXX  X   XX  X   X   XXXXX  X
9   10  11  12     13  14  15  16  17     18  19  20  21  22     23

XX  X   X   XXXXX  X   XX  X   X   XXXXX  X   XX  X   X   XXXXX  X
24  25  26  27     28  29  30  31  32     33  34  35  36  37     38

XX  X   X   XXXXX  X   XX  X   X   XXXXX  X   XX  X   X   XXXXX  X
39  40  41  42     43  44  45  46  47     48  49  50  51  52     53

XX  X   X   XXXXX  X   XX  X   X   XXXXX  X   XX  X   X   XXXXX  X
54  55  56  57     58  59  60  61  62     63  64  65  66  67     68

XX  XX  XX  XX  XX  XX  XX  XX  XX  X   X   XXX  XX  XX  X   X   @   XX  [CR]  [LF]
69  70  71  72  73  74  75  76  77  78  79  80   81  82  83  84  85  86
```

1	Header		1 character
2	Command		2 characters
3	Site name	Upper- and lowercase letters, numbers, periods (.) hyphens (-) and spaces ( )	20 characters
4	Parameter 1 code	(1) Parameter code	2 characters
5	Parameter 1 selection	0: No selection; 1: Selection made	1 character
6	Parameter 1 error	(6) Parameter error code	1 character
7	Parameter 1 data	5 characters including decimal point, right-justified with blanks filled	5 characters
8	Parameter 1 unit	(2) Unit code	1 character
9	Parameter 2 code	(1) Parameter code	2 characters
10	Parameter 2 selection	0: No selection; 1: Selection made	1 character
11	Parameter 2 error	(6) Parameter error code	1 character
12	Parameter 2 data	5 characters including decimal point, right-justified with blanks filled	5 characters
13	Parameter 2 unit	(2) Unit code	1 character
14	Parameter 3 code	(1) Parameter code	2 characters
15	Parameter 3 selection	0: No selection; 1: Selection made	1 character
16	Parameter 3 error	(6) Parameter error code	1 character
17	Parameter 3 data	5 characters including decimal point, right-justified with blanks filled	5 characters
18	Parameter 3 unit	(2) Unit code	1 character
19	Parameter 4 code	(1) Parameter code	2 characters
20	Parameter 4 selection	0: No selection; 1: Selection made	1 character

21	Parameter 4 error	(6) Parameter error code	1 character
22	Parameter 4 data	5 characters including decimal point, right-justified with blanks filled	5 characters
23	Parameter 4 unit	(2) Unit code	1 character
24	Parameter 5 code	(1) Parameter code	2 characters
25	Parameter 5 selection	0: No selection; 1: Selection made	1 character
26	Parameter 5 error	(6) Parameter error code	1 character
27	Parameter 5 data	5 characters including decimal point, right-justified with blanks filled	5 characters
28	Parameter 5 unit	(2) Unit code	1 character
29	Parameter 6 code	(1) Parameter code	2 characters
30	Parameter 6 selection	0: No selection; 1: Selection made	1 character
31	Parameter 6 error	(6) Parameter error code	1 character
32	Parameter 6 data	5 characters including decimal point, right-justified with blanks filled	5 characters
33	Parameter 6 unit	(2) Unit code	1 character
34	Parameter 7 code	(1) Parameter code	2 characters
35	Parameter 7 selection	0: No selection; 1: Selection made	1 character
36	Parameter 7 error	(6) Parameter error code	1 character
37	Parameter 7 data	5 characters including decimal point, right-justified with blanks filled	5 characters
38	Parameter 7 unit	(2) Unit code	1 character
39	Parameter 8 code	(1) Parameter code	2 characters
40	Parameter 8 selection	0: No selection; 1: Selection made	1 character
41	Parameter 8 error	(6) Parameter error code	1 character
42	Parameter 8 data	5 characters including decimal point, right-justified with blanks filled	5 characters
43	Parameter 8 unit	(2) Unit code	1 character
44	Parameter 9 code	(1) Parameter code	2 characters
45	Parameter 9 selection	0: No selection; 1: Selection made	1 character
46	Parameter 9 error	(6) Parameter error code	1 character
47	Parameter 9 data	5 characters including decimal point, right-justified with blanks filled	5 characters
48	Parameter 9 unit	(2) Unit code	1 character
49	Parameter 10 code	(1) Parameter code	2 characters
50	Parameter 10 selection	0: No selection; 1: Selection made	1 character
51	Parameter 10 error	(6) Parameter error code	1 character
52	Parameter 10 data	5 characters including decimal point, right-justified with blanks filled	5 characters
53	Parameter 10 unit	(2) Unit code	1 character
54	Parameter 11 code	(1) Parameter code	2 characters
55	Parameter 11 selection	0: No selection; 1: Selection made	1 character
56	Parameter 11 error	(6) Parameter error code	1 character
57	Parameter 11 data	5 characters including decimal point, right-justified with blanks filled	5 characters
58	Parameter 11 unit	(2) Unit code	1 character
59	Parameter 12 code	(1) Parameter code	2 characters

60	Parameter 12 selection	0: No selection; 1: Selection made	1 character
61	Parameter 12 error	(6) Parameter error code	1 character
62	Parameter 12 data	5 characters including decimal point, right-justified with blanks filled	5 characters
63	Parameter 12 unit	(2) Unit code	1 character
64	Parameter 13 code	(1) Parameter code	2 characters
65	Parameter 13 selection	0: No selection; 1: Selection made	1 character
66	Parameter 13 error	(6) Parameter error code	1 character
67	Parameter 13 data	5 characters including decimal point, right-justified with blanks filled	5 characters
68	Parameter 13 unit	(2) Unit code	1 character
69	Year	00 to 99	2 characters
70	Month	01 to 12	2 characters
71	Day	01 to 31	2 characters
72	Hour	00 to 23	2 characters
73	Minute	00 to 59	2 characters
74	Second	00 to 5	2 characters
75	Longitude (degrees)	00 to 90 or "--" (no GPS data)	2 characters
76	Longitude (minutes)	00 to 59 or "--" (no GPS data)	2 characters
77	Longitude (seconds)	00 to 59 or "--" (no GPS data)	2 characters
78	Unused		1 character
79	North latitude/South latitude	N: North; S: South	1 character
80	Latitude (degrees)	000 to 180 or "---" (no GPS data)	3 characters
81	Latitude (minutes)	00 to 59 or "--" (no GPS data)	2 characters
82	Latitude (seconds)	00 to 59 or "--" (no GPS data)	2 characters
83	Unused		1 character
84	East longitude/West longitude	E: East; W: West	1 character
85	Delimiter character		1 character
86	Frame check sequence (FCS)		2 characters

When no data exists, or memory is at capacity)

#	RM	@	XX	[CR]	[LF]
1	2	3	4		

1	Header	1 character
2	Command	2 characters
3	Delimiter character\	1 character
4	Frame check sequence (FCS)	2 characters

Memory data count request

Request command format

#	RN	@	XX	[CR]	[LF]
1	2	3	4		

1	Header	1 character
2	Command	2 characters
3	Delimiter character\	1 character
4	Frame check sequence (FCS)	2 characters

Response format

#	RN	XXXXX	@	XX	[CR]	[LF]
1	2	3	4	5		

1	Header		1 character
2	Command		2 characters
3	Total data count	0 to 10000	5 characters
4	Delimiter character\		1 character
5	Frame check sequence (FCS)		2 characters

Command parse failure response

#	??	X	XX	X	@	XX	[CR]	[LF]
1	2	3	4	5	6	7		

1	Header	1 character
2	Command	2 characters
3	Command parse failure reason*4	1 character
4	Received command*5	2 characters
5	(3) Status code for probe status*5	1 character
6	Delimiter character	1 character
7	Frame check sequence (FCS)	2 characters

*4: List of command parse failure reasons

1: Frame length error
2: FCS mismatch
3: Undefined command
4: Data error
5: Data out of range
6: No "@" delimiter character
7: No "#" header character
8: No [Carriage return] + [Line feed] footer
9: Cannot accept command in this timing.

*5: Only set for command parse failure reason 9, [Cannot accept command in this timing]. Otherwise this field is filled with spaces.

4 Maintenance

Tip

HORIBA recommends regular manufacturer maintenance checks in order to ensure a long product life.

4.1 Routine care

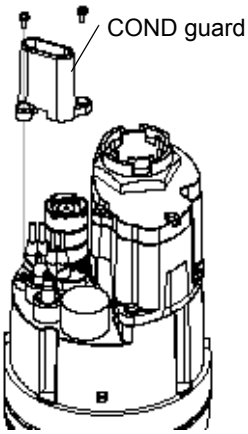
- **After measurement**

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power OFF.**

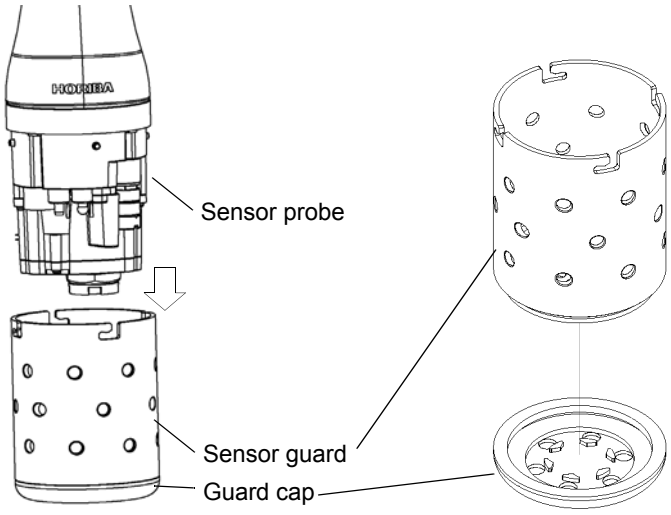
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Remove the sensor guard, and clean the sensor with tap water.**
3. **Clean the turbidity sensor with the cleaning brush provided.**
4. **Remove the two screws securing the COND guard, and the COND guard itself, and use a test tube brush to gently remove any dirt from the electrical conductivity electrode.**



5. **Wipe off any dirt with a soft cloth. If parts are very dirty, clean them with neutral detergent, then rinse them. If parts are contaminated by oil, wipe it off with a soft cloth soaked in alcohol.**
6. **Put the COND guard back in place.**
7. **Remove the sensor guard's guard cap, wash off any dirt with tap water, then put the guard cap back in place.**



4.2 Every 2 months maintenance

● Dissolved oxygen (DO) sensor

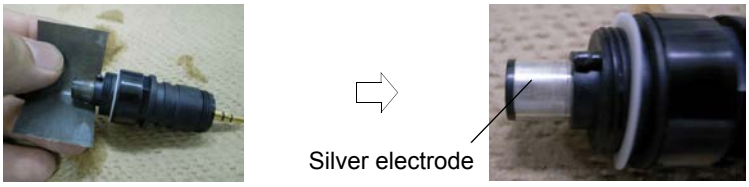
Note

- **The DO sensor's internal solution is potassium chloride (KCl). Although KCl is harmless, protective equipment such as gloves and goggles should be worn when working with it.**
- **Internal solution can be disposed of down a sink.**

- Replace the membrane cap.
- Polish the gold and silver electrodes when replacing the membrane cap.
  The gold electrode does not need to be polished if it is not dirty.

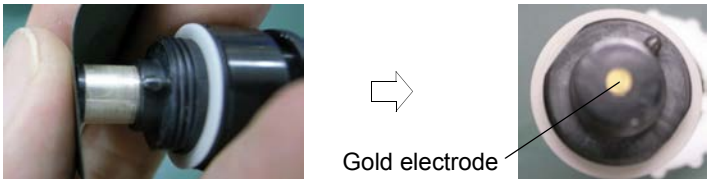
- **Silver electrode**

  Polish a silver electrode part with sandpaper (#500) and then wash metal electrode parts with water.



- **Gold electrode**

  Polish a gold electrode part with sandpaper (#8000) and then wash metal electrode parts with water.



Replace a membrane cap after clean metal electrodes parts.
Refer to “ 4.5 Replacing the membrane cap ” (page 87).

- **Reference electrode**

Note

- **The pH reference internal solution is potassium chloride (KCl). Although KCl is harmless, protective equipment such as gloves and goggles should be worn when working with it.**
- **Internal solution can be disposed of down a sink.**

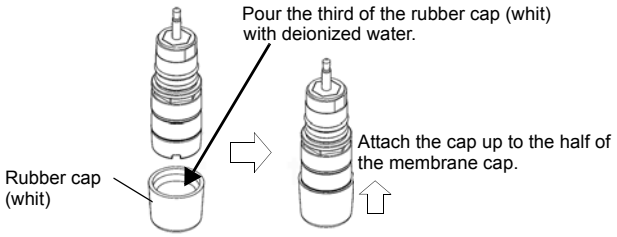
1. **Remove the rubber liquid junction plug from the reference electrode and dispose of the internal solution.**
2. **To prevent air entering, fill the reference electrode to the brim with its internal solution (No. 330).**
3. **Put the rubber liquid junction plug back in place.**

   If the rubber liquid junction plug is dirty, replace the liquid junctions (set of two; No. 9037005100). The reference electrode's internal solution will spill when replacing the liquid junctions. Rinse parts with tap water and dry them with a soft cloth.

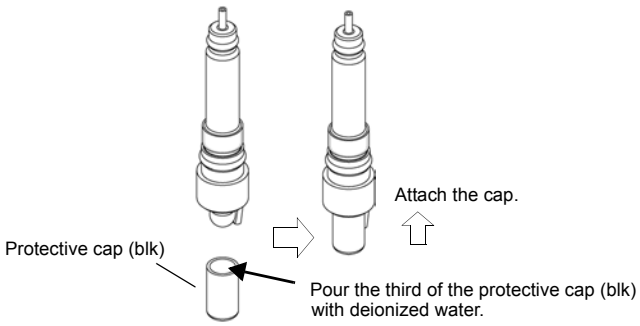
4.3 Storage

Short-term (under 2 months) storage

- Before storing the DO sensor, pour the third of the rubber cap (whit) provided with deionized water and cover the DO sensor with them.



- Before storing the pH sensor, pour the third of the protective cap (blk) provided with deionized water and cover the pH sensor with them.



Note

Before measuerment, remove the rubber cap (whit) and the protective cap (blk).

Long-term (2 months or more) storage

- Remove a membrane cap from DO sensor, and wash the gold electrode and silver electrode parts with water. Wipe off the moisture before storing DO sensor in the pack.
- Prevent internal solution seeping out of the reference chip by taping over the point of seepage with electrical tape.
- Before storing the system, remove the control unit's batteries to prevent battery leakage.

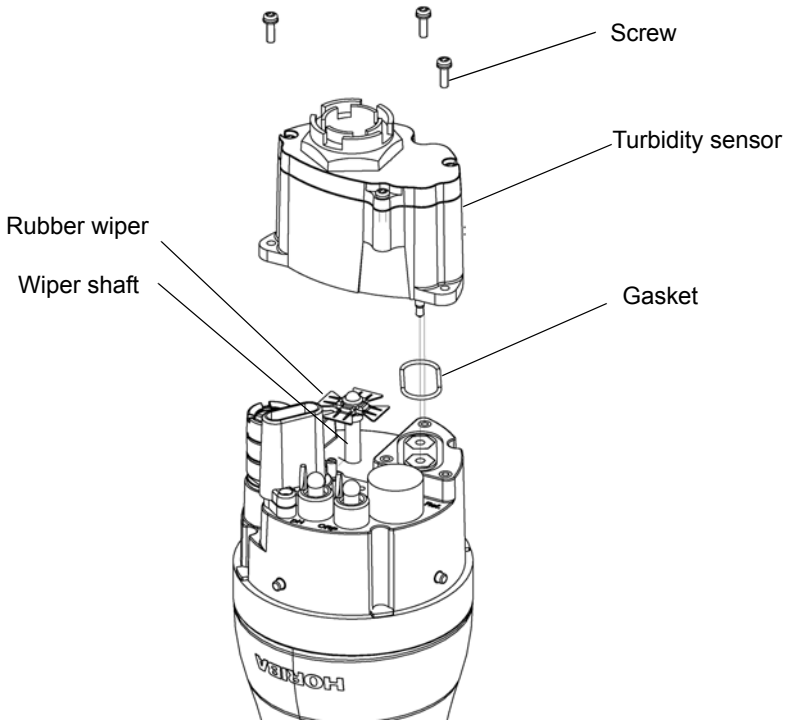
4.4 Replacing the turbidity sensor

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power OFF.**

Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Remove the sensor guard, and clean the sensor probe with tap water.**
3. **Use dry air to blow away and dry off any moisture.**
4. **Remove the three screws holding the turbidity sensor by using No. 2 Phillips head screwdriver.**
5. **Pull out the turbidity sensor horizontally.**
6. **Remove the rubber wiper and gasket, and use a soft cloth to wipe off any dirt from the wiper shaft and turbidity sensor attachment. If parts are very dirty, use a soft cloth soaked in neutral detergent or alcohol.**
7. **Replace the rubber wiper and gasket with new ones. Coat the gasket with a thin layer of grease (No. 3014017718).**
8. **Attach the new turbidity sensor and fasten it in place with the three screws.**
9. **Perform four-point calibration before using the sensor.**



4.5 Replacing the membrane cap

Replacement procedure

1. **Prepare the DO sensor.**

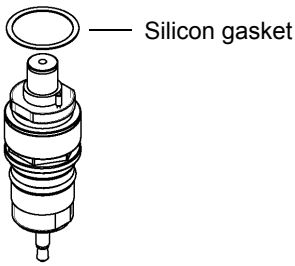
- Take a DO sensor out of pack (newly purchasing).
- Remove a DO sensor from the sensor probe (after use).

Newly purchasing

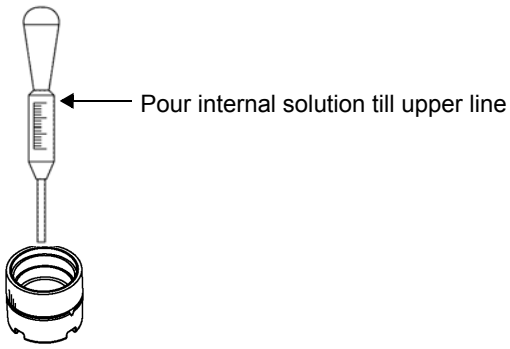
Undo a DO sensor from the sensor probe

- Twist a membrane cap from DO sensor.
- Wash the gold electrode and silver electrode parts with water.

2. **Replace the silicone gasket with a new one.**



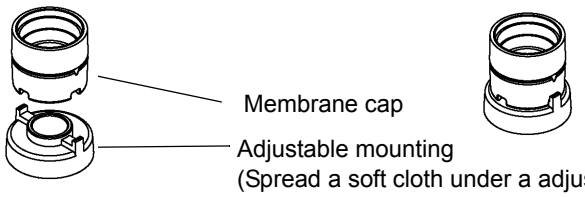
3. **Pour internal solution into a membrane cap with a dropper.**



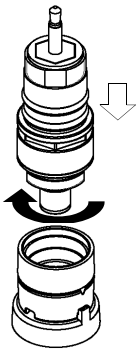
- Check air bubbles in a membrane cap.

Pick a Cap up and drop it down, if there is air bubbles in internal solution of it.

4. **Set up a membrane cap on a adjustable mounting.**



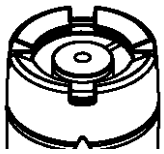
5. **Attach a membrane cap to DO sensor**



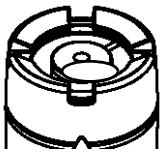
Twist a DO sensor
with holding a membrane cap tight.

6. **Check for membrane surface**

Check air bubbles in a membrane cap.



Good: Limited air bubbles



NG: Air bubbles of more than 5 mm in diameter

- NG → Replace a membrane cap again.
- Check that span calibration can be performed.

If the membrane cap is not attached correctly, sensitivity may be lost or response speed may decrease.

4.6 Troubleshooting

Note

If the sensor probe is removed while the control unit is indicating an error, errors cannot be canceled by using the ESC key. Either reconnect the sensor probe or restart the control unit.

4.6.1 Error displays

Error	Cause	Solution
Probe ADC error	Internal IC failure	Contact your nearest sales outlet to have the sensor probe repaired.
Probe EEPROM error/Factory	Internal IC failure	Turn the power OFF, then restart the system. If the error persists, initialize the system from the "System" menu. If the error still persists, contact your nearest sales outlet to have the sensor probe repaired.
Probe EEPROM error/User	Internal IC failure	Turn the power OFF, then restart the system. If the error persists, initialize the system from the "System" menu. If the error still persists, contact your nearest sales outlet to have the sensor probe repaired.
Turbidity sensor light source error	Turbidity sensor light source failure	Turn the power OFF, wipe off any water droplets on the probe, then remove the turbidity sensor. Check there are no water droplets around the turbidity sensor connector, then mount the sensor again. If the error persists, replace the turbidity sensor.
Turbidity sensor wiper motor error	The turbidity sensor wiper is not operating.	Press the ESC key. Check there are no obstacles near the wiper, then perform the measurement again. If the error persists, the motor will need to be replaced. Contact your nearest sales outlet to have the sensor probe repaired.
Probe capacitor error	Low battery voltage or internal IC failure	Turn the power OFF. Replace the display's batteries. If the error persists, contact your nearest sales outlet to have the sensor probe repaired.
Probe EEPROM error	Internal IC failure	Press the ESC key, then redo the operation. If the error persists, turn the power OFF, then restart the system (the current data will not be saved). If the error still persists, contact your nearest sales outlet to have the display repaired.
Probe board error	Probe board failure	Turn the power OFF. Contact your nearest sales outlet to have the sensor probe repaired.

Error	Cause	Solution
Zero-point calibration error	pH sensor 1. The pH standard solution is contaminated. 2. The pH-responsive membrane is dirty. 3. The concentration of the reference electrode's internal solution has changed. 4. The pH-responsive membrane is torn.	pH sensor 1. Replace the standard solution with new solution. 2. Clean the pH-responsive membrane. 3. Refil the reference electrode's internal solution. 4. Replace the sensor.
	COND sensor 1. There is moisture on the sensor. 2. The sensor is dirty. 3. The COND sensor is broken.	COND sensor 1. Blow-dry the moisture off the sensor. 2. Clean the sensor. 3. Contact your nearest sales outlet.
	TURB sensor 1. There are air bubbles on the cell. 2. The cell window is dirty. 3. The sensor is being affected by ambient light. 4. The solution is dirty. 5. The TURB sensor has failed.	TURB sensor 1. Shake the sensor probe vigorously. 2. Clean the cell window. 3. Calibrate using the calibration cup provided. 4. Replace the solution with new solution. 5. Replace the TURB sensor.
	DO sensor 1. There are air bubbles in the internal solution. 2. The DO sensor has failed.	DO sensor 1. Replace the diaphragm with a new one, and fill the DO sensor with new internal solution. 2. Replace the DO sensor.
	Water depth sensor 1. The water depth sensor is dirty. 2. The water depth sensor has failed.	Water depth sensor 1. Clean the water depth sensor. 2. Contact your nearest sales outlet.

Error	Cause	Solution
Span calibration error	pH sensor 1. The pH standard solution is contaminated. 2. The pH-responsive membrane is dirty. 3. The concentration of the reference electrode's internal solution has changed. 4. The pH-responsive membrane is torn.	pH sensor 1. Replace the standard solution with new solution. 2. Clean the pH-responsive membrane. 3. Refil the reference electrode's internal solution. 4. Replace the sensor.
	ORP sensor 1. The ORP standard solution is contaminated. 2. The ORP electrode is dirty. 3. The concentration of the reference electrode's internal solution has changed. 4. The ORP electrode has failed.	ORP sensor 1. Replace the standard solution with new solution. 2. Clean the ORP electrode. 3. Refil the reference electrode's internal solution. 4. Replace the ORP electrode.
	COND sensor 1. The calibration solution is not correct. 2. The sensor is dirty. 3. The COND sensor has failed.	COND sensor 1. Use the correct calibration solution for calibration. 2. Clean the sensor. 3. Contact your nearest sales outlet.
	TURB sensor 1. There are air bubbles on the cell. 2. The cell window is dirty. 3. The sensor is being affected by ambient light. 4. The solution is dirty. 5. The TURB sensor has failed.	TURB sensor 1. Shake the sensor probe vigorously. 2. Clean the cell window. 3. Calibrate using the calibration cup provided. 4. Replace the solution with new solution. 5. Replace the TURB sensor.
	DO sensor 1. The diaphragm is torn. 2. There are air bubbles in the internal solution. 3. The DO sensor has failed.	DO sensor 1. Replace the diaphragm with a new one, and fill the DO sensor with new internal solution. 2. Replace the diaphragm with a new one, and fill the DO sensor with new internal solution. 3. Replace the DO sensor.
	Temperature sensor The temperature sensor has failed.	Temperature sensor Contact your nearest sales outlet.
Calibration stability error	The calibration value of an individual parameter is not stable. 1. The sensor is dirty. 2. The sensor has not adjusted to the standard solution. 3. The temperature was unstable during calibration.	1. Clean the sensor. 2. Fill the transparent calibration cup with pH 4 standard solution, and wait for at least 20 minutes of conditioning before starting calibration. 3. Start calibration after the temperature has stabilized.
Turbidity calibration error	Error in turbidity measurement sequence	Turbidity calibration failed. Redo calibration after removing the displayed error.
Wet check	The cable connector is submerged.	Turn the power OFF and disconnect the cable connector. Wipe or blow-dry off all the water droplets on the probe. If the error persists, contact your nearest sales outlet to have the display and sensor probe repaired.
Power voltage error	The display's power board has failed.	This error could also be caused by poor cable contact. Turn the power OFF and disconnect the cable connector. Reconnect the connector and turn the power ON. If the error persists, contact your nearest sales outlet to have the display and sensor probe repaired.
Turbidity lamp power voltage error	The remaining battery level is low.	Turn the power OFF and replace the display's batteries with new ones.

Error	Cause	Solution
Display RTC error	The time display is incorrect.	Replace the coin battery.
Display FROM error	Internal IC failure	Contact your nearest sales outlet to have the control unit repaired.
Display EEPROM error	Internal IC failure	Contact your nearest sales outlet to have the control unit repaired.
Display save error	Insufficient memory space	Move data from the display, use the data operations screen to delete data, then redo the measurement.
Measurement sequence error	● When the measurement item is turbidity 1. The battery power is low. 2. The wiper is not operating normally. 3. The light source lamp is not lit. ● If items other than turbidity are also displayed 4. Board failure	1. Replace the batteries with new ones. 2. Check there are no obstacles near the wiper, then redo the measurement. If the error persists, the motor will need to be replaced. Contact your nearest sales outlet to have the sensor probe repaired. 3. Wipe off any water droplets on the probe, then remove the turbidity sensor. Check there are no water droplets around the turbidity sensor connector, then mount the sensor again. If the error persists, replace the turbidity sensor. 4. Contact your nearest sales outlet to have the sensor probe repaired.
Out of measurement range	The attempted measurement is outside the measurement range supported for that item.	The system must be used within its supported measurement ranges.
Last zero-point calibration invalid	pH sensor 1. The pH standard solution is contaminated. 2. The pH-responsive membrane is dirty. 3. The concentration of the reference electrode's internal solution has changed. 4. The pH-responsive membrane is torn.	pH sensor 1. Replace the standard solution with new solution. 2. Clean the pH-responsive membrane. 3. Refil the reference electrode's internal solution. 4. Replace the sensor.
	COND sensor 1. There is moisture on the sensor. 2. The sensor is dirty. 3. The COND sensor has failed.	COND sensor 1. Blow-dry the moisture off the sensor. 2. Clean the sensor. 3. Contact your nearest sales outlet.
	TURB sensor 1. There are air bubbles on the cell. 2. The cell window is dirty. 3. The sensor is being affected by ambient light. 4. The solution is dirty. 5. The TURB sensor has failed.	TURB sensor 1. Shake the sensor probe vigorously. 2. Clean the cell window. 3. Calibrate using the calibration cup provided. 4. Replace the solution with new solution. 5. Replace the TURB sensor.
	DO sensor 1. There are air bubbles in the internal solution. 2. The DO sensor has failed.	DO sensor 1. Replace the diaphragm with a new one, and fill the DO sensor with new internal solution. 2. Replace the DO sensor.
	Water depth sensor 1. The water depth sensor is dirty. 2. The water depth sensor has failed.	Water depth sensor 1. Clean the water depth sensor. 2. Contact your nearest sales outlet.
Out of measurement range	[See above.]	[See above.]
Last zero-point calibration invalid		

Error	Cause	Solution
Last span calibration invalid	pH sensor 1. The pH standard solution is contaminated. 2. The pH-responsive membrane is dirty. 3. The concentration of the reference electrode's internal solution has changed. 4. The pH-responsive membrane is torn.	pH sensor 1. Replace the standard solution with new solution. 2. Clean the pH-responsive membrane. 3. Refil the reference electrode's internal solution. 4. Replace the sensor.
	ORP sensor 1. The ORP standard solution is contaminated. 2. The ORP electrode is dirty. 3. The concentration of the reference electrode's internal solution has changed. 4. The ORP sensor glass is broken.	ORP sensor 1. Replace the standard solution with new solution. 2. Clean the ORP electrode. 3. Refil the reference electrode's internal solution. 4. Replace the sensor.
	COND sensor 1. The calibration solution is not correct. 2. The sensor is dirty. 3. The COND sensor has failed.	COND sensor 1. Use the correct calibration solution for calibration. 2. Clean the sensor. 3. Contact your nearest sales outlet.
	TURB sensor 1. There are air bubbles on the cell. 2. The cell window is dirty. 3. The sensor is being affected by ambient light. 4. The solution is dirty. 5. The TURB sensor has failed.	TURB sensor 1. Shake the sensor probe vigorously. 2. Clean the cell window. 3. Calibrate using the calibration cup provided. 4. Replace the solution with new solution. 5. Replace the TURB sensor.
	DO sensor 1. The diaphragm is torn. 2. There are air bubbles in the internal solution. 3. The DO sensor has failed.	DO sensor 1. Replace the diaphragm with a new one, and fill the DO sensor with new internal solution. 2. Replace the diaphragm with a new one, and fill the DO sensor with new internal solution. 3. Replace the DO sensor.
	Temperature sensor ● The temperature sensor has failed.	Temperature sensor ● Contact your nearest sales outlet.
Out of measurement range Last zero-point calibration invalid	[See above.]	[See above.]
Last span calibration invalid	The calibration value of an individual parameter is not stable. 1. The sensor is dirty. 2. The sensor has not adjusted to the standard solution. 3. The temperature was unstable during calibration.	1. Clean the sensors. 2. Fill the transparent calibration cup with pH 4 standard solution, and wait for at least 20 minutes of conditioning before starting calibration. 3. Start calibration after the temperature has stabilized.
Out of measurement range Last zero-point calibration invalid	[See above.]	[See above.]
Calibration value is factory default value.	Internal IC failure	Turn the power OFF, then restart the system. If the error persists, initialize the system from the "System" menu. If the error still persists, contact your nearest sales outlet to have the sensor probe repaired.

Error	Cause	Solution
Sample is unstable.	1. The concentration of the sample is unstable. 2. External light disturbance has affected the sensor. 3. Water has entered the turbidity sensor's connector.	1. Use a stirrer to agitate the sample during measurement. 2. Perform measurement away from direct sunlight. 3. Turn the power OFF, wipe off any water droplets on the probe, then remove the turbidity sensor. Check there are no water droplets around the turbidity sensor connector, then mount the sensor again. If the error persists, replace the turbidity sensor.

4.6.2 Error displays in sensor information

Error display	Cause	Solution
Measurement sequence error	Measurement sequence error	Turn the power OFF, then restart the system. If the error persists, have the probe repaired.
Out of measurement range	The measurement value is outside the measurement range.	Samples for measurement must be within the measurement range.
Last calibration invalid	The last calibration failed.	Redo calibration.
Calibration invalid	The calibration value is the factory default value.	Redo calibration.
Background unstable	The U-53 turbidity sensor is exposed to direct light.	Mount the guard cap and sensor guard and perform measurement away from direct sunlight.
	The turbidity value changed rapidly during measurement.	Measure a sample that has stable turbidity.

5 Specifications

Specification		Basic value	Model				
			U-51	U-52	U-52G	U-53	U-53G
Sensor probe	Measurement temperature range	−10°C to 55°C	✓	✓	✓	✓	✓
	Maximum sensor outer diameter	Approx. 96 mm					
	Sensor length	Approx. 340 mm					
	Cable length	2 m (standard) 10 m/30 m (options)					
	Mass	Approx. 1800 g					
	Auto calibration function	Uses pH 4 standard solution.					
	Measurement depth	30 m max.	✓	✓	✓	✓	✓
	Wet-part materials*3	PPS, glass, SUS316L, SUS304, FKM, PEEK, Q, titanium, FEP membrane, POM					
	Waterproofing standard	IP-68					
Control unit	Outer dimensions (W × D × H)	115 × 66 × 283 mm	✓	✓	—	✓	—
		115 × 66 × 335 mm	—	—	✓	—	✓
	Mass	Approx. 800 g	✓	✓	✓	✓	✓
	LCD	320 × 240 mm graphic LCD (monochrome) with backlight	✓	✓	✓	✓	✓
	Memory data items	10000	✓	✓	✓	✓	✓
	Communication interface	USB peripheral	✓	✓	✓	✓	✓
	Batteries	C-size dry cells (×4)	✓	✓	✓	✓	✓
	Waterproofing standard	IP-67	✓	✓	✓	✓	✓
	GPS unit	● Reception method (12 channel parallel) ● Measurement precision [With PDOP (high precision): 30 m or less (2 drms)]	—	—	✓	—	✓
	Estimated battery life*1	—	70 hours (no backlight)			500 measurements (no backlight)	
	Storage temperature range	−10°C to 60°C	✓	✓	✓	✓	✓
	Ambient temperature range	−5°C to 45°C					

Specification		Basic value	Model				
			U-51	U-52	U-52G	U-53	U-53G
pH measurement Two calibration	Measurement method	Glass electrode method	✓	✓	✓	✓	✓
	Range	pH 0 to 14					
	Resolution	0.01 pH					
	Precision*2	±0.1 pH					
Dissolved oxygen measurement ● Salinity conversion (0 to 70 PPT, automatic) ● Automatic temperature compensation	Measurement method	Polarographic method	✓	✓	✓	✓	✓
	Film thickness	25 μm					
	Range	0 mg/L to 50.0 mg/L					
	Resolution	0.01 mg/L					
	Precision*2	0 mg/L to 20 mg/L: ±0.2 mg/L 20 mg/L to 50 mg/L: ±0.5 mg/L					
Electrical conductivity measurement ● Auto range ● Automatic temperature conversion (25°C)	Measurement method	Four-AC-electrode method	✓	✓	✓	✓	✓
	Range	0 S/m to 10 S/m (0 mS/cm to 100 mS/cm)					
	Resolution	0.000 mS/cm to 0.999 mS/cm: 0.001 1.00 mS/cm to 9.99 mS/cm: 0.01 10.0 mS/cm to 99.9 mS/cm: 0.1 0.0 mS/m to 99.9 mS/m: 0.1 0.100 S/m to 0.999 S/m: 0.001 1.00 S/m to 9.99 S/m: 0.01					
	Precision*2	1% of full-scale (midpoint of two calibration points)					
Salinity measurement	Measurement method	Electrical conductivity conversion	✓	✓	✓	✓	✓
	Range	0 PPT to 70 PPT (parts per thousand)					
	Resolution	0.1 PPT					
	Precision	±3 PPT					
TDS (total dissolved solid) measurement ● Conversion coefficient setting	Measurement method	Electrical conductivity conversion	✓	✓	✓	✓	✓
	Range	0 g/L to 100 g/L					
	Resolution	0.1% of full-scale					
	Repeatability	±2 g/L					
	Precision	±5 g/L					
Seawater specific gravity measurement ● σt, σ0, σ15 display	Measurement method	Electrical conductivity conversion	✓	✓	✓	✓	✓
	Range	0 σt to 50 σt					
	Resolution	0.1 σt					
	Precision	±5 σt					

Specification		Basic value	Model				
			U-51	U-52	U-52G	U-53	U-53G
Temperature measurement	Measurement method	Platinum temperature sensor	✓	✓	✓	✓	✓
	Range	−10°C to 55°C					
	Resolution	0.01°C					
	Sensor	Platinum temperature sensor, JIS Class B (0.3 + 0.005 |t|)					
Turbidity measurement	Measurement method		–	LED forward 30° transmission/ scattering method		Tungsten lamp 90° transmission scattering method	
	Range			0 NTU to 800 NTU		0 NTU to 1000 NTU	
	Resolution			0.1 NTU		0.01 NTU	
	Precision*2			±5%of readout or ±1 NTU, whichever is larger		● ±0.5NTU (for 0 NTU to 10 NTU measurement range) ● 3% of readout or 1 NTU, whichever is larger (for 10 NTU to 1000 NTU measurement range)	
	Turbidity sensor wiper			–		✓	
Water depth measurement	Measurement method	Pressure method	–	–	✓	✓	✓
	Range	0 m to 30 m					
	Resolution	0.05 m					
	Precision*2	±0.3 m					
ORP (oxidation reduction potential) measurement	Measurement method	Platinum electrode method	✓	✓	✓	✓	✓
	Range	−2000 ～ +2000 mV					
	Resolution	1 mV					
	Precision*2	±15 mV					

*1: Battery life is estimated under following conditions.
- Continuous operation
- Using batteries: C-size alkaline dry cells
- Ambient temperature of the control unit: 20°C or more
- Backlight off

*2: The precision is defined by measuring the standard solution in the following cases.
- Turbidity and conductivity: after four point calibration
- pH and DO: after two point calibration
- Water depth and ORP: after one point calibration

*3: Metallic parts are made of stainless steel. Immersing in seawater may erode metallic parts.

6 Reference

6.1 Consumable parts

● Sensor

Name	Model	No.	Description
pH sensor	#7112	3014057312	Standard type pH sensor
pH sensor ToupH	#7113	3200170923	Tough glass type pH sensor
ORP sensor	#7313	3200170920	
DO sensor	#7543	3200170924	
Reference electrode	#7210	3200043582	
R bush unit	—	3200043587	Reference electrode liquid junction
TURB cell U-52	#7800	3200172803	For U-52/U-52G
TURB cell U-53	#7801	3200172800	For U-53/U-53G
Membrane cap	—	3200170194	For DO sensor

● Standard solution and inner solution

Name	Model	No.	Description
pH 4 (For automatic calibration) 500 mL	#100-4	3200043638	Standard solution for auto calibration. Also used for manual pH span calibration.
pH 4 (For automatic calibration) 4 L	#140-4	3200174430	
pH 7 500 mL	#100-7	3200043637	Standard solution for pH zero-point calibration.
pH 9 500 mL	#100-9	3200043636	Standard solution for pH manual span calibration.
Powder for ORP standard solution 10 packs	#160-51	3200043618	For ORP calibration.
Powder for ORP standard solution 10 packs	#160-22	3200043617	
Inner solution for DO sensor, 50 mL	#306	3200170938	Internal solution for DO sensor.
Internal solution for pH, 250 mL	#330	3200043641	Supplementary internal solution for pH reference electrode.

Others

Name	Model	No.	Description
Silicone grease	—	3014017718	Silicone grease for coating sensor O-ring.
Sponge brush unit	—	3200169531	Brush for cleaning sensor probe.
O-ring set for reference electrode	—	3200169376	O-rings for reference electrode.
O-ring set for DO sensor	—	3200169426	O-rings for DO sensor.
Rubber cap set for sensor guard	—	3200169428	Rubber caps used between sensor guard and sensor probe.
O-ring set for pH and ORP sensor	—	3200169520	O-rings for pH and ORP sensors.
Wiper unit	—	3200169789	Rubber wiper for U-53/U-53G turbidity sensors.
Protective cap (blk) for pH sensor	—	3200175019	Cap attached to tip of pH sensor for sensor probe storage.
Rubber cap (whit) for DO sensor	—	3200175020	Cap attached to tip of DO sensor for sensor probe storage.

6.2 Options sold separately

Name	Model	No.	Description
Bag	U-5030	3200174772	Storage bag for sensor probes and flow cell. Can be carried in one hand.
Flow cell assy	—	3200156570	Used when collecting measurement samples by pump.
Probe guard	—	3200167002	Used for taking measurements in locations where there is a current or where there is a thick layer of sludge.
Communication cable	—	3200174823	A PC connection cable. Comes with data collection software.

6.3 pH measurement

6.3.1 Principle of pH measurement

U-50 series use the glass electrode method for pH measurements. The glass electrode method measures a potential difference between the glass film for pH and the reference electrode. For more information, refer to “JIS Z 8802 pH measurement method”.

6.3.2 Temperature compensation

The electromotive force generated by the glass electrode changes depending on the temperature of the solution.

Temperature compensation is used to compensate for the change in electromotive force caused by temperature.

This function does not compensate the change in pH caused by the temperature of the solution. When pH is to be measured, the temperature of the solution must be recorded along with that pH value, even if a pH meter has automatic temperature compensation function. If the solution temperature is not recorded, the results of the pH measurement may be meaningless.

6.3.3 Standard solutions

When measuring pH, the pH meter must be calibrated using standard solution. There are five kinds of standard solutions specified in “JIS Z 8802 pH measurement”. For normal measurement, two of standard solutions with pH of 4, 7, and 9 are sufficient to accurately calibrate the meter.

For standard solutions, refer to “JIS Z 8802 pH measurement”.

pH 4 standard solution: (Phthalate) 0.05 mol/L potassium hydrogen phthalate aqueous solution

pH 7 standard solutio: (Neutral phosphate) 0.025 mol/L potassium dihydrogenphosphate, 0.025 mol/L disodium hydrogenphosphate aqueous solution

pH 9 standard solution: (Borate) 0.01 mol/L sodium tetraborate aqueous solution

Table 2 pH values of pH standard solutions at various temperatures settings

Temp. (℃)	pH 4 standard solution Phthalate	pH 7 standard solution Neutral phosphate	pH 9 standard solution Borate
0	4.01	6.98	9.46
5	4.01	6.95	9.39
10	4.00	6.92	9.33
15	4.00	6.90	9.27
20	4.00	6.88	9.22
25	4.01	6.86	9.18
30	4.01	6.85	9.14
35	4.02	6.84	9.10
40	4.03	6.84	9.07
45	4.04	6.84	9.04

6.4 DO measurement

6.4.1 Principle of DO measurement

Dissolved oxygen (DO) refers to the amount of oxygen that is contained in water.
The concentration of dissolved oxygen is generally given as mg/L or as a percentage value (the dissolved oxygen saturation ratio).
Dissolved oxygen is essential for maintaining the self-purifying ability of rivers and seas and also for fish to live. The concentration of dissolved oxygen acts as an indicator of water quality. It is often measured when processing waste water and managing water quality. Fig. 1 provides an overview of the principles behind dissolved oxygen sensor measurement.

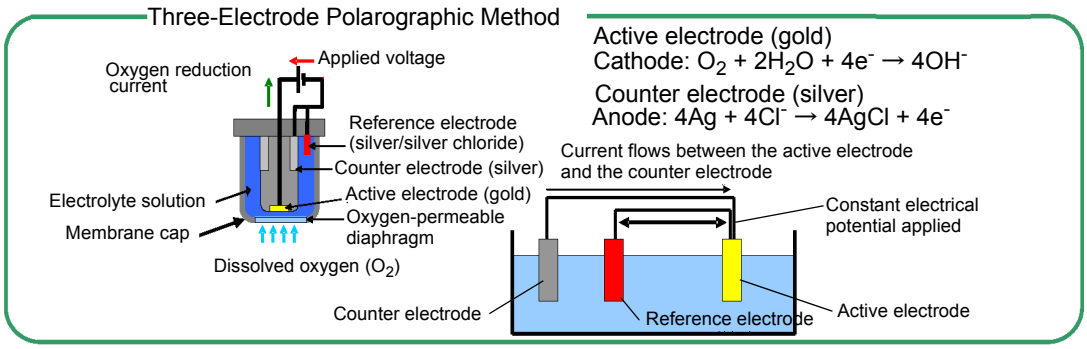


Fig. 1 Overview of principles behind dissolved oxygen sensor

The polarographic oxygen sensor is an enclosed sensor wherein voltage is applied to a cathode made of a precious metal (such as gold or platinum) and an anode also made of a precious metal (such as silver) via an external circuit, and a cap with an oxygen permeable diaphragm (membrane) is filled with electrolyte solution. As indicated in Fig. 1, the concentration of dissolved oxygen can be measured by measuring the current proportional to the amount of reduced oxygen when oxygen that has dispersed through the oxygen permeable diaphragm produces a reductive reaction on the surface of the active electrode (gold). The method of measuring dissolved oxygen based on the above principle is called the Membrane Electrode Method. Compared to the Chemical Analysis Method, which requires complicated pre-processing to alleviate the effect of reduced materials and oxidizing materials, this method allows dissolved oxygen to be measured very easily. It is also easy to remove undesired buildup from the silver electrode by polishing and cleaning if an insulator forms on it due to oxidation, making the method reusable.

6.4.2 Salinity calibration

When the solution and air come into contact and form an equilibrium (i.e. saturation), the relationship between the concentration of dissolved oxygen in the solution, C, [mol/L], and the partial pressure of oxygen in the air, Ps, [MPa/(mg/L)], can be represented by the following formula:

$$C = Ps/H$$

Where H [MPa/(mg/L)] is the Henry constant, a value that changes according to the composition of the solution. As H typically becomes larger as the salinity of the water increases, C becomes smaller.

The DO sensor detects the partial pressure of oxygen (Ps) in the above formula. Accordingly, if the DO sensor is immersed in deionized water saturated with air, or in an aqueous solution containing salt, the output current does not change, resulting in an erroneous measurement. For example, when salt is added to a sample, the amount of oxygen that can be dissolved in the solution decreases, but because the partial pressure of oxygen does not change, the value displayed by the control unit stays the same regardless of salt content. This concept is indicated in graph form below. (Fig. 2)

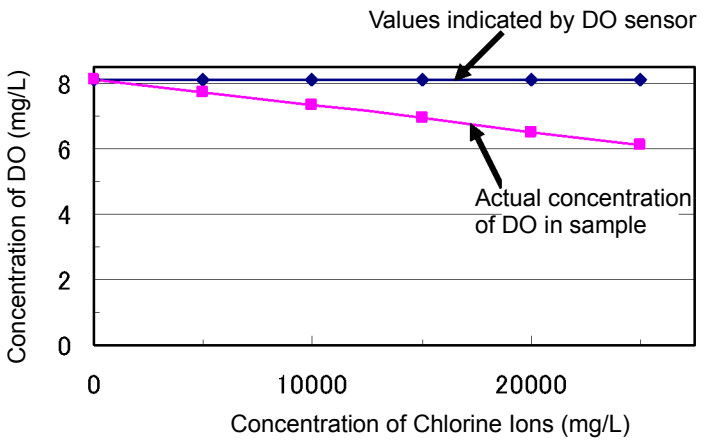


Fig. 2 Relationship between chlorine ion concentration and dissolved oxygen concentration

In samples with a high salt concentration, the solubility of oxygen is lower, but as the partial pressure of oxygen does not change, the value actually indicated on the control unit is higher than the actual value. In order to obtain a measurement of the concentration of dissolved oxygen in an aqueous solution that contains salt, it is therefore necessary to first perform salinity compensation. Conventionally, dissolved oxygen sensors have performed salinity compensation by inputting the salinity of the sample. This is fine as long as the salinity is already known. However, in most cases salinity is unknown, so even if dissolved oxygen sensors contained a salinity compensation function, it was of no practical use.

The U-50 Series can calculate and measure salinity in samples from electrical conductivity values, and can thus be used to automatically compensate for salinity.

6.5 Conductivity (COND) measurement

6.5.1 Four-AC-electrode method

Conductivity is an index of the flow of electrical current in a substance.

Salts dissolved in water are separated into cations and anions. Such solution is called electrolytic solution.

Electrolytic solution has the property of allowing the flow of current according to Ohm's law. This property is referred

to as ionic conductivity, since current flow is caused by ion movement in electrolytic solution.

Metals, on the other hand, allow the flow of current by means of electrons. This property is called electronic conductivity,

which is distinguished from ionic conductivity.

A cube with 1 m on each side, as shown in Fig. 3, is used to demonstrate an electrolytic solution. Two electrode plates are placed on opposite sides, and the cube is filled with solution. If the resistance between these two electrode plates is represented by r(Ω), the conductivity of the solution L($S \cdot m^{-1}$) is represented as L=1/r. S stands for Siemens, a unit of measurement of conductance.

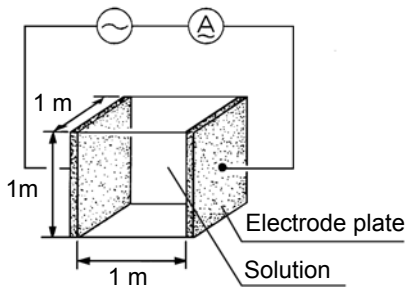


Fig. 3 Definition of conductivity

The most general method for measuring conductivity is based on the above principle, and is called the 2-electrode method.

In the 2-electrode method the influence of polarization cannot be ignored for solutions with high conductivity and conductivity cannot be measure accurately. In addition, contamination on the surface of the electrode increases apparent resistance, resulting in inaccurate measurement of conductivity.

The U-50 series has adopted the 4-electrode method to overcome these disadvantages of the the 2-electrode method.

As shown in Fig. 4, the U-50 series uses two voltage-detecting electrodes and two voltage-applying electrodes, for a total of four electrodes. The voltage-detecting electrodes are for detecting AC voltage, and the voltage-applying electrodes are for applying AC voltage.

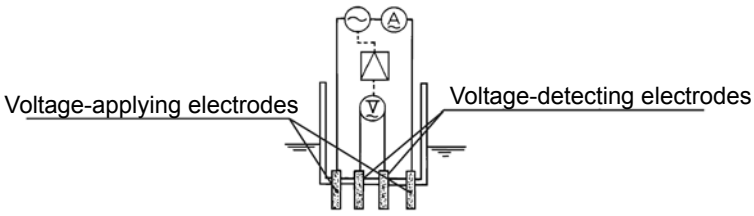


Fig. 4 Principle of the 4-electrode method

Let us assume that the current, I(A), flows in a sample of conductivity L – under automatic control of the voltage-applying electrodes – so that the voltage at the voltage-detecting-electrodes, E(V), remains constant at all times.
Then, the resistance of the sample, R(Ω), across the voltage-detecting electrodes is represented as R=E/I. The resistance, R, of the sample is inversely proportional to its conductivity, L. Accordingly, a measurement of current, Is,
of a standard solution of known conductivity, Ls, enables calculation of conductivity of a sample according to the formula L = Ls (I/Is) from the ratio L : Ls = I : Is.
Even in the 4-electrode method, polarization occurs, since AC current flows in the voltage-applying electrodes. The voltage-detecting electrodes are, however, free from the effects of polarization, since they are separated from the voltage-applying electrodes, and furthermore, current flow is negligible. Therefore, the 4-electrode method is an excellent method to enable measurement of conductivity covering a very high range.

6.5.2 SI units

New measurement units, called SI units, have been in use from 1996. Accordingly, the U-50 series also uses SI units. The following conversion table is provided for people who use the conventional kind of conductivity meter.
Note that along with the change in unit systems, the measurement values and cell counts have also changed.

	Former units	→	SI unit
Measurement value	0.1 mS/cm	→	0.01 S/m
	1 mS/cm	→	0.1 S/m
	100 mS/cm	→	10 S/m

6.5.3 Temperature coefficient

In general, the conductivity of a solution varies largely with its temperature.
The conductivity of a solution depends on the ionic conductivity, described earlier. As the temperature rises, conductivity becomes higher since the movement of the ions becomes more active.
The temperature coefficient shows the change in % of conductivity per °C, with a certain temperature taken as the reference temperature. This is expressed in units of %/°C. The temperature coefficient assumes the premise that the conductivity of a sample changes linearly according to temperature.
Strictly speaking, with actual samples, however, conductivity changes along a curve. Furthermore, the cuve varies with the type of sample. In the ranges of smaller temperature changes, however, samples are said to have the temperature coefficient of 2%/°C (at reference temperature 25°C); this holds for most samples, except in certain special cases.
(The temperature coefficients for various types of solutions are listed on the next page.)
The U-50 series uses an automatic temperature conversion function to calculate conductivity at 25°C at a temperature
coefficient of 2 %/°C based on the measured value of the temperature. Results are displayed on the readout.
The U-50 series's temperature conversion function is based on the following formula.
$L_{25} = L_t / \{ 1 + K (t - 25) \}$
L_{25} : Conductivity of solution converted to 25°C
t : Temperature of solution at time of measurement (°C)
L_t : Conductivity of solution at t (°C)
K : Temperature coefficient (%/°C)

Conductivity and temperature coefficient for various solutions

Conductivity and related temperature coefficients of representative substances (at 25°C) are shown in the table below.

Substance	Temp. (ºC)	Conc. (wt%)	Cond. (S/m)	Temp.coef. (%/°C)	Substance	Temp. (ºC)	Conc. (wt%)	Cond. (S/m)	Temp.coef. (%/°C)
NaOH	15	5	19.69	2.01	NaCl	18	5	6.72	2.17
		10	31.24	2.17			10	12.11	2.14
		15	34.63	2.49			15	16.42	2.12
		20	32.70	2.99			20	19.57	2.16
		30	20.22	4.50			25	21.35	2.27
		40	11.64	6.48	Na_2SO_4	18	5	4.09	2.36
KOH	15	25.2	54.03	2.09			10	6.87	2.49
		29.4	54.34	2.21			15	8.86	2.56
		33.6	52.21	2.36	Na_2CO_3	18	5	4.56	2.52
		42	42.12	2.83			10	7.05	2.71
NH_3	15	0.1	0.0251	2.46			15	8.36	2.94
		1.6	0.0867	2.38	KCl	18	5	6.90	2.01
		4.01	0.1095	2.50			10	13.59	1.88
		8.03	0.1038	2.62			15	20.20	1.79
		16.15	0.0632	3.01			20	26.77	1.68
HF	18	1.5	1.98	7.20			21	28.10	1.66
		4.8	5.93	6.66	KBr	15	5	4.65	2.06
		24.5	28.32	5.83			10	9.28	1.94
HCl	18	5	39.48	1.58			20	19.07	1.77
		10	63.02	1.56	KCN	15	3.25	5.07	2.07
		20	76.15	1.54			6.5	10.26	1.93
		30	66.20	1.52			—	—	—
H_2S0_4	18	5	20.85	1.21	NH_4Cl	18	5	9.18	1.98
		10	39.15	1.28			10	17.76	1.86
		20	65.27	1.45			15	25.86	1.71
		40	68.00	1.78			20	33.65	1.61
		50	54.05	1.93			25	40.25	1.54
		60	37.26	2.13	NH_4NO_3	15	5	5.90	2.03
		80	11.05	3.49			10	11.17	1.94
		100.14	1.87	0.30			30	28.41	1.68
		—	—	—			50	36.22	1.56
HNO_3	18	6.2	31.23	1.47	$CuSO_4$	18	2.5	10.90	2.13
		12.4	54.18	1.42			5	18.90	2.16
		31	78.19	1.39			10	32.00	2.18
		49.6	63.41	1.57			15	42.10	2.31
		62	49.64	1.57	CH_3COOH	18	10	15.26	1.69
H_3PO_4	15	10	5.66	1.04			15	16.19	1.74
		20	11.29	1.14			20	16.05	1.79
		40	20.70	1.50			30	14.01	1.86
		45	20.87	1.61			40	10.81	1.96
		50	20.73	1.74			60	4.56	2.06

6.6 Salinity (SAL) conversion

The U-50 series is designed to calculate salinity as well as the other parameters.
Note that the “salinity” here is the salinity of sea water. There is a constant relation between conductivity and salinity at certain temperatures.
Therefore, if data on the conductivity and temperature are available, the corresponding salinity can be known. In other words, the salinity measurement of the U-50 series is based on the principle of calculating the salt content, making use of the measured values of conductivity and temperature.
Note therefore, that measured results of all substances whose conductivity is detected are displayed as salinity. For example, the measured result is displayed as NaCl concentration, even if in fact the sample component is, hydrochloric acid (HCl).

6.7 TDS conversion

TDS is short for Total Dissolved Solids and means the total dissolved solid amount.
The conductivity of a solution is affected by the amount of salinity, minerals, and dissolved gases. That is, conductivity is an index that shows the total amount of all substances in the solution. Of these substances, TDS indicates only the amount of dissolved solids.
TDS can be used for a comparison of the state of substances composed of a single component such as NaCl. However, the use of TDS for the comparison of solutions of different types causes serious errors.
Conductivity and TDS are expressed by the following formulas.
Conductivity in SI units (S/m) ..... TDS(g/L) = L (S/m) $\times$ K $\times$ 10
TDS(g/L) = L (mS/m) $\times$ K $\div$ 100
Conductivity in the old units (mS/cm) ..... TDS(g/L) = L (mS/cm)$\times$ K
K = TDS coefficient
Initial settings use the values listed in the table (Page 80) that generally uses TDS coefficients.
For accurate TDS comparisons, find the TDS coefficient from measured conductivity values. Then set the value thus obtained and make measurements.

6.8 σt conversion

- **Specific gravity of seawater**

The density and specific gravity of seawater are equal numerically and generally are not distinguished strictly. Since seawater density ρ is between 1.000 and 1.031, 1 is subtracted from ρ and σ is obtained by multiplying the value by 1000.
The resultant value is used as the specific gravity of seawater.
$\sigma = (\rho - 1) \times 1000$
The density of seawater ρ is expressed by function of temperature, hydraulic pressure, and salinity. The density of seawater under the atmospheric pressure is expressed as σ_t. The density of seawater under the atmospheric pressure is determined by temperature and salinity.
The U-50 Series models make salinity measurement through temperature measurements and conductivity conversion and find σ_t through calculations.
In Japan σ_{15} at 15°C is called a standard specific gravity and widely used while in foreign countries σ_0 at 0°C is employed. σ_{15} and σ_0 are determined by the function of salinity.
In ocean surveys, in particular, these values σ_t, σ_{15}, and σ_0 are more widely used than conductivity and salinity and, in the U-50 Series models, newly added as measurement components.

6.9 Turbidity (TURB) measurement

6.9.1 Principle of turbidity measurement

U-52 and U-53 sensors measure turbidity using the Transmitting and Scattering Method shown in Fig. 5. U-52 sensors use a pulse light LED (infra-red emitting diode) as a light source, and detect scattered light from a 30° angle off center. U-53 sensors use a tungsten lamp as a light source and detect scattered light from a 90° angle. Both models display turbidity as a ratio of scattered light to transmitted light to reduce the affect of the color of the sample. The U-53 method conforms to EPA Method 180.1, and employs wipers to reduce the affect of air bubbles.

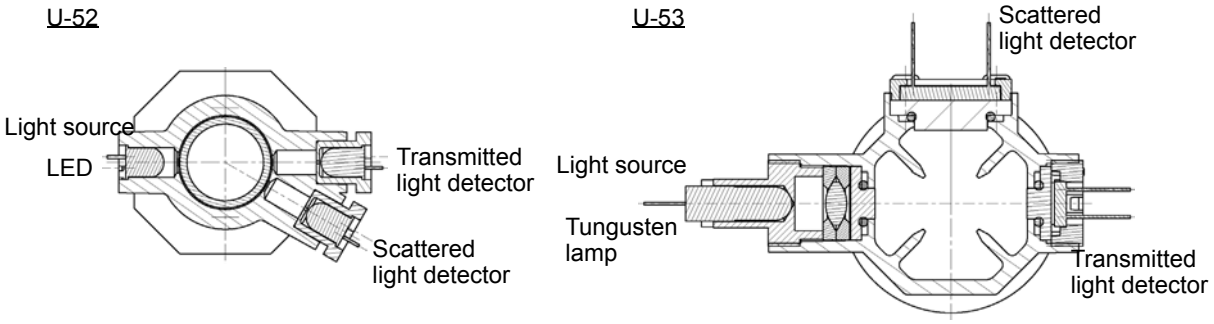


Fig. 5 Turbidity cell

6.9.2 Standard solution

U-50 series can perform calibration using formazin (NTU) or kaolin standard solutions as a turbidity standard solution. However, units for the solution used for calibration should be displayed in measurements. Do not use more than 400 mg/L of kaolin standard solution because it increases precipitation speed, resulting in measurement error.

6.10 Depth (DEPTH) measurement

6.10.1 Principle of depth measurement

For the W-22XD and W-23XD models, depth measurement can be made through use of a pressure gauge. The principle of the depth measurement uses the relation between depth and pressure.

Although the measurement with the depth sensor is affected by atmospheric pressure, the depth sensor, however, makes zero-point adjustments through the automatic calibration before measurements.

6.10.2 Influence of temperature and calibration

The depth sensor depends greatly on temperature. For a wide difference between the temperature at which the sensor has been automatically calibrated and the temperature of the measurement sample, the sensor can make depth measurements with a higher accuracy by the following method:

1. **Immerse the depth sensor of the sensor probe in the sample.**
2. **Keep the sensor immersed in the sample for about 30 minutes until the temperatures of the sensor and the sample are the same.**
3. **Then make the zero calibration of the sensor manually.**

6.11 Oxidation reduction potential (ORP) measurement

6.11.1 Principle of ORP measurement

ORP is an abbreviation for oxidation-reduction potential. ORP is the energy level (potential) determined according to the state of equilibrium between the oxidants (M^{Z+}) and reductants $M^{(Z-N)+}$ that coexist within a solution.

$$M^{Z+} + ne^- \Leftrightarrow M^{(Z-N)+} \qquad \cdots (1)$$

If only the solution, forming the ORP measuring system shown in Fig. 6. The difference of potential between two electrodes is generally expressed by the following equation.

$$E = E_0 - \frac{RT}{nF} \ln \frac{a_M{}^{(z-n)+}}{a_M{}^{z+}} \qquad \cdots (2)$$

E: Electric potential E_0 : Constant R: Gas constant T : Absolute temperature
n: Electron count F : Faraday constant a : Activity

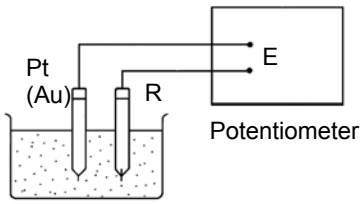


Fig. 6 Measuring mV

For example, for a solution in which trivalent iron ions coexist with bivalent iron ions, equations 1 and 2 would be as follows.

$$Fe^{3+} + e^- \Leftrightarrow Fe^{2+} \qquad \cdots (1)$$

$$E = E_0 - \frac{RT}{F} \ln \frac{a_{Fe}{}^{2+}}{a_{Fe}{}^{3+}} \qquad \cdots (2)$$

When only one type of state of equilibrium uniquely by equation (Fe^{3+}) and the reductant (Fe^{2+}) (using the equation $a_{Fe}{}^{2+}/ a_{Fe}{}^{3+}$). Actually, however many kinds of states of equilibrium exist simultaneously between various kinds of ions, in most solutions. This means that under actual circumstances, ORP cannot be expressed using the simple equation shown above and that the physical and chemical significance with respect to the solution is not very clear.
In this respect, the value of ORP must be understood to be only one indicator of the property of a solution. The measurement of ORP is widely used, however, as an important index in the analysis of solutions (potentiometric titration) and in the waste water treatment.

6.11.2 Standard electrode (reference electrode) types and ORP

The ORP is obtained comparing with corresponding reference electrode employed.
If different kinds of reference electrodes are used for measurement, the ORP value of the same solution may appear to be different. HORIBA's reference electrode uses Ag/AgCl with 3.33 mol/L KCl as inner solution. According to general technical literature, normal hydrogen electrodes (N.H.E.) are often used as the standard electrode.
The relationship between N.H.E. and the ORP that is measured using an Ag/AgCl with 3.33 mol/L KCl electrode is expressed by the following equation.
$E_{N.H.E.} = E + 206 - 0.7(t - 25)$ mV t = 0 - 60°C
$E_{N.H.E.}$: Measured ORP value using N.H.E. as the reference electrode

E: Measured ORP value using Ag/AgCl with 3.33 mol/L KCl as the reference electrode
Potential sign
Standard ORP is expressed in the following way, in literature related to electrochemistry and analytical chemistry.

A $Li^{+} + e^{-} \rightarrow Li$
$E_0 = -3.024$ V VS N.H.E.

However, in some literature, the "+" and "-" signs are reversed.

B $Li \rightarrow Li^{+} + e^{-}$
$E_0 = +3.024$ V VS N.H.E.

In expressions like B, above, the reaction is just reversed and there is no essential difference. But this kind of expression does invite confusion. The majority of the world, today, is consistent in its use of the signs as they are used in A, above.
For this reason, HORIBA, too, uses signs concerning ORP that are consistent with A, above.

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Flow cell for U-50 series U-50FC Instruction Manual

The flow cell U-50FC is used to measure the pumped water stably by using the U-50 series.

Warranty and Responsibility

HORIBA warrants that the Product shall be free from defects in material and workmanship and agrees to repair or replace free of charge, at HORIBA's option, any malfunctioned or damaged Product attributable to HORIBA's responsibility for a period of one (1) year from the delivery unless otherwise agreed with a written agreement. In any one of the following cases, none of the warranties set forth herein shall be extended;

- Any malfunction or damage attributable to improper operation
- Any malfunction attributable to repair or modification by any person not authorized by HORIBA
- Any malfunction or damage attributable to the use in an environment not specified in this manual
- Any malfunction or damage attributable to violation of the instructions in this manual or operations in the manner not specified in this manual
- Any malfunction or damage attributable to any cause or causes beyond the reasonable control of HORIBA such as natural disasters
- Any deterioration in appearance attributable to corrosion, rust, and so on
- Replacement of consumables

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Generally, company names and brand names are either registered trademarks or trademarks of the respective companies.

For your safety

Warning messages are described in the following manner. Read the messages and follow the instructions carefully.

Meaning of warning messages

⚠ DANGER	This indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations.
⚠ WARNING	This indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
⚠ CAUTION	This indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices. Without safety alert indication of hazardous situation which, if not avoided, could result in property damage.

Symbols

❗	Description of what should be done, or what should be followed
⃠	Description of what should never be done, or what is prohibited

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For any questions regarding this product, please contact your local agency, or inquire from the HORIBA website.
(http://global.horiba.com/contact_e/index.htm)

■ Safety Precautions

This section provides precautions to enable you to use the product safely and correctly and to prevent injury and damage. The terms of DANGER, WARNING, and CAUTION indicate the degree of imminency and hazardous situation. Read the precautions carefully as it contains important safety messages.

⚠ CAUTION

Keep the exit of the flow cell open.
If the internal pressure exceeds 30 kPa, it may damage the product or a user.

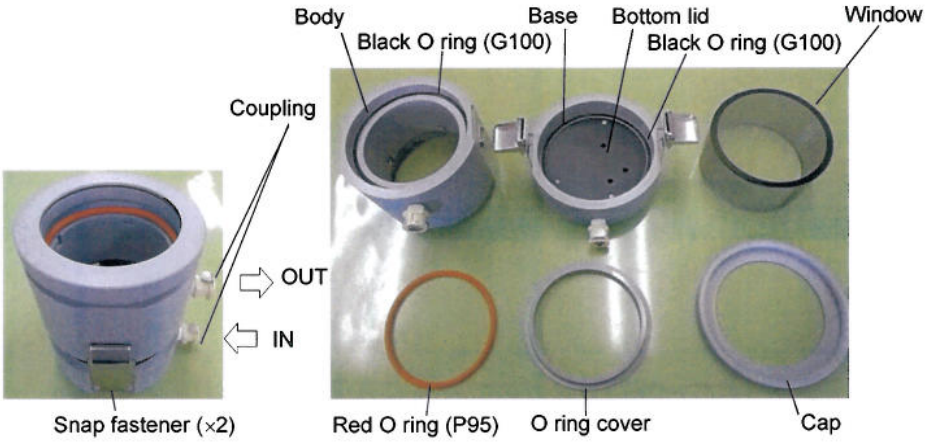
1 Specifications

Items	Specifications
Usable fluid	Water or water solution only
Flow rate	0.1 L/min to 0.5 L/min.
Sample temperature	−5°C to 55°C/23°F to 131°F
Inner diameter of connecting tube	6.4 mm (1/4 inch) or 9.5 mm (3/8 inch) I.D. tubes
Material	Polyvinylchloride, Stainless steel, Acrylic resin, FKM, Silicon rubber

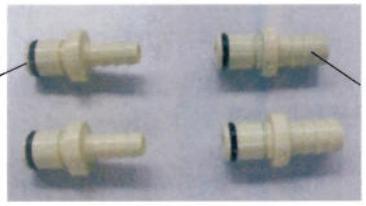
2 Precautions

- The flow cell U-50FC is applicable only to the sensor probe of U-50 series.
- Do not bend the tube and do not put something on the tube to avoid clogging the flow.
- It is necessary to keep the sensor probe standing vertically when measuring.
- The flow cell cannot be used for sample including organic solvent.
  Please use tap water and do not use organic solvent when you clean the flow cell.
- Do not use a hard brush when cleaning the cell to avoid rubbing the cell.
- Remove the sensor guard of sensor probe to set up the sensor probe to the flow cell. Becareful not to make the sensor hit to something.

3 Name of parts

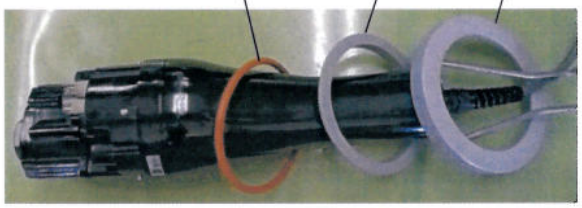


For fitting the sample IN/OUT tube

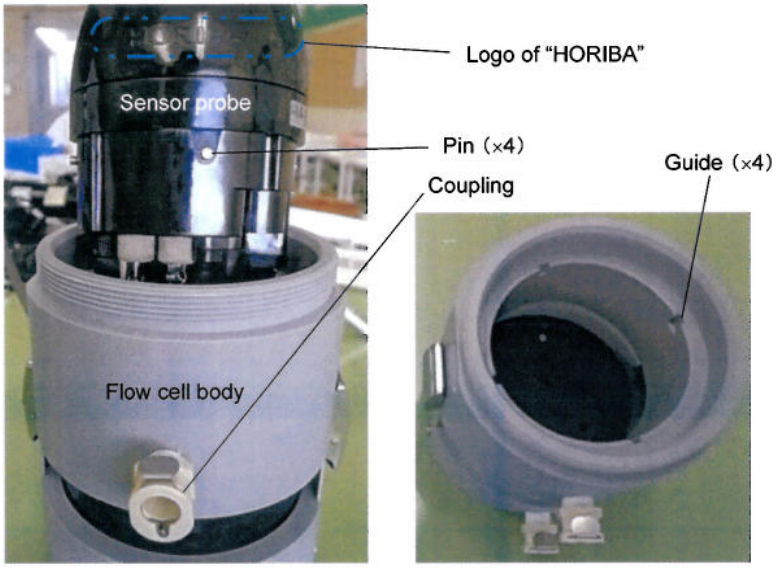


4 Setup

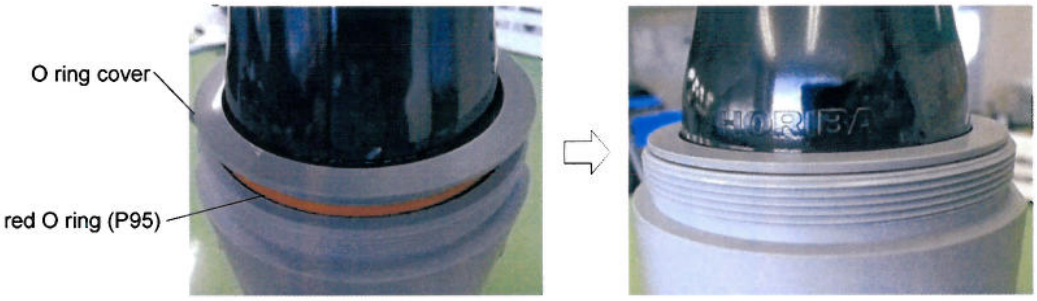
1. **Remove the cap, O ring cover, and red O ring (P95) from the flow cell body.**
2. **Pass the cap, O ring cover, and red O ring (P95) through the sensor probe from sensor side. Remove the sensor guard of sensor probe.**



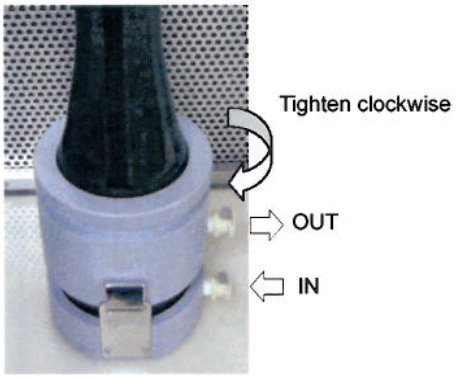
3. **Put the sensor probe in the flow cell so that four pins of the sensor probe may get into the guide of the flow cell body.**
   - Make the coupling of the flow cell and logo of "HORIBA" of the sensor probe the same direction. It is necessary to match the direction for accurate measurement of turbidity and dissolved oxygen.
   - After putting the sensor probe in the flow cell, turn the sensor probe clockwise until there is a hit according to the guide.
   - Confirm the sensor probe does not remove by pulling up it.



4. **Put red O ring (P95) between the sensor probe and the flow cell body, and push down it by O ring cover.**

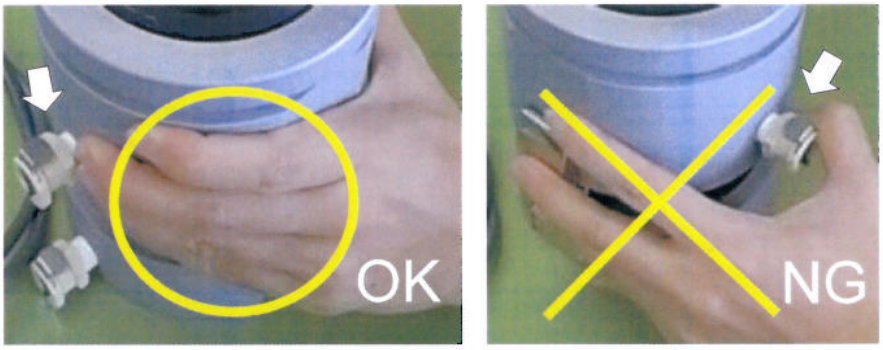


5. **Tighten the cap firmly, fit tubes to the fittings, and connect with the couplings.**
   Setup is completed.

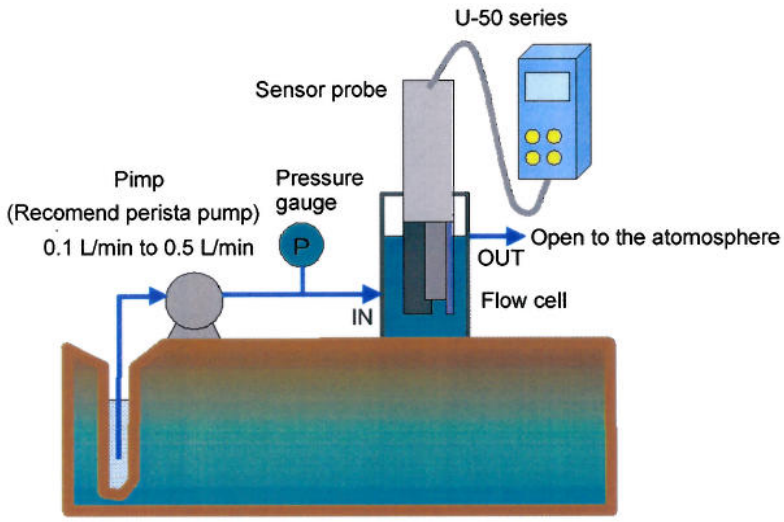


Note

Do not hold the couplings when you tighten the cap.



● **Example for installation of flow cell**



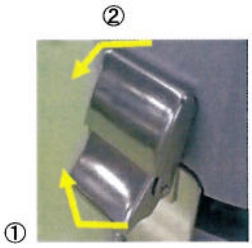
5 Confirmation of Flow rate

1. **Flow sample through the flow cell.**
2. **Spill effluent into your graduated cylinder for a fixed time.**
3. **Convert the amount of the effluent into the flow rate.**

6 Disassembling the flow cell

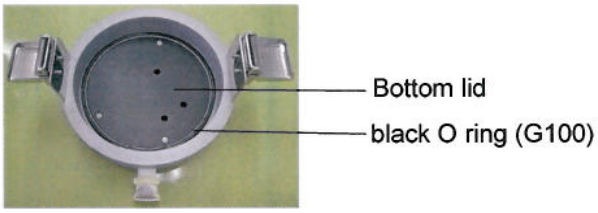
You can disassemble the flow cell so that it can be cleaned easily. It is recommended to clean the flow cell after the measurement.

1. **Remove the cap, O ring cover, and red O ring (P95) from the body.**
2. **Unfasten two snap fasteners.**



3. **Remove the body and remove the window.**

4. **Remove black O ring (G100) and the bottom lid.**



You can assemble in the reverse order.

Note

When leakage occurs, it may be the cause of O rings deterioration.
In this case, replace the red O ring (P95) and the black O ring (G100).
If leakage cannot be prevented by such countermeasure, contact your local agency.

Parts No.	Parts name	Note
3200192737	Red O ring (P95)	
3200192739	Black O ring (G100)	2 pcs./set

Appendix J

EPA Deliverable Guidance Documents

EPA Region 10
Monitoring and Analytical Data Deliverables
Data Submission Process for WQX Compatible Deliverables
For Yakima Dairies
(Docket No. SDWA-10-2013-0080)

Water Quality Exchange (WQX) is EPA's national database for long term storage of environmental monitoring data. Data that are placed in WQX are available to the public via both table-downloading functionality and map viewing applications deployed by EPA Headquarters. EPA Region 10 maintains a local version of WQX (called AWQMS) from which project-specific data mapping applications are served. Together these databases and mapping applications provide critical data-sharing and archiving functionality to project teams, external partners and stakeholders, and the public.

Data deliverables must contain the information specified in the Region 10 WQX Electronic Data Deliverable Specifications document (R10WQXEDD), contained in the attached zip file.

Data Submission Process for WQX Compatible Data

Monitoring and analytical data shall be submitted in tab-delimited text files prepared in accordance with specifications in the Region 10 WQX Electronic Data Deliverable (R10WQXEDD) which accompanies this document in zip file format (R10WQXEDD.zip).

Completed data files must be sent to EPA Region 10 via email. Each submittal must be accompanied by a cover letter that includes the following information:

- Submitting entity's name, affiliation, physical address, phone number, and email address
- Point of contact name, phone number, and email address
- Date of submittal
- Data file type, data file name, number of records
- Yakima Dairies (Docket No. SDWA-10-2013-0080)
- Comments or other information relating to the data submittal

Format of WQX Compatible Electronic Data Deliverables

All electronic data deliverables shall be reviewed for completeness as well as compliance with the R10WQXEDD specifications prior to submittal to EPA Region 10. The submitting entity is responsible for the content and quality of the data provided. If the deliverable is incomplete or erroneous, corrected data shall be re-submitted.

There are three general categories of data that are addressed in the attached R10WQXEDD: projects; stations; and physical and chemical results data. The R10WQXEDD provides detailed specifications on how each category of data should be formatted, identifies allowable values for the data fields (also known as data codes or valid values), and provides example data submittals.

Data shall be prepared as tab-delimited text files with column headers. Many software products allow for export of tab delimited text files (including Excel, Access, Notepad, and Open Office products). No other delimiters, such as quotation marks, commas, colons, or semi-colons shall be included in the files. No tabs shall be included in the actual data values themselves, and additional limitations on the use of special characters are identified in the R10WQXEDD. A set of allowable values are identified in the R10WQXEDD; however, because these may have been updated since release of the R10WQXEDD, referencing the most current list is recommended. It is available at: http://www.epa.gov/storet/wqx/wqx_getdomainvalueswebservice.html.

The attached R10WQXEDD.zip file contains the R10 WQX Electronic Data Deliverable (R10WQXEDD). It includes the following three templates which specify the format of data deliverables:

- R10WQXEDDPart1-ProjectandMonitorLocationTemplate.xlsx
- R10WQXEDDPart2-ActivitiesAndResultsTemplate.xlsx
- R10WQXEDDTemplateExamples.xlsx

EPA Region 10
Geographic Information Systems Data Deliverable Guidance
For Yakima Dairies
(Docket No. SDWA-10-2013-0080)

Introduction and Scope

This document is intended to provide specific requirements and file delivery formats for Geographic Information System (GIS) products which are generated by external entities for submission to EPA. These products include GIS and imagery files.

GIS Data Files

GIS data files must be in a format specified in this document. All electronic geospatial data, whether vector or raster, must include a correct definition of the map projection and coordinate system, either embedded in, or associated with, the data file. In the case of CAD data, the projection must NOT be in page space or a custom site-specific projection. All CAD data shall be in known real world coordinate space, ideally in geographic/decimal degrees/NAD83. Should tabular data containing attribute information be appropriate to connect to location information then documentation must be provided that describes the nature of the relationship between the location data and tabular data, including cardinality, primary and foreign keys, and field definitions. Should coordinate information be provided in tabular format it should contain at minimum the following fields:

ID – a unique identifier given to each feature

Latitude – the Y coordinate in decimal degrees

Longitude – the X coordinate in decimal degrees

Horizontal Datum – the datum of the coordinates

Collection Method – if known provide a brief description (e.g. GPS, address geocoding, map interpolation)

Additionally, all static maps must be in an electronic Adobe PDF format with fonts embedded and at a resolution of 300 dots per inch (dpi) or greater. Finally, all ArcMap documents (.mxd) or equivalent map document files used in final map production are also required for delivery to EPA with accompanying data in a stand-alone directory structure. Map document (.mxd) formats also need to be configured to use relative paths and not be set to use a printer-specific paper setting.

Metadata and Projection Requirements

Federal Geographic Data Committee (FGDC) compliant metadata on all GIS data files must be developed for deliverables. It is important to understand that deliverables are not considered complete without metadata. Region 10 also requires that all dynamic maps (ArcMap documents) have metadata completed. The Content Standard for Digital Geospatial Metadata can be found at

http://www.fgdc.gov/. Metadata, including information about the data's projection, can be developed using one of several built-in or add on tools within a GIS, and typically is associated with the geometry file as an XML file. EPA has created the EPA Metadata Editor (EME) which is available for free download from: https://edg.epa.gov/EME/ and this tool can be used to help create FGDC compliant metadata.

All GIS files submitted to EPA must have spatial reference information that describes the projection, datum, and where applicable the collection methods. All vector data must be submitted in geographic coordinate system, decimal degree units, and either NAD83 or WGS84 datum. Raster data, such as aerial photographs may be submitted in their native projection, and maps should be in the appropriate projection/coordinate system for the area depicted.

Delivery Requirements and Standard Organizational Structures

EPA will accept data delivered on CD-ROM, DVD, or external hard drive, as well as direct electronic submission via email or FTP site.

A directory structure and readme text file in the upper level directory that describes the structure are required. A recommended directory structure is as follows:

<Project_Name>

|_ **Docs** (reports, SOPs, correspondence, and other such documents)

|_ **Images** (aerial photos, satellite imagery, logos, DEMs, and other raster type data)

|_ **Maps** (MXDs and PDFs. Map names should use the project name as a prefix)

|_ **Shapes** (geodatabases, shape files, and other approved vector data formats)

|_ **Source** (original unmodified data that may have been acquired from external/internal sources)

|_ **Tables** (MS-Access databases, spreadsheets, delimited text files, or other such tabular data not stored in a geodatabase)

File naming conventions shall be descriptive, dated, consistent, and contain no spaces or special characters. An underscore may be used in lieu of a space.

EPA Acceptable Data Formats

The following file formats are considered acceptable and all maps and data must include an associated metadata document:

DATA
Vector - projected to geographic, decimal degrees, NAD83/WGS84 (preferred) – other defined projections allowed
Shape File (.shp, .shx, .dbf, .prj, .sbx, .sbn) File Geodatabase (.gdb) Personal Geodatabase (.mdb) XML Workspace Document with dependencies clearly documented (.xml)
Raster - native projection acceptable
TIFF image with world reference file or as a GeoTIFF (.tif, .tfw) JPEG image with world reference file (.jpg, .jpw) ERDAS Imagine image with pyramid file (.img, .rrd) MrSid image (.sid) ESRI Grid DEM
Terrain Dataset - appropriate real world projection/coordinate system for the area depicted
File Geodatabase (.gdb) for mass point collections (e.g. lidar, sonar, photogrammetric data)
TINs - appropriate real world projection/coordinate system for the area depicted
ESRI TIN
CAD - appropriate real world projection/coordinate system for the area depicted
DXF layer separates (.dxf)
Tabular - primary and foreign keys should be clearly identified/documented
MS-Access database (.mdb) MS-Excel spreadsheet (.xls) Delimited text file (.txt, .csv)
MAPS
Static
Adobe PDF at 300 dpi or better with embedded fonts (.pdf)
Dynamic
ArcMap document with associated data files in a stand-alone directory structure using relative paths (.mxd)
FGDC Compliant METADATA
XML (.xml) FGDC CSDGM XML (.xml) ArcMap (.mxd) "Description" metadata within the document

CHECKLIST

The following checklist may be used to assist in complying with these standards:

	DATA
	Is each vector file, CAD included, in geographic, decimal degrees, NAD83 or WGS84?
	Is each raster file in its native projection?
	Is each data file one of the EPA acceptable formats?
	Does each data file have FGDC compliant metadata in an associated file?
	Are the primary and foreign keys documented for tabular data?
	Is a README text file included with a directory structure explaining how the structure is organized?
	MAPS
	Is each static map provided in an electronic format at a resolution of 300 dpi or higher?
	Does each static map have fonts embedded?
	Has the page and print setup for map documents been configured to NOT use printer-specific paper settings?
	Are map documents set to use relative paths?
	Are map names prefixed with the project name?
	Are map documents accompanied with their relevant data in a stand-alone directory structure?
	Does each map have FGDC compliant metadata in an associated file?