Appendix 5: Field Practices for Ground-Water Data Collection

Field Practices for Ground-Water Levels

5.2.1 Minimum Field Standards

The following section outlines various methods and techniques to make consistent periodic and continuous water-level measurements. The field collection of ground-water levels includes a number of important elements to ensure data quality, including:

- Training
- Pre-collection site review and preparation
- On-site preparation
- Water-level collection and data recording

Field-sampling procedures must take these elements into account in order to ensure that:

- Water levels are being taken at the correct location, source, and time
- Water-level data are handled in a manner that preserves their integrity and data value
- Information recorded during measurements contains all of the information needed to normalize and compare analysis results
- Measures are taken to ensure the accuracy of the result

This appendix outlines specific procedures and documents most of the minimum elements needed to define the standards of a successful field exercise; however, the elements of the water-level program should be defined in a written set of procedures specific to the field exercise.

5.2.1.1 Training

Operator training is necessary prior to field collection of ground-water levels to ensure consistent data quality. This document and the documents referenced herein can serve as the fundamental basis for that training. Appropriate training includes formal training classes through universities or vendors and hands-on field experience through mentoring, on-site (on the job), and follow-up training to ensure that data are being collected consistently and correctly. Examples of training include:

- Establishment of measurement point
- Water-level measurement with electric or steel tape
- Field measurements with a continuous recorder or pressure transducers
- Decontamination of field equipment
- Data recording and entry
- Safety
- Decontamination methods

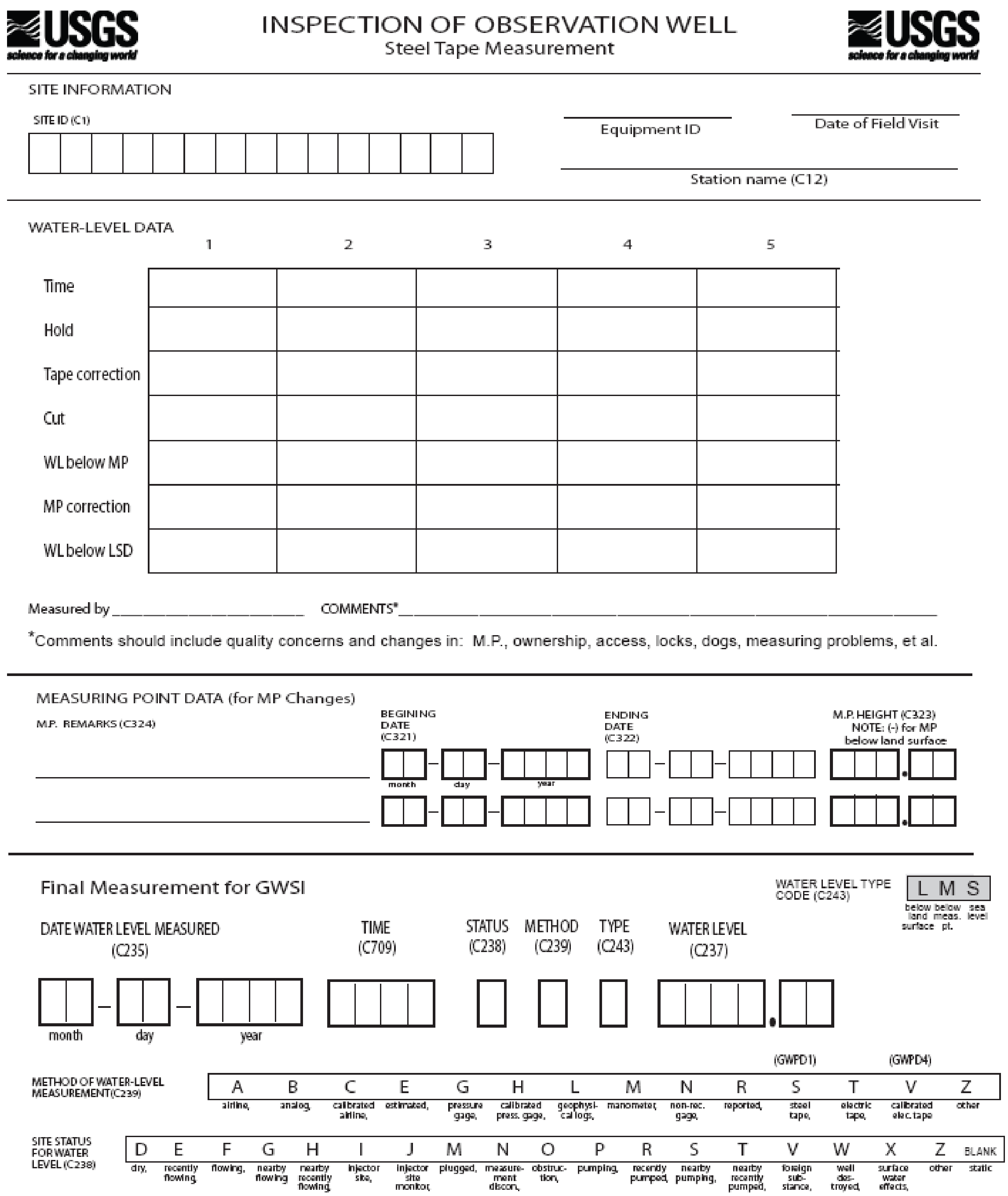
5.2.1.2 Pre-Collection Site Review and Preparation

Preparation for water-level measurements includes the gathering of equipment and supplies. Creating a checklist of the equipment and supplies needed for each measurement trip will help the measurer avoid delays and prevent the collection of invalid measurements. For example, a checklist should include all equipment such as wrenches, keys, site folder, including photographs, maps, etc., and field computer (if applicable). Additionally, equipment that will be used to collect continuous water levels should be calibrated and tested to ensure accuracy. Decontamination and calibration of steel and electric tapes should be conducted as near in time as practical to field measurement. A record of decontamination and calibration should be maintained for all equipment. Sheets for recording water-level measurements should include space for the name of the well, date, time, water level below measurement point, land surface correction, elevation of measurement point, etc.

A recommended list of equipment and materials for miscellaneous water-level measurements follows:

A suitable map (optionally, an aerial photograph and a town plat/lot number map), compass or handheld global positioning system (GPS), site form for recording site information, water-level measurement form (**figure 5.2.1.2**), steel tape (graduated in feet, tenths, and hundredths of feet) optionally with an attached weight made of brass, steel or iron, blue carpenters chalk and clean rags, an electric water-level measurement tape, pen, blue or black ink, at least two adjustable wrenches, allen wrenches, hammer or other tools needed for well access, a bottle of sodium-hypochlorite for disinfection, and latex-free vinyl gloves.

Prior knowledge of measurement site conditions is essential to the successful collection of measurements. For example, prior knowledge of water-level depth below measurement point can be helpful to determine length of steel tape to be chalked.



USGS science for a changing world

INSPECTION OF OBSERVATION WELL
Steel Tape Measurement

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SITE INFORMATION

SITE ID (C1)

Equipment ID

Date of Field Visit

Station name (C12)

WATER-LEVEL DATA

	1	2	3	4	5
Time					
Hold					
Tape correction					
Cut					
WL below MP					
MP correction					
WL below LSD					

Measured by ______________________ COMMENTS*______________________

*Comments should include quality concerns and changes in: M.P., ownership, access, locks, dogs, measuring problems, et al.

MEASURING POINT DATA (for MP Changes)

M.P. REMARKS (C324)

BEGINING DATE (C321) — month – day – year

ENDING DATE (C322)

M.P. HEIGHT (C323) NOTE: (-) for MP below land surface

Final Measurement for GWSI

WATER LEVEL TYPE CODE (C243): L M S (below land surface, below meas. pt., sea level)

DATE WATER LEVEL MEASURED (C235): month – day – year

TIME (C709)

STATUS (C238)

METHOD (C239)

TYPE (C243)

WATER LEVEL (C237)

METHOD OF WATER-LEVEL MEASUREMENT (C239): A airline, B analog, C calibrated airline, E estimated, G pressure gage, H calibrated press. gage, L geophysical logs, M manometer, N non-rec. gage, R reported, S steel tape, (GWPD1) T electric tape, V calibrated elec. tape (GWPD4), Z other

SITE STATUS FOR WATER LEVEL (C238): D dry, E recently flowing, F flowing, G nearby flowing, H nearby recently flowing, I injector site, J injector site monitor, M plugged, N measurement discon., O obstruction, P pumping, R recently pumped, S nearby pumping, T nearby recently pumped, V foreign substance, W well destroyed, X surface water effects, Z other, BLANK static

Figure 5.2.1.2: Ground-water level measurement form for steel tape.

5.2.1.3 Minimum Data Elements

Each water-level measurement site has inherent data elements that need to be verified and recorded preferably prior to water-level measurements. The person making the water-level measurement should check to ensure minimum data elements are available prior to conducting measurements to ensure that it is accurate and up to date when in the field. Corrections and updates to the information should be made prior to measurement.

The ASTM has a recommended list of minimum data elements for inclusion in a ground-water level network (ASTM, 2007) as does the USGS (Drost, 2005), USEPA, and other regional and State agencies. A compiled list of minimum data elements for reporting water-level results for a national network of ground-water wells is described in Appendix 6.

5.2.1.4 Onsite Preparation

Preparing the site for measurement should include the following elements:

- Site verification. This can be accomplished in several ways including having made a previous visit to the site, comparing the site to a known grid reference using Global Positioning System equipment, comparing photographs of the listed site to the actual site, or identifying the site by a physical label on the wellhead or identifying sign.
- Equipment decontamination. Equipment must be decontaminated between water-level collections to prevent cross contamination between wells.
- Site condition notations. These include the date and time of day, weather conditions (rain, snow, etc.), measurement-point condition, damage, deterioration and any other factors that could affect the results of the current water-level measurement or future measurements.
- Site access. This may include access to the property (gate opening, etc.) and opening the cap or shelter that encloses the well.
- Establishing a site measurement point. (see Drost, 2000, section 8—Appendixes; GWPD 8.1h—Establishing a measuring point).

5.2.1.5 Water-Level Measurements

Numerous technical procedures have been written to describe the procedures to use when measuring water levels, either manually or with recorders designed to automatically measure water levels on a continuous basis. Procedures from USEPA, USGS, ASTM, WMO were evaluated. Because these technical procedures do not appreciably vary in terms of the quality of data that would result, the following sections refer to the technical procedures already documented by these organizations.

All measurements should be recorded either on a computer/personal data assistant (PDA) or on paper forms (see figure 5.2.1.2). If electronic recording of measurements is chosen, all information required on the paper form also should be available electronically. Electronic files should be downloaded when returning from the field and backed up as a method for retaining original field measurements. Field measurements recorded on paper should be electronically entered into available databases shortly after returning from the field. Paper forms should be filed appropriately and not returned to the field.

5.2.1.5.1 Manual Water-Level Measurements

All manual water-level measurements should be designed to have repeatable and accurate methods of determining the elevation of the water-level surface. Manual (or discrete) water-level measurements can be made by use of several methods, including the graduated steel or wetted tape method (USEPA, 2001; Drost, 2005 (GWPD 8.1d); ASTM, 2007a), the electric-tape method (USEPA, 2001; Drost, 2005 (GWPD 8.1e); ASTM, 2007a), the air-line method (Drost, 2005 (GWPD 8.1f), or recent noncontact methods, such as sound waves and radar waves (see the main report, Section 5.5—New Technologies).

The method one chooses to use depends on the conditions of the site (such as well construction, well diameter, depth of the well, and accessibility) and status of the water level (for example, flowing wells require different methods than nonflowing wells; see Drost, 2005 (GWPD 8.1g)).

5.2.1.5.2 Automated Water-Level Measurements

Automated water-level measurements are made so that a continuous (or near-continuous) record of water levels can be made with minimal human intervention. Automated (continuous or near-continuous) water-level measurements can be made with pressure transducers (Drost, 2005 (GWPD 8.1j)) or float-activated recorders (USGS, 1981; Rantz and others, 1982; WMO, 1994). Regardless of the method of measurement, care should be taken to ensure that the entire expected range of water levels can be measured with the device at the expected accuracy. For example, a well with a relatively shallow water level (<30 ft) and small (<10 ft) change in water level might require a lower rated (0-5 psi) pressure transducer to ensure accuracy to within 0.01 ft (Freeman and others, 2002). Use of a higher rated (10-30 psi) pressure transducer might limit the accuracy of the data.

Generally, the water-level recorder should be placed in a well and calibrated against a manual water-level measurement (+/–0.01 ft). A calibration worksheet (for example, see Freeman and others, 2002) and other documentation should be maintained to ensure accurate measurements, including date/time of calibration; the type, serial number, and range of measurement device; and what units are being measured (ft, psi, m). A field form should be located in the shelter house or wellhead, or taken to the field for future water-level measurements and calibration.

5.2.2 Minimum Data Standards

The following section outlines various standards to which water-level measurements should adhere, to ensure a nationally consistent level of data quality. Various types of water-level measurements can be made, and the standards vary with the type of equipment used to make the measurements.

5.2.2.1 Manual Water-Level Measurements

In general, manual water-level measurements should be made repeatedly to ensure the measurement is accurate to within at least 0.02 ft between consecutive measurements. For electric-tape measurements, the USGS (Wilde and others, 1999; Drost, 2005) recommends that at least three measurements be made, with two consecutive measurements within 0.02 ft. Some methods of manual measurement (acoustic, air-line, flowing wells) will not have that level of repeatability (see documentation above). Regardless of the method of measurement, all measurements should be recorded for the record or the archive and the accuracy of the water-level measurements (based on the repeatability of the measurements) should be made and documented.

5.2.2.2 Automated Water-Level Measurements

The accuracy of automated (continuous) water-level measurements should be at least 0.02 ft. Instrument drift and faulty instrumentation can affect the accuracy and limitations of the data collected.

The frequency of which the water-level recorder should be visited should be based on the stability of the transducer, the storage limitations of the recording device, and knowledge of the expected hydrograph of the aquifer. Generally, a routinely scheduled field visit of 6-8 weeks should be sufficient. Regardless of the measurement device, measurements should be made often enough that the recording devices onsite will not run out of paper/memory and so that the accuracy of the measurements is not compromised through excessive drift or range of water level. A large annual drawdown/recharge cycle would necessitate additional visits and perhaps require resetting the float or transducer during different parts of the hydrograph cycle. Real-time (or near-real-time) telemetry can also be added to the well; a stable well displaying real-time data may be visited much less frequently than other wells.

Instrument drift corrections, calibration corrections, and datum corrections all can affect the accuracy of measurements and should be applied after downloading the data.

5.2.3 Data Handling and Management

Throughout this document, stress is placed on documentation of field and office procedures to ensure that the quality of the data is not compromised. This section covers some specific data handling and management procedures that might not have been covered previously, either in this document or in documents that were referenced herein. Much of this section is derived from Sauer (2001), which was developed for surface-water electronic data entry and analysis; however, many of the concepts are completely analogous to ground-water data.

5.2.3.1 Electronic Entry of Data

The first step in processing water-level data is entry of unit value data (measured or computed values associated with a specific instantaneous date and time), field data, and related information into an electronic database and/or processing system. Field data may include water-level measurements (with associated time and date), elevation of measurement point, site conditions and other remarks, or notes from the site (Sauer, 2001).

5.2.3.2 Verification and Editing of Unit Values

Unit values must be checked carefully and verified against field measurements before being used in further analysis. Erroneous or suspicious values may require editing and identifying individual values that might be incorrect, relative to field measurements or to known extremes of record. Prior to editing, original unit values should be archived; a copy of the original data file should be edited, and this copy should also be archived upon completion of editing (Sauer, 2001).

Various issues can arise in the collection of unit value data, including errors with times and dates and instrument drift or datum errors. Sauer (2001) provides methods for corrections for time, date, instrument, and datum errors that are analogous to ground-water unit-value data. One major difference between ground-water data and surface-water data that should be pointed out is treatment of missing values: in surface-water analysis, missing values are sometimes estimated relative to an established rating curve; in ground-water, missing values typically are not estimated because of the heterogeneous nature of most ground-water systems.

5.2.3.3 Verification and Analysis of Field-Measurement Data

Field-measurement data includes discrete water-level measurements, well-construction data, and miscellaneous field notes. Field-measurement and related data usually are entered into the electronic system in the office, although some data can be entered by PDA's or portable field computers. Various computations and comparisons should be made to ensure accuracy of the data and consistency of the information (Sauer, 2001).

Arithmetic errors (such as a conversion from water-level depth below measurement point to water-level depth below land surface), transcription errors, and logic errors (such as depth of well less than water level), should all be checked and corrected before final entry into the database. All data should be entered into the database with the same precision and significant figures as recorded in the field. Calculated values should be rounded to the significant figures recorded in the field notes. Significant figures for water-level measurements typically are the same as for water-surface gage height and elevation for surface-water data (Sauer, 2001; table 2). Measurement point elevations (analogous to gage datum analysis in Sauer, 2001) should be a permanent datum maintained as accurately as possible throughout the lifetime of the station. Surveying or leveling should be performed periodically to ensure that corrections can be made to adjust for movement of the datum.

It cannot be stressed enough that original paper records should not be modified, deleted or erased, or returned to the field because this increases the chance they will get damaged or lost. Archival of these paper notes should be done so that all editing of errors, instrument or time drift corrections, and such can be recreated if necessary.

5.2.4 Measurement Frequency

The contents of this section have been incorporated into the main body of the report.

Field Practices for Ground-Water Quality

5.3.1 Minimum Field Standards

The implementation of minimum standards for collecting water-quality samples is critical to the value of the data derived from an analysis of the samples. Proper attention to pre-sampling site review and sampling preparation, on-site preparation, collection procedures, sample preservation and handling, and use of appropriate data recording will ensure that information obtained can be integrated into a national monitoring network data-collection system and will be comparable to other sample data in both space and time.

5.3.1.2 Pre-Collection Site Review and Preparation

Planning and preparing for a ground-water-sampling event is an important step in the sampling process. Each sampling site has inherent data elements that need to be verified prior to sampling. For example, the name, location, sampling source, sampling depth, and aquifer name should be known. The sampler should check this information prior to conducting sampling to ensure that it is accurate and up to date. Corrections and updates to the information should be made prior to sampling. Preparation for sampling includes the gathering of equipment and supplies. Creating a checklist of the equipment and supplies needed for each sampling will help the sampler avoid delays and prevent the collection of invalid samples. For example, a checklist should include all equipment such as, pumps, bailers, probes, analysis kits, meters, and coolers and all supplies such as batteries, bottles, preservatives, cooling media, forms, labels, filter media, tape, and gloves. Additionally, equipment that will be used to collect and/or conduct a field analysis of samples should be decontaminated and calibrated in accordance with the manufacturer’s instructions. Calibration solutions should only be used if they are within the shelf life recommended by the manufacturer. Decontamination and calibration should be conducted as near in time as practicable to field sampling. A record of decontamination and calibration should be maintained for all equipment.

Prior knowledge of sampling site conditions is essential to the successful collection of samples. For example, knowing that a sampling point is located in a gully that is prone to flooding could prevent unnecessary time being spent attempting to sample during wet conditions and could affect the methods used to clean the sampling point prior to sampling. Other factors, such as knowing whether or not the sampling point has a functional pump or is secured with a lock, can help the sampler avoid foreseeable problems.

The sampler should determine sampling container need for each field-sampling event and either obtain pre-treated or prepared sample containers from the laboratory that will conduct the analyses or prepare containers themselves using appropriate pre-treatment or decontamination procedures.

5.3.1.3 Minimum Data Elements

Each water-quality measurement site has inherent data elements that need to be verified and recorded either prior to or during the sampling event. The person making the water-quality measurement should check to ensure minimum data elements are available prior to conducting the sampling to ensure that it is accurate and up to date when in the field. Corrections and updates to the information should be made prior to making a measurement.

The following is a list of the minimum data elements that should be recorded as part of a sampling event; some of these are the same or similar to the minimum data elements required for a water-level measurement:

Site/well information:

- Site name: A unique identifier for the well such as a well number or state registration number

- Grid reference: The coordinates of the well in either latitude/longitude or UTM coordinates (NOTE: If UTM coordinates are used, the datum also should be recorded)
- Section, Township, Range and footages from at least two lines for states that use the rectangular survey system
- Contact information: Name, address, and telephone number of the person on whose property the well resides (if available)
- Operating interval: The depth to the top and bottom of the screened, slotted, or open-hole interval
- Total depth: The total depth of the wellbore
- Fluid level: Depth to top of fluid prior to purging
- Pump depth (if known)
- Pump status: Pump on or off upon arrival
- Pump status time: Time pump was started prior to arrival, if known
- Well construction
- Measuring point: The identification of the point on the wellhead from which the depth to top of fluid was measured.
- Measuring point elevation: The elevation of the measuring point typically given in feet above or below sea level.
- Special instructions: Any instruction specific to the sampling site that will facilitate future sampling such as pump configuration, wellhead locking or capping, and fluid depth.

Sampling information:

- Sampling procedure: The identification of the sampling procedure used.
- Date and time of sampling
- Weather: The conditions present during sampling such as air temperature, humidity, and precipitation.
- Name of sampler
- Affiliation of sampler: Name of the sampler's organization or company
- Purge method: The method used to purge the well such as pumping, bailing, etc.
- Purge volume: The calculated volume of fluid to be purged from the well
- Sample appearance: The color, turbidity or cloudiness, and odor (e.g., strong or weak, metallic or sulphuric etc.) of the sample
- Preservation: The precise preservation and handling techniques used on each sample (e.g. filtered, preserved using a X% nitric acid solution to a pH of less than 2 and cooled to less than 4° C)
- Analyses: A list of the analyses to be conducted on the sample
- Method: The specific analytical method to be used to test the sample (e.g., EPA Method 300.1)
- Transfer date: The date on which the custody of the sample was transferred to the laboratory.

5.3.1.4 Onsite Preparation

Preparing the site for sampling should include the following elements:

- Site verification. This can be accomplished in several ways including having made a previous visit to the site, comparing the site to a known grid reference using GPS equipment, comparing photographs of the listed site to the actual site, and identifying the site by a physical label on the wellhead or on an identifying sign.
- Cleaning the sampling point. Depending on the analysis to be conducted, the cleaning of the sampling point may be as simple as washing the wellhead or spigot or as complex as sterilization. Prior knowledge of the sampling parameters will determine which cleaning methods are appropriate for the sampling point.
- Equipment decontamination. Equipment must be decontaminated between sample collections.
- Pre-purging measurement of depth to top of fluid. Fluid measurement should be taken using an appropriate physical process such as a steel tape or electronic probe. Taking a Barometric pressure reading can also assist the sampler in the proper interpretation of the water level.
- Purge calculation. The amount of fluid that must be purged from a well prior to sample capture can be calculated using several methods including prior knowledge of purge volumes for the site or the use of a formula that takes into account the depth of the well, radius of the casing, and depth to top of fluid to estimate the total volume of fluid contained within the casing. Regardless of the method used, wells should be purged of no less than three casing volumes.
- Pump installation (if needed).
- Fluid level measurement. Determining the fluid level is important because fluid levels can have an effect on analytical results. Consequently, the fluid level becomes one of the parameters that must be considered when normalizing the data obtained from sampling. NOTE: It is recommended that the tape or probe used to measure fluid level be decontaminated prior to use.
- Site condition notations. These include the date and time of day, weather conditions, sample point condition, e.g., damage, deterioration etc., and any other factors that could affect the results of a sample analysis.

5.3.1.5 Sample Collection

Sample collection techniques play an important role in sample viability. The use of appropriate sample containers and collection techniques are critical elements of proper sample collection. Additionally, the proper purging of the wellbore is essential to the collection of a representative sample of formation fluids. Viable sample collection specifications should include the following elements:

Purging of at least three casing volumes of fluid is necessary. During purging, the sampler should monitor the temperature, conductivity, and pH to assess the adequacy of the purging operation and record the results at least once for each casing volume of fluid purged. If possible, continuous water-level measurements in the well during purging should be made to ensure that drawdown of more than 1 ft if the pump inlet is above a screened interval or 6 inches if the pump inlet is within the screened interval does not occur. Whenever possible, purging should be conducted using low-flow purging techniques.

- Purging efficacy check. The purging operation is complete if:
  - A total of three casing volumes of fluid has passed through the tubing connecting the pump to the container, and
  - The difference between the last two field measurements of temperature, conductivity, and pH falls within the following change allowance:
    - Temperature ± 0.2°C
    - Conductivity ± 3%
    - pH ± 0.1 pH unit.
- Sampler preparation. Depending on the parameters to be analyzed, the sampler may need to put on clean or, if possible, sterile powder-free latex gloves before sampling.
- Sample container preparation. Sample containers should be labeled prior to use and should be appropriate for the sample being collected. For example, at some laboratories samples collected to measure chlorofluorcarbons require a glass bottle with a capacity of at least 125 milliliters (mL), whereas an acid-preserved sample should be collected in a new or acid-washed plastic, polyethylene, or polypropylene bottle. A list of appropriate sampling containers, seals, and volumes can be found in the laboratory's Quality Assurance Management Plan.
- Filling method. Samples should be collected under laminar flow conditions. Thus, the pumping rate for sample collection should be low enough to prevent turbulent flow or aeration of the sample. Further, the collection tube should be placed at the bottom of the sampling container, and the container should be filled slowly and evenly until the container is overflowing to prevent the introduction of air into the sample. This is a typical sample-collection method; however, the specific method used to fill containers should reflect the type of analyses to be performed.

5.3.1.6 Sampling Preservation, Handling, and Transport

After collection of the sample, it may be necessary to preserve or chill the sample to prevent degradation. A list of appropriate sample preservation techniques can be found in the laboratory Quality Assurance Management Plan. The need for sample preservation or chilling is based on the analyses to be conducted. For example, samples collected for the analysis of cations or metals must be preserved using nitric acid to a pH of less than 2 and such samples may be, but need not be, chilled, provided they do not freeze. Also, many samples have a holding time restriction. For example, samples collected for total dissolved solids have a holding time of no more than 28 days from date of collection. A list of appropriate sample holding times can be found in the laboratory Quality Assurance Management Plan. Samples should be transported in appropriate clean coolers or containers that are designed to keep the contents at a constant or even temperature, prevent the spillage of samples, and prevent damage to sample containers from reasonable impacts.

5.3.2 Automated Water-Quality Measurements

The use of real-time/automated water-quality measurements in routine ground-water-quality monitoring programs is atypical for most parameters. Inasmuch as the well must be purged prior to sampling in order to obtain representative samples, in most ground-water systems the use of such automated sampling without well purging would not be expected to yield data that represent formation conditions. Consequently, it is recommended that unless a system is designed to purge the well prior to automated sampling, water-quality samples be obtained during a field-sampling event by using the procedures described in Section 5.3.1.5 above.

5.3.3 Data Handling and management

Throughout this document, emphasis is placed on documentation of field and office procedures to ensure that the quality of the data is not compromised. This section covers specific data handling and management procedures that may not have been covered previously, either in this document or in documents that are referenced herein. The information in this section is primarily drawn from *"A National Protocol for State of the Environment Groundwater Sampling in New Zealand", (Ministry for the Environment, 2006).*

5.3.3.1 Data Recording

Because the collection of data from the analysis of ground-water samples is the principal purpose of sampling, the onsite recording of data is essential to the comparability of the data being collected. The methods used to collect field data range from pen and paper on forms to direct electronic data entry into a database. Although the methods used to collect data in the field vary, the final goal is the electronic entry of data into a database. A critical factor in collecting field data is having a structured method of collection so that critical elements are not left out. For example, simply entering the data elements into a field notebook without benefit of a form that contains a list of the elements is more likely to result in the omission of important information. Electronic field data collection is preferable for many reasons. For example, the use of an existing database can eliminate errors such as misidentification of wells or entering data that fall outside an established set of data parameter limits. Further, the use of electronic data entry can save time and prevent transcription errors because there would be no need to conduct separate data entry after the fact.

5.3.4 Sampling Frequency

The contents of this section have been incorporated into the main body of the report.