# Underground Injection Control

# Carbon Sequestration

# Class VI Permit Application

## QUALITY ASSURANCE AND SURVEILLANCE PLAN

## 40 CFR 146.90(k)

## Section 8.11

## Tallgrass High Plains Carbon Storage, LLC
## Western Nebraska Sequestration Hub

January 2025

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# 8.9 QUALITY ASSURANCE AND SURVEILLANCE PLAN 40 CFR 146.90(k)

## WESTERN NEBRASKA SEQUESTRATION HUB

### Facility Information

| | |
|---|---|
| Facility name: | Western Nebraska Sequestration Hub<br>Conestoga I-1 |
| Facility contacts: | **Craig Spreadbury \| Vice President, Carbon Capture & Sequestration**<br>Tallgrass High Plains Carbon Storage, LLC<br>370 Van Gordon St<br>Lakewood, CO 80228<br>craig.spreadbury@tallgrass.com<br><br>**Jessica Gregg \| Director, Geoscience Compliance**<br>Tallgrass High Plains Carbon Storage, LLC<br>370 Van Gordon St<br>Lakewood, CO 80228<br>jessica.gregg@tallgrass.com |
| Well location: | Kimball County, Nebraska<br>[redacted] |

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## Acronyms and Abbreviations

| | |
|---|---|
| 2D | two-dimensional |
| °C | degrees Celsius |
| µS/cm | microseconds per centimeter |
| **A** | |
| AoR | area of review |
| ASTM | American Society for Testing and Materials |
| **C** | |
| CBL | cement bond log |
| CG | gas chromatography |
| $CO_2$ | carbon dioxide |
| **D** | |
| DAS | distributed acoustic sensing |
| DTS | distributed temperature survey |
| DO | dissolved oxygen |
| **E** | |
| EPA | U.S. Environmental Protection Agency |
| **M** | |
| MFL | Magnetic flux leakage casing inspection tool |
| meq | milliequivalents |
| MIT | mechanical integrity testing |
| MVA | monitoring, verification, and accounting |
| **N** | |
| NACE | National Associated of Corrosion Engineers |
| **P** | |
| PISC | post-injection site care and closure |
| Project | San Juan Basin, New Mexico Carbon Sequestration Project |
| PNL | pulsed neutron logging |
| **Q** | |
| QA | quality assurance |
| QASP | quality assurance and surveillance plan |
| QA/QC | quality assurance/quality control |
| QC | quality control |
| **S** | |
| SCADA | supervisory control and data acquisition |
| SOP | standard operating procedures |
| **T** | |
| TBD | to be determined |
| TDS | total dissolved solids |
| **U** | |
| UIC | Underground Injection Control |
| USDW | underground sources of drinking water |
| USIT | ultra sonic imager tool |

## TITLE AND APPROVAL SHEET

The Quality Assurance and Surveillance Plan (QASP) will be developed as details of the facility are finalized, including, but not limited to surface and sub-surface equipment and infrastructure, details of instrumentation, sampling and analytical procedures, organizational structure and personnel, and record keeping.

This QASP is approved for use and implementation at DJ Basin, Nebraska Carbon Sequestration Project, Conestoga I-1.

The signatures below denote the approval of this document and intend to abide by the procedures outlined within.

1/28/25

Signature Date
Craig Spreadbury
Vice President, Carbon Capture & Sequestration

1/27/25

Signature Date
Jessica Gregg
Director, Geoscience Compliance

## DISTRIBUTION LIST

The DJ Basin, Nebraska Carbon Sequestration Project (Project) participants, acting as key project managers (listed below), will receive the completed QASP and all future updates for the duration of the Project.

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# 8 TESTING AND MONITORING PLAN (CONT.)

## *8.11 Quality Assurance and Surveillance Plan*

## *A. PROJECT MANAGEMENT*

### A.1 Project/Task Organization

#### *A.1.a Key Individuals and Responsibilities*

Tallgrass High Plains Carbon Storage, LLC (High Plains) Project Managers will lead the Project with testing and monitoring activities shared among the High Plains staff. The Project is divided into five subcategories:

- Groundwater Monitoring Well Logging
- Mechanical Integrity Testing (MIT)
- Pressure/Temperature Monitoring
- Carbon Dioxide ($CO_2$) Stream Analysis
- Geophysical Monitoring

#### *A.1.b Independence from Project Quality Assurance Manager and Data Gathering*

The Testing and Monitoring Plan data is analyzed, processed, or witnessed by independent third parties outside the Project management structure.

#### *A.1.c Quality Assurance Project Plan Responsibility*

High Plains is responsible for maintaining and periodically distributing an official, approved Quality Assurance (QA) Project Plan. High Plains will periodically review this QASP and will consult with the U.S. Environmental Protection Agency (EPA) if changes to the plan are warranted.

#### *A.1.d Organizational Chart for Key Project Personnel*

The Project organizational structure is provided in **Figure 8.11.1**. High Plains will provide the Program Director a contact list of individuals fulfilling these roles.

[redacted]

Figure 8.11.1—Project organization structure.

## A.2 Project Definition/Background

### *A.2.a Reasoning*

High Plains proposes drilling and completing a carbon sequestration injection well (Conestoga I-1) and monitoring well (Conestoga M-1) for the safe sequestration of carbon dioxide at the Western Nebraska Sequestration Hub (WNS Hub) in Kimball County, approximately 11 miles south of the city of Dix, Nebraska and 13 miles southeast of Kimball, Nebraska. The WNS Hub monitoring, verification, and accounting (MVA) program consists of three components: operational, verification, and environmental monitoring. Operational monitoring ensures safety with all procedures associated with fluid injection, monitoring the response of the injection zone, and movement of the $CO_2$ plume. Key monitoring parameters include:

- Tubing and annulus pressure of Conestoga I-1 and Conestoga M-1
- Injection zone pressure monitoring in Conestoga I-1
- Confining zone integrity
- Lowermost underground source of drinking water (USDW)

Additional monitoring parameters include injection rate, total volume injected, injection well temperature profiles, and [redacted]. The verification and environmental components inform High Plains if $CO_2$ leaks through the caprock and is released into the shallow subsurface or biosphere. At the well bore, [redacted]

### *A.2.b Reasons for Initiating the Project*

The goal of the injection Project is to permanently sequester industrial-scale volumes of $CO_2$ to reduce atmospheric concentrations of $CO_2$. A strict MVA Plan is proposed to demonstrate that injected $CO_2$ is retained within the Lyons Formation.

The Class VI Rule requires owners or operators of Class VI wells to perform several methods of monitoring activities during the lifetime of the Project. These activities are done to ensure that:

- The injection well maintains mechanical integrity
- Fluid migration and pressure increase are within the limits described in the permit application
- USDWs are not altered

Monitoring activities include MITs (Mechanical Integrity Tests), injection well testing, ground water monitoring, and $CO_2$ plume and pressure front monitoring. This document details both the measurements taken and the steps to ensure that the quality of all the data is such that the data can be used with confidence in making decisions during the life of the Project.

## A.3 Project/Task Description

### *A.3.a Summary of Work to be Performed*

**Table 8.11.1** provides a summary of the testing and monitoring tasks for the Project.

**Table 8.11.2** provides details of the instrumentation that will be installed and used for monitoring.

**Table 8.11.3** shows the geophysical monitoring tools and timelines.

**Figure 8.11.2** depicts the Project area and the location of the Conestoga I-1 and Conestoga M-1. The location and design of monitoring infrastructure is in progress and will iteratively be added to the map.

Table 8.11.1—Summary of testing and monitoring.

| Activity | Location(s) | Method | Analytical Technique | Pre-Injection Baseline | Operation Period (12 years) | PISC Period (50 years) | Lab/ Custody | Purpose |
|---|---|---|---|---|---|---|---|---|
| Carbon Dioxide Stream Analysis | [redacted] | | | | | | | |
| Injection Rate and Volume | [redacted] | | | | | | | |
| Injection Pressure | [redacted] | | | | | | | |
| Annular Pressure | [redacted] | | | | | | | |
| Annular Pressure | [redacted] | | | | | | | |
| Downhole Pressure/ Temperature | [redacted] | | | | | | | |
| Pressure/Temperature | [redacted] | | | | | | | |
| Corrosion Monitoring | [redacted] | | | | | | | |

| Activity | Location(s) | Method | Analytical Technique | Pre-Injection Baseline | Operation Period (12 years) | PISC Period (50 years) | Lab/ Custody | Purpose |
|---|---|---|---|---|---|---|---|---|
| Mechanical Integrity | [redacted] | | | | | | | |
| USDW Monitoring | | | | | | | | |
| Cement Evaluation | | | | | | | | |
| Pressure Fall Off Testing | | | | | | | | |
| Near Surface USDW Monitoring | | | | | | | | |

Table 8.11.2—Instrumentation summary. T=Temperature; P=Pressure; F=Flow.

| Monitoring Location | Instrument Type | Monitoring Target | Data Collection Location(s) | Explanation |
|---|---|---|---|---|
| $CO_2$ Facility | [redacted] | | | |
| Conestoga M-1 | | | | |
| Conestoga I-1 | | | | |

T = Temperature gauge
P = Pressure gauge
F = Flow meter

Table 8.11.3—Geophysical surveys.

| Monitoring Activity | Well | Tool or Survey | Pre-Injection Baseline | Injection Phase Repeat Survey Interval | PISC Repeat Survey Interval | Description |
|---|---|---|---|---|---|---|
| [redacted] | | | | | | |

[redacted]

Figure 8.11.2—Map of the Project area and wells.

### *A.3.b Resource and Time Constraints*

High Plains does not anticipate any additional resource or time constraints for the Testing and Monitoring Plan beyond Project funding levels and the proposed timeline outlined in **Figure 8.11.3**.

[redacted]

Figure 8.11.3—Anticipated timeframe for High Plains' proposed $CO_2$ sequestration project as part of the Western Nebraska Sequestration Hub.

## A.4 Quality Objectives and Criteria

### *A.4.a Performance/Measurement Criteria*

This QASP provides confidence that the underground storage project is operating as planned and permitted; thus, the Project is not altering USDWs. Near-surface groundwater monitoring will be conducted during the pre-injection, injection, and post-injection phases of the Project in aquifer(s) identified as being the primary utilized aquifer(s) in the Project AoR. Minimum fluid analytical and field monitoring parameters for the near-surface aquifer are listed in **Table 8.11.4.** Analytical parameters for $CO_2$ stream monitoring, corrosion coupon assessment, and gauge specifications are shown in **Table 8.11.5** through **Table 8.11.8**.

Continuous $CO_2$ stream monitoring using a gas chromatograph will be monitoring for the following components:

[redacted]

Table 8.11.4—Summary of analytical and field parameters for fluid samples.

| Parameters | Analytical Methods(1) | Detection Limit/Range | Typical Precisions | QC Requirements |
|---|---|---|---|---|
| [redacted] | | | | |

Table 8.11.5—Summary of analytical methods for characterizing the $CO_2$ stream (if lab-tested).

| Parameters | Analytical Methods[1] | Detection Limit/Range | Typical Precisions | QC Requirements |
|---|---|---|---|---|
| [redacted] | | | | |

| Parameters | Analytical Methods(1) | Detection Limit/Range | Typical Precisions | QC Requirements |
|---|---|---|---|---|
| [redacted] | | | | |

Table 8.11.6—Summary of analytical parameters for corrosion coupons.

| Parameters | Analytical Methods(1) | Detection Limit/Range | Typical Precisions | QC Requirements |
|---|---|---|---|---|
| [redacted] | | | | |

Table 8.11.7—Summary of measurement parameters for field gauges.

| Parameters | Methods[1] | Detection Limit/Range | Typical Precisions | QC Requirements |
|---|---|---|---|---|
| [redacted] | | | | |

Table 8.11.8—Actionable testing and monitoring outputs.

| Activity or Parameter | Project Action Limit | Detection Limit | Anticipated Reading |
| --- | --- | --- | --- |
| [redacted] | | | |

### *A.4.b Precision*

Fluid sample data precision will be assessed by the collection and analysis of field blanks to test sampling procedures and matrix spikes to test lab procedures. Field blanks will be taken no less than once per sampling event to spot-check for sample bottle contamination. Laboratory assessment of analytical precision will be the responsibility of the individual laboratories per their standard operating procedures.

### *A.4.c Bias*

Laboratory assessment of analytical bias will be the responsibility of the individual laboratories per their standard operating procedures and analytical methodologies. For direct pressure or logging measurements, there is no bias.

### *A.4.d Representativeness*

For fluid sampling, data representativeness expresses the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. A sampling network was designed to provide data representative of site conditions. For analytical results of individual groundwater samples, representativeness will be estimated by ion and mass balances. Ion balances with ±10% error or less will be considered valid. Mass balance assessment will be used in cases where the ion balance is greater than ±10% to help determine the source of error. For a sample and its duplicate, if the relative percent difference is greater than 10%, the sample may be considered non-representative.

### *A.4.e Completeness*

For fluid sampling, data completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. It is anticipated that data completeness of 90% for fluid sampling will be acceptable to meet monitoring goals. For direct pressure and temperature measurements, it is expected that data will be recorded no less than 90% of the time.

### *A.4.f Comparability*

Data comparability expresses the confidence with which one data set can be compared to another. The data sets to be generated by this Project will be very comparable to future data sets because of the use of standard methods and the level of quality assurance/quality control (QA/QC) effort. Direct pressure, temperature, and logging measurements will be directly comparable to previously obtained data.

### *A.4.g Method Sensitivity*

**Table 8.11.9** through **Table 8.11.15** provide additional details on gauge and surveillance logging specifications and sensitivities.

Table 8.11.9—Pressure and temperature—downhole gauge specifications.

| Parameter | Value |
|---|---|
| Calibrated working pressure range | [redacted] |
| Initial pressure accuracy | |
| Pressure resolution | |
| Pressure drift stability | |
| Calibrated working temperature range | |
| Initial temperature accuracy | |
| Temperature resolution | |
| Temperature drift stability | |
| Max temperature | |
| Instrument calibration frequency | |

psi = Pounds per square inch
psia = Pounds per square inch (ambient)

Table 8.11.10—Representative surveillance logging tool specifications.

| Parameter | Value |
|---|---|
| Logging speed | [redacted] |
| Vertical resolution | |
| Investigation | |
| Temperature rating | |
| Pressure rating | |

ft/hr = Feet per hour
psi = Pounds per square inch

Table 8.11.11—Pressure field gauge specifications.

| Parameter | Value |
|---|---|
| Calibrated working pressure range | [redacted] |
| Initial pressure accuracy | |
| Pressure resolution | |
| Pressure drift stability | |

mA = Milliamp
psi = Pounds per square inch

Table 8.11.12—Pressure field gauge—injection tubing pressure.

| Parameter | Value |
|---|---|
| Calibrated working pressure range | [redacted] |
| Initial pressure accuracy | |
| Pressure resolution | |
| Pressure drift stability | |

mA = Milliamp
psi = Pounds per square inch

Table 8.11.13—Pressure field gauge—annulus pressure.

| Parameter | Value |
|---|---|
| Calibrated working pressure range | [redacted] |
| Initial pressure accuracy | |
| Pressure resolution | |
| Pressure drift stability | |

mA = Milliamp
psi = Pounds per square inch

Table 8.11.14—Temperature field gauge—injection tubing temperature.

| Parameter | Value |
| --- | --- |
| Calibrated working temperature range | [redacted] |
| Initial temperature accuracy | |
| Temperature resolution | |
| Temperature drift stability | |

mA = Milliamp

Table 8.11.15—Mass flow rate field gauge—$CO_2$ mass flow rate.

| Parameter | Value |
| --- | --- |
| Calibrated working flow rate range | [redacted] |
| Initial mass flow rate accuracy | |
| Mass flow rate resolution | |
| Mass flow rate drift stability | |

## A.5 Specialized Training and Certifications

### *A.5.a Specialized Training and Certifications*

The geophysical survey equipment and wireline logging tools will be operated by trained, qualified, and certified personnel, according to the service company that provides the equipment. The subsequent data will be processed and analyzed according to industry standards (**Appendix B**). Trained personnel conducting groundwater sampling are not required to have specialized certifications. Groundwater sampling will be conducted by personnel trained to understand and follow the project-specific sampling procedures. Upon request, High Plains will provide the agency with all laboratory standard operation procedures (SOPs) developed for the specific parameter using the appropriate standard method. Each laboratory technician conducting the analysis will be trained on the SOP developed for each standard method. High Plains will include the technician's training certification with the biannual report.

### *A.5.b Training Provider and Responsibility*

Training for personnel will be provided by the operator or by the subcontractor responsible for the data collection activity.

## A.6 Documentation and Records

### *A.6.a Report Format and Package Information*

A semi-annual report from High Plains to EPA will contain all required Project data, including testing and monitoring information as specified by the UIC Class VI Permit. Data will be provided in electronic or another format as required by the UIC Program Director.

### *A.6.b Other Project Documents, Records, and Electronic Files*

Other documents, records, and electronic files such as well logs, test results, or other data will be provided as required by the UIC Program Director.

### *A.6.c Data Storage and Duration*

High Plains or a designated contractor will maintain the required Project data as provided elsewhere in the permit.

#### *A.6.d Quality Assurance and Surveillance Plan Distribution Responsibility*

The High Plains Director of $CO_2$ Storage will be responsible for ensuring that all those on the distribution list will receive the most current copy of the approved QASP.

## *B. DATA GENERATION AND ACQUISITION*

This section focuses on fluid sampling and does not address monitoring methods that do not gather physical samples (e.g., logging, seismic monitoring, and pressure/temperature monitoring).

During the pre-injection and injection phases, fluid sampling in the primary utilized near-surface USDW is planned to include an extensive set of chemical parameters to establish aqueous geochemical reference data. Parameters will include selected constituents that:

- Are the most responsive to interaction with $CO_2$ or brine
- Are needed for QC
- May be needed for geochemical modeling

The minimum set of parameters is provided in **Table 8.11.4**. After a sufficient baseline is established, the monitoring scope may shift to a subset of indicator parameters that are:

- The most responsive to interaction with $CO_2$ or brine
- Are needed for QC

Implementation of a reduced set of parameters would be performed in consultation with the EPA. All samples will be analyzed by a third-party laboratory. Dissolved $CO_2$ will be analyzed by methods consistent with Test Method B of ASTM D 513-06, Standard Test Methods for Total and Dissolved Carbon Dioxide in Water or equivalent.

### B.1 *SAMPLING PROCESS DESIGN*

#### *B.1.a Design Strategy*

##### B.1.a.i. $CO_2$ Stream Monitoring Strategy

The $CO_2$ injection stream will be analyzed with sufficient frequency to yield data representative of its chemical and physical characteristics. The objective of this analysis is to evaluate the potential interactions of $CO_2$ and other constituents of the injectate with formation solids, fluids, or any components of the injection system. Testing will be conducted using gas chromatography analysis. This analysis will also test for constituents that include sulfur dioxide, hydrogen sulfide, nitrogen oxides, hydrocarbons, carbon monoxide, methane, water vapor, nitrogen, oxygen, mercury, and arsenic. The gas chromatography equipment will meet American Society for Testing and Materials (ASTM) testing standards.

##### B.1.a.ii. Corrosion Monitoring Strategy

A corrosion coupon system will be installed, and the coupons will be deployed upstream of the wellhead through which the injection stream passes. This monitoring method will detect any possible metal loss due to the chemical or electrochemical reactions that may result in loss of mass or thickness or pitting of injection well components. The coupons will be prepared, analyzed, installed, and QA/QC protocols will be implemented using the National Association of Corrosion Engineers (NACE) Standard Recommended Practice (RP)-0775 and ASTM Standards G1 and G4.

B.1.a.iii. Groundwater Monitoring Strategy

[redacted] With the planned monitoring frequencies, it is expected that baseline conditions can be documented, natural variability in conditions can be characterized, unintended brine or $CO_2$ leakage could be detected should it occur, and sufficient data will be collected to demonstrate that the effects of $CO_2$ injections are limited to the intended storage reservoir. Groundwater sampling and analysis from near-surface ground water monitoring well(s) will take place during baseline, injection and post-injection on an annual basis.

B.1.a.iv. Soil Sampling Strategy

[redacted]

*B.1.b Type and Number of Samples/Test Runs*

Sampling activities are detailed in **Table 8.11.1**.

*B.1.c Site/Sampling Locations*

Table 8.11.16—Site sampling locations.

| Well Name | Latitude* | Longitude* | PLSS |
|---|---|---|---|
| Conestoga I-1 | [redacted] | [redacted] | [redacted] |

* NAD83

*B.1.d Sampling Site Contingency*

No problems of site accessibility are expected within the Project area. If inclement weather makes site access difficult, sampling schedules will be reviewed, and alternative dates may be selected that would still meet permit-related conditions.

*B.1.e Activity Schedule*

Sampling activities and frequency are detailed in **Table 8.11.1**.

*B.1.f Critical/Informational Data*

Detailed field and laboratory documentation will be taken during field sampling and analytical efforts. Documentation will be recorded in field and laboratory forms and notebooks. Critical information will include time and date of activity, person/s performing activity, location of activity (wellfield sampling) or instrument (lab analysis), field or laboratory instrument calibration data, field parameter values. For laboratory analyses, much of the critical data are generated during the analysis and provided to end users in digital and printed formats. Non-critical data may include appearance and odor of the sample, problems with well or sampling equipment, and weather conditions.

### *B.1.g Sources of Variability*

Potential sources of variability related to monitoring activities include:

- Natural variation in fluid quality, formation pressure and temperature, and seismic activity
- Variation in fluid quality, formation pressure and temperature, and seismic activity due to Project operations
- Changes in instrument calibration during sampling or analytical activity
- Different staff collecting or analyzing samples
- Differences in environmental conditions during field sampling activities
- Changes in analytical data quality during life of Project
- Data entry errors related to maintaining Project database

Activities to eliminate, reduce, or reconcile variability related to monitoring activities include:

- Collecting long-term baseline data to observe and document natural variation in monitoring parameters
- Evaluating data in timely manner after collection to observe anomalies in data that can be addressed be resampled or reanalyzed
- Conducting statistical analysis of monitoring data to determine whether variability in a data set is the result of Project activities or natural variation
- Maintaining weather related data using on-site weather monitoring data or data collected near Project site (such as from local airports)
- Checking instrument calibration before, during and after sampling or sample analysis
- Thoroughly training staff,
- Conducting laboratory QA checks using third party reference materials, and/or blind and/or replicate sample checks
- Developing a systematic review process of data that can include sample-specific data quality checks (i.e., cation/anion balance for aqueous samples).

## B.2 Sampling Methods

### *B.2.a Sampling Standard Operation Procedures*

Laboratory SOPs have been developed by the service provider. All procedures for sampling shall be consistent with the U.S. Environmental Protection Agency (EPA) *Groundwater Sampling Guidelines for Superfund and RCRA Project Managers* (May 2002). **Table 8.11.17** summarizes stabilization criteria during well purging.

Table 8.11.17—Stabilization criteria of water quality parameters during fluid purging.

| Field Parameter | Stabilization Criteria |
|---|---|
| [redacted] | |

### *B.2.b In-situ Monitoring*

High Plains does not plan to perform in-situ monitoring of groundwater chemistry.

### *B.2.c Continuous Monitoring*

High Plains will collect periodic pressure data (e.g., hourly to daily) from Conestoga I-1, and Conestoga M-1.

### *B.2.d Sample Homogenization, Composition, Filtration*

To obtain a representative sample, each well will be purged at a flow rate between 10 and 50 gallons per minute (gpm). Samples will be collected within 24 hours of the well being purged. If a monitoring well does not supply adequate water for sampling, the condition of the well will be investigated, and it may be considered for replacement.

To ensure the collection of a representative sample, a series of water quality indicator measurements will be collected using a water quality meter prior to collecting an aliquot(s) for the analytical laboratory sample. Purging will continue until three successive measurements of the indicator parameters meet the stabilization criteria per **Table 8.9.17**.

Following indicator parameter stabilization, fluid samples collected for laboratory analysis will be obtained via direct capture of liquid from the sample port into clean, unused laboratory analytical method-specific containers.

### *B.2.e Sample Containers and Volumes*

Sample collection devices for groundwater fluids will be carefully chosen to minimize the potential for altering the quality of the sample. Teflon and stainless steel are preferred materials, although polyvinyl chloride (PVC), high-density polyethylene (HDPE), and other similar materials are considered sufficient in some cases

Stream monitoring samples for $CO_2$ will be collected in a clean sample container rated for the appropriate collection pressure (i.e., mini cylinders or polybags provided by Airborne Labs International Inc., Somerset, NJ, or a similar lab).

Assay for $CO_2$ Quarterly Gas Analysis:

[redacted]

[redacted]

For fluid samples, all sample bottles will be new. Sample bottles and bags for analytes will be used as received (i.e. ready for use) from the vendor or contract analytical laboratory for the analyte of interest. A summary of sample containers is presented in **Table 8.11.18**.

Table 8.11.18—Summary of sample containers, preservation treatments, and holding times for groundwater samples.

| Target Parameters | Volume/Container Material | Preservation Technique | Sample Holding Time |
|---|---|---|---|
| [redacted] | | | |

HDPE = High density polyethylene
mL = Milliliter

### *B.2.f Sample Preservation*

**Table 8.11.18** provides sample preservation techniques for collected fluid samples.

Sample preservation is not required or used for the $CO_2$ gas stream. Additional details of sampling requirements are shown in **Table 8.11.19**. Corrosion coupon sampling only requires that the coupons be physically separated (e.g., sleeves, baggies) during transportation to prevent physical abrasion.

Table 8.11.19—Summary of sample containers, preservation treatments, and holding times for $CO_2$ gas stream analysis.

| Target Parameters | Volume/Container Material | Preservation Technique | Sample Holding Time (max) |
|---|---|---|---|
| [redacted] | | | |

### *B.2.g Cleaning/Decontamination of Sampling Equipment*

Equipment used for sampling and other activities associated with on-site work will be decontaminated before and after performance of a given activity. Decontamination procedures will vary depending on the material being decontaminated and manufacturer recommendations. At a minimum, decontamination will include external cleaning using a non-phosphate detergent, followed by a minimum of three rinse cycles using deionized water. All reusable field glassware will be cleaned with tap water to remove any loose dirt, washed in a diluted nitric acid solution, and rinsed three times with deionized water before use. Disposable items will be disposed of as solid waste in an approved, permitted client facility.

$CO_2$ gas stream sampling containers will be either disposed of or decontaminated by the analytical lab.

No sampling equipment will be utilized with the corrosion coupons or annual field gauge calibrations.

### *B.2.h Support Facilities*

The following instruments are required to collect fluid samples: air compressor, vacuum pump, generator, multi-electrode water quality sonde, analytical meters (e.g., pH, specific conductance). Field activities are usually completed in field vehicles and portable laboratory trailers located on site.

Sampling tubing, connectors and valves required to sample the $CO_2$ gas stream. These will be supplied by the analytical lab providing the sampling containers. Sampling will occur within the existing $CO_2$ compression building.

Similarly, corrosion coupons will be removed from the $CO_2$ injection line within the existing $CO_2$ compression building.

Field gauges will be removed from the injection and monitoring wells utilizing existing standard industry tools and equipment. Deployment and retrieval of well gauges will be performed using procedures and equipment recommended by the vendor, subcontractor, or is standard per industry practice.

### *B.2.i Corrective Action, Personnel, and Documentation*

The sampling and analysis service providers will be responsible for testing instruments and equipment and preforming corrective action on defective equipment. Corrective action taken on equipment will be documented.

## B.3 Sample Handling and Custody

Sample holding times (**Table 8.11.18** and **Table 8.11.19**) are consistent with those described in US EPA (1974), American Public Health Association (APHA, 2005), Wood (1976), and ASTM Method D6517-00 (2005). After collection, samples will be placed in ice chests in the field and maintained thereafter at approximately 4 degrees Celsius (°C) until analysis. The samples will be maintained at their preservation temperature and sent to the designated laboratory within 24 hours. Analysis of the samples will be completed within the holding time listed in (**Table 8.11.18** and **Table 8.11.19**). As appropriate, alternative sample containers and preservation techniques approved by the Program Director will be used to meet analytical requirements.

### *B.3.a Maximum Hold Time/Time Before Retrieval*

Refer to **Table 8.11.18** and **Table 8.11.19** for sample holding times.

### *B.3.b Sample Transportation*

The samples will be maintained at their preservation temperature and sent to the designated laboratory within 24 hours. During transportation, precautions will be implemented to ensure that sample integrity is not affected by extreme temperatures and/or excessive vibration.

Upon arrival at the service provider, the samples will be reviewed to ensure the following:

- The sample arrived intact without container leakage or breakage.
- Chain of custody documentation and sample labels agree
- Confirmation that the sample was preserved correctly.

### *B.3.c Sample Documentation*

Field notes will be recorded on all Lyons fluid sample collections. These notes will be retained and archived as reference. The sample documentation is the responsibility of fluid sampling personnel.

An analysis authorization form shall be provided with each $CO_2$ gas stream sample provided for analysis as shown by the example in **Figure 8.11.4**.

F-L8v10 (09/17)

**$CO_2$ Analysis Authorization Form** — Airborne Labs International

*This form MUST be completed & returned with your sample shipment. Analytical testing cannot be performed unless this form is completed and returned.*

| | | | | |
|---|---|---|---|---|
| **1. REPORT RESULTS TO:** **Please attach complete billing address if different from reporting address.* | | | | |
| **COMPANY:** | | | | |
| **ADDRESS:** | Street Address | City | State & Zip Code | Country |
| **CONTACT(S):** | | | | |
| **EMAIL ADDRESS(ES):** | | | | |
| **P.O. #:** | | **INVOICE # OR QUOTE #:** | | |
| **TELEPHONE:** | | **CREDIT CARD TYPE:** | Credit Card Type | |
| **SAMPLED ON (MM/DD/YY):** | | **CC # / EXPIRATION DATE:** | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **2. SAMPLE IDENTIFICATION:** | | | | | | | |
| **INDICATE HOW YOUR SAMPLE SHOULD BE IDENTIFIED & ATTACH A LOG FOR MULTIPLE SAMPLES:** | | | | | | | |
| **# OF SAMPLES TAKEN:** | | | | | | | |
| **CONTAINER TYPES:** *Please check all that apply* | GAS SAMPLING BAG(S) | | MINICYL(S) | | NVR CAN(S) | | *IF OTHER, PLEASE DESCRIBE |
| | HI PRESSURE CYLINDER | | STD ALI NO-HAZ SAMPLING KIT | | OTHER* | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **3. SAMPLE DESCRIPTION:** | | | | | | | | | | |
| **FINAL PRODUCT** | | IDENTIFY PHASE: | VAPORIZED LIQUID $CO_2$ | | LIQUID $CO_2$ | | VAPOR OVER LIQUID | | DRY ICE (SNOW) | |
| **IN-PROCESS** | | | | | | | | | | |
| **FEED GAS** | | IDENTIFY SOURCE: | FERMENTATION | | COMBUSTION | | SELF GEN | | ETO | |
| | | | AMMONIA | | NATURAL WELL | | BIOGAS | | | |
| **OTHER*** | | *IF OTHER, PLEASE DESCRIBE: | | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **4. PURITY GRADE TYPE:** | | | | | | | |
| Please check what type of purity grade is needed: | ISBT BEVERAGE | | FEED GAS | | INDUSTRIAL | | *IF OTHER, PLEASE DESCRIBE |
| | FOOD | | MEDICAL | | OTHER* | | |
| **5. POTENTIAL HAZARDS:** | | | | | | | |
| Please specify any hazards: | STD $CO_2$ HANDLING PRECAUTIONS | | | | OTHER PRECAUTIONS* | | *IF OTHER, PLEASE DESCRIBE: |

| | | | | | | |
|---|---|---|---|---|---|---|
| **6. ANALYTICAL PROGRAM OR INDIVIDUAL TEST(S) REQUESTED:** | | | | | | |
| Please check **one** desired *ALI* test program or select tests that are required (if applicable): | STANDARD CONTRACTUAL PGM | | STANDARD FEED GAS PGM | | FOUNTAIN STANDARD PGM | |
| | ISBT PROGRAM | | ADVANCED FEED GAS PGM | | FOUNTAIN CRITICAL PGM | |
| | ISBT PROGRAM WITH H2O | | HARPC | | GHG PGM | |
| | STANDARD COCA-COLA PGM | | STD FOOD GRADE | | MEDICAL GRADE | |
| | STANDARD PEPSI PGM | | DRY ICE PGM | | OTHER* | |

***If OTHER -Please select ALL Individual Tests Required:** ☐ % $CO_2$ Purity ☐ Non-Condensable Gases = ($H_2$-$N_2$-Ar-$O_2$-$CH_4$-CO) ☐ Oxygen ☐ CO ☐ THC ☐ TNMHC ☐ IR Scan ☐ Vol Oxygenates (VOX) ☐ Chloride (VCl) ☐ Siloxanes ☐ Specific Gravity
☐ Benzene ☐ $NH_3$ ☐ HCN ☐ GC/MS Scan ☐ Heavy Metals ☐ Vol Halogenated Hydrocarbons ☐ Helium ☐ $PH_3$ ☐ $NO_x$ ☐ NO ☐ $NO_2$ ☐ Microscopic Exam ☐ Density ☐ Acid Gases
☐ Total Sulfur ☐ $H_2S$ ☐ $SO_2$ ☐ Acetaldehyde (AA) ☐ Vol Sulfurs ☐ Volatile Hydrocarbons ($C_1$-$C_6$+) ☐ BTEX ☐ VXH ☐ $CH_4$ ☐ COS ☐ Vinyl ☐ NVR/NVOR Oil ID ☐ Radon ($Rn^{222}$) ☐ Water Vapor

| | | | | | |
|---|---|---|---|---|---|
| **7. SAMPLE DISPOSITION:** **Samples will be saved for 3 business days after report distribution unless otherwise noted.* | | | | | |
| Please indicate what you'd like *ALI* to do with your sample after testing. | DISPOSE | | RETAIN FOR SPECIFIED TIME PERIOD** | | **PLEASE INDICATE TIME PERIOD: |
| | CLEAN & RETURN CUSTOMER OWNED KIT | | OTHER*** | | *** PLEASE SPECIFY |
| | RETURN REMAINING SAMPLE* | | *SHIP TO ADDRESS & ANY SPECIFIC INSTRUCTIONS: | | |
| **8. SERVICE DESIRED:** **Additional fees will apply for non-standard test scheduling. You MUST contact ALI to confirm any expedited service request. By checking below, you agree that respective fees listed will be applied to the total cost of your program.* | | | | | |
| Please indicate how quickly you would like your test results reported. | 3-5 WORKDAYS (STANDARD) | | SAME DAY* (AM- 325% PM-375%) | | *IF OTHER, PLEASE SPECIFY: |
| | 2 WORKDAYS* (225%) | | EMERGENCY / OTHER: WEEKEND*(400%) / HOLIDAY* (600%) | | |
| | 1 WORKDAY* (275%) | | | | |

Figure 8.11.4—Example of $CO_2$ gas stream analysis authorization form.[1]

[1] www.airbornelabs.com/images/editor/files/co2-analysis-authorization-form.pdf

### *B.3.d Sample Identification*

Samples will be identified with the sampling location, date, sample identification, sampler, and sample type.

### *B.3.e Sample Chain-of-Custody*

An analysis authorization form for $CO_2$ stream analyses will accompany the samples to the lab at which point a chain-of-custody accompanies the sample through their processes.

High Plains will provide the program administrator with a sample chain-of-custody once the third-party contractor is selected. An example chain-of-custody form is provided in **Figure 8.11.5**. Copies of the form will be provided to the person/lab receiving the samples as well as the person/lab transferring the samples. These forms will be retained and archived to allow simplified tracking of sample status. The chain-of-custody form and record keeping is the responsibility of fluid sampling personnel.

**Chain of Custody Record**

| | | |
|---|---|---|
| **Project No.** | **Project Title** | **Organization** |
| | | |
| **Shipping Container No.** | | **Contact** |
| **Field Samplers:** *print* | *signature* | **Address** |

| Date | Time | Site/Location | Sample Type | Sample ID | Remarks |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

| Relinquished by (*print and signature*): | Received by (*print and signature*): | **Comments** |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

**Chain of Custody Record**

| **Project No.** | **Project Title** | **Organization** |
|---|---|---|
| | | |

Laboratory/Plant: ______________________________

| Sample Number | Number of Container | Sample Description |
|---|---|---|
| | | |
| | | |
| | | |

| Person responsible for samples | | | Time: | | Date: |
|---|---|---|---|---|---|
| Sample Number | Relinquished By: | Received By: | Time: | Date: | Reason for change in custody |
| | | | | | |
| | | | | | |

Figure 8.11.5—Example chain of custody form.[2]

[2] https://www3.epa.gov/ttnamti1/files/ambient/pm25/qa/vol2sec08.pdf

## B.4 Analytical Methods

### *B.4.a Analytical Standard Operational Procedures (SOP)*

See **Table 8.11.4** and **Table 8.11.5** for details on Analytical SOPs. The selected laboratory will use standard EPA laboratory analytical methods to quantify the [redacted] Laboratory QC procedures are inherent to the analysis methodology. The laboratory is responsible for documenting and maintaining compliance with these measures in accordance with industry standards and state licensing. If other water quality objectives are required, High Plains will coordinate with the designated analytical laboratory prior to the sample event to evaluate the appropriate laboratory procedures and sample equipment necessary to fulfill the Project objectives.

### *B.4.b Equipment/Instrumentation Needed*

Equipment and instrumentation is specified in the individual analytical methods referenced in **Table 8.11.4** and **Table 8.11.5**.

### *B.4.c Method Performance Criteria*

Non-standard method performance criteria are not anticipated for this Project.

### *B.4.d Analytical Failure*

Each laboratory conducting analyses in **Table 8.11.4** and **Table 8.11.5** will be responsible for appropriately addressing analytical failure according to their individual SOPs.

### *B.4.e Sample Disposal*

Each laboratory conducting analyses will be responsible for appropriate sample disposal according to their individual SOPs.

### *B.4.f Laboratory Turnaround*

High Plains will request analytics turn-around times to meet all permitted reporting requirements with the understanding that laboratory turnaround will vary by laboratory, but generally turnaround of verified analytical results within 1 month will be suitable for Project needs.

### *B.4.g Method Validation for Non-Standard Methods*

Non-standard methods are not anticipated for this Project. Should non-standard methods be required or proposed in the future, the injection program administrator will be consulted on additional appropriate actions to be taken.

## B.5 Quality Control

### *B.5.a Quality Control Activities*

#### B.5.a.i. Field Blanks

For fluid sampling, a field blank will be collected and analyzed for the inorganic analytes in **Table 8.11.4** and **Table 8.11.5**.

at a frequency of 10% or greater. Field blanks will be exposed to the same field and transport conditions as the groundwater samples. The field blanks will be utilized for deep groundwater sampling and analyzed for the inorganic analytes at a frequency of 10% or greater in **Table 8.11.4** and **Table 8.11.5**. Field blanks will be used to detect contamination resulting from the collection and transportation process.

#### B.5.a.ii. Duplicates

Duplicate fluid samples will be collected in separate containers from the primary samples and processed separately. Duplicate samples will be used to assess sample heterogeneity and analytical precision. Duplicate samples will be collected at a frequency of one duplicate per 20 sample sets per sampling event.

### *B.5.b Exceeding Control Limits*

If the sample analytical results exceed control limits (i.e., ion balances > ±10%), further examination of the analytical results will be achieved by evaluating the ratio of the measured TDS to the calculated TDS (i.e., mass balance) per APHA. The method indicates which ion analyses should be considered suspect based on the mass balance ratio. Suspect ion analyses will be reviewed in the context of historical data and interlaboratory results, if available. Suspect ion analyses will be brought to the attention of the analytical laboratory for confirmation and/or reanalysis. The ion balance will be recalculated, and if the error is still not resolved, suspect data are identified and may be given less importance in data interpretations.

### *B.5.c Calculating Applicable Quality Control Statistics*

#### B.5.c.i. Charge Balance

The analytical results will be evaluated to determine correctness of analyses based on anion-cation charge balance calculation. Because all potable waters are electrically neutral, the chemical analyses should yield equally negative and positive ionic activity. The anion-cation charge balance will be calculated using the formula in **Equation 8.11.1**:

Equation 8.11.1—Formula for anion-cation charge balance.

$$\%\ \text{difference} = 100 \times \frac{\Sigma_{\text{cations}} - \Sigma_{\text{anions}}}{\Sigma_{\text{cations}} + \Sigma_{\text{anions}}}$$

Where the sums of the ions are represented in milliequivalents (meq) per liter and the criteria for acceptable charge balance is ±10%.

#### B.5.c.ii. Mass Balance

The ratio of the measured TDS to the calculated TDS will be calculated in instances where the charge balance acceptance criteria are exceeded using the formula shown in **Equation 8.11.2**.

Equation 8.11.2—Ratio of measured vs. calculated TDS.

$$1.0 < \frac{\text{measured TDS}}{\text{calculated TDS}} < 1.2$$

where the anticipated values are between 1.0 and 1.2.

B.5.c.iii. Outliers

It is essential to determine statistical outliers prior to the statistical evaluation of fluid samples. High Plains will use the EPA's Unified Guidance (March 2009) as a basis for the selection of recommended statistical methods to identify outliers in fluid chemistry data sets as appropriate. These techniques include Probability Plots, Box Plots, Dixon's test, and Rosner's test. The EPA-1989 outlier test may also be used as another screening tool to identify potential outliers.

## B.6 Instrument/Equipment Testing, Inspection, and Maintenance

Logging tool equipment will be maintained as per wireline industry best practices (see **APPENDIX B—Schlumberger Wireline Log Quality Control Reference Manual**). For fluid sampling, field equipment will be maintained, factory serviced, and factory calibrated per the manufacturer's recommendations. Spare parts that may be needed during sampling will be included in supplies on-hand during field sampling. For all laboratory equipment, testing, inspection, and maintenance will be the responsibility of the analytical laboratory per standard practice, method-specific protocol, or NELAP requirements.

## B.7 Instrument/Equipment Calibration and Frequency

### *B.7.a Calibration and Frequency of Calibration*

Pressure/temperature gauge calibration information is located in **Table 8.11.9** through **Table 8.11.15**.

Logging tool calibration will be at the discretion of the service company providing the equipment, following standard industry practices noted in **APPENDIX B**. Calibration frequency will be determined by standard industry practices.

For fluid sampling, sondes used to determine field parameters (e.g., pH, temperature, specific conductance, dissolved oxygen) are calibrated according to manufacturer recommendations and equipment manuals (Hach, 2006) each day before sample collection begins. Recalibration is performed if any components yield atypical values or fail to stabilize during sampling.

### *B.7.b Calibration Methodology*

Logging tool calibration methodology will follow standard industry practices in Appendix B.

For fluid sampling, standards used for calibration are typically 7 and 10 for pH, a potassium chloride [redacted]

### *B.7.c Calibration Resolution and Documentation*

Logging tool calibration resolution and documentation will follow standard industry practices in **APPENDIX B**.

## B.8 Inspection/Acceptance for Supplies and Consumables

### *B.8.a Supplies, Consumables, and Responsibilities*

Supplies and consumables for field and laboratory operations will be procured, inspected, and accepted as required from vendors approved by High Plains or the respective subcontractor responsible for the data collection activity. Acquisition of supplies and consumables related to groundwater analyses will be the responsibility of the laboratory per established standard methodology or operating procedures.

## B.9 Non-Direct Measurements

### *B.9.a Data Sources*

[redacted]

[redacted]

### *B.9.b Relevance to Project*

[redacted]

[redacted]

### *B.9.c Acceptance Criteria*

Following standard industry practices will ensure that the [redacted] be used for accurate monitoring.

### *B.9.d Resources/Facilities Needed*

Under review by selected third-party contractor and laboratory within ASTM recommended guidelines.

### *B.9.e Validity Limits and Operating Conditions*

Under review by selected third-party contractor and laboratory within ASTM recommended guidelines.

## B.10 Data Management

### *B.10.a Data Management Scheme*

High Plains will maintain the required Project data as provided elsewhere in the permit. Data will be backed up on hard drive media or held on secure servers.

#### *B.10.b Record-Keeping and Tracking Practices*

All records and gathered data will be securely held and properly labeled for auditing purposes.

#### *B.10.c Data Handling Equipment/Procedures*

All infrastructure used to store data will be properly maintained and operated according to proper industry standard techniques. The High Plains SCADA-like system and vendor data acquisition systems will interface; therefore, all subsequent data will be stored on a secure server.

#### *B.10.d Responsibility*

The primary Project managers will be responsible for ensuring proper data management is maintained.

#### *B.10.e Data Archival and Retrieval*

Under review—all data will be held by High Plains.

#### *B.10.f Hardware and Software Configurations*

All High Plains and vendor hardware and software configurations will be appropriately interfaced.

#### *B.10.g Checklists and Forms*

Checklists and forms will be procured and generated as necessary.

## *C. ASSESSMENT AND OVERSIGHT*

### C.1 Assessments and Response Actions

#### *C.1.a Activities to be Conducted*

Please refer to **Table 8.11.1** for a work summary and schedule and frequency of fluid sample collections. After completion of sample analysis, results will be reviewed for QC criteria as noted in *Section B.5.* If the data quality fails to meet criteria set in *Section B.5* samples will be reanalyzed, if still within holding time criteria. If the holding time has passed, additional samples may be collected, or sample results may be excluded from data evaluations and interpretations. Evaluation for data consistency will be performed according to procedures described in the USEPA 2009 Unified Guidance (USEPA, 2009).

#### *C.1.b Responsibility for Conducting Assessments*

Companies collecting data are in charge of conducting their own internal reviews.

#### *C.1.c Assessment Reporting*

All assessment information should be reported to the individual organization's project manager outlined in *Section A.1.a—Key Individuals and Responsibilities*.

#### *C.1.d Corrective Action*

Corrective action that only affects an individual organization's data collection duty will be addressed, verified, and documented within the organization and communicated to other stakeholders as necessary.

Corrective actions that involve multiple organizations will be addressed by all stakeholders involved and communicated to other members on the distribution list for the QASP. High Plains will coordinate all corrective actions and assessments that involve multiple organizations.

## C.2 Reports to Management

### *C.2.a QA Status Reports*

High Plains does not plan to send QA status reports.

# *D. DATA VALIDATION AND USABILITY*

## D.1 Data Review, Verification, and Validation

### *D.1.a Criteria for Accepting, Rejecting, or Qualifying Data*

Data validation will include a review of the sample collection process, sample units, sample holding times, and a comparison and review of the appropriate duplicate, or blank QC/QA results. Results will be catalogued and periodically reviewed and compared to previous data. Analytical results will be reported on a frequency based on the approved UIC permit conditions. Data in these reports will be presented in a variety of formats as appropriate to characterize water quality and identify any changes with time.

## D.2 Verification and Validation Methods

### *D.2.a Data Verification and Validation Processes*

See *Sections D.1.a* and *B.5* for information related to High Plains data verification and validation process.

### *D.2.b Data Verification and Validation Responsibility*

High Plains or a contractor approved by High Plains will verify and validate data.

### *D.2.c Issue Resolution Process and Responsibility*

High Plains or a project manager approved by High Plains will oversee the data review process and take the appropriate actions to resolve any issues that may arise.

### *D.2.d Checklist, Forms, and Calculations*

High Plains will generate checklists, forms and calculations designed to meet all permit requirements.

## D.3 Reconciliation with User Requirements

### *D.3.a Evaluation of Data Uncertainty*

Software will be employed to determine data consistency.

### *D.3.b Data Limitations Reporting*

High Plains or project managers approved by High Plains will be responsible for making sure that all reported data is presented with the appropriate data-use limitations.

## REFERENCES

American Public Health Association (APHA), 2005, *Standard methods for the examination of water and wastewater*, 21st edition: American Public Health Association, Washington, DC.

American Society for Testing and Materials (ASTM), 2005, Method D6517-00 (reapproved 2005), *Standard guide for field preservation of groundwater samples*: ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA.

Hach Company, 2006, *Hydrolab DS5X, DS5, and MS5 water quality multiprobes user manual*, February 2006: Hach Company, 73 p.

U.S. Environmental Protection Agency (US EPA), 1974, *Methods for chemical analysis of water and wastes*: U.S. Environmental Protection Agency, Cincinnati, OH, EPA-625/6-74-003a.

U.S. Environmental Protection Agency (US EPA), 2002, *Groundwater sampling guidelines for Superfund and RCRA project managers*: Washington, DC, EPA 542-S-02-001, 49 p.

Wood, W.W., 1976, *Guidelines for collection and field analysis of groundwater samples for selected unstable constituents*, in *U.S. Geological Survey, Techniques for Water Resources Investigations*, chapter D-2, 24 p.

## APPENDIX A [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

## APPENDIX B—SCHLUMBERGER WIRELINE LOG QUALITY CONTROL REFERENCE MANUAL

Schlumberger

# Wireline Log Quality Control Reference Manual

Schlumberger

# Logging Quality Control Reference Manual

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Schlumberger
225 Schlumberger Drive
Sugar Land, Texas 77478

www.slb.com

Produced by Schlumberger Oilfield Marketing Communications



11-FE-0065



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# Foreword

The certification of acquired data is an important aspect of logging. It is performed through the observation of quality indicators and can be completed successfully only when a set of specified requirements is available to the log users.

This Log Quality Control Reference Manual (LQCRM) is the third edition of the log quality control specifications used by Schlumberger. It concisely provides information for the acquisition of high-quality data at the wellsite and its delivery within defined standards. The LQCRM is distributed to facilitate the validation of Schlumberger wireline logs at the wellsite or in the office.

Because the measurements are performed downhole in an environment that cannot be exhaustively described, Schlumberger cannot and does not warrant the accuracy, correctness, or completeness of log data.

Large variations in well conditions require flexibility in logging procedures. In some cases, important deviations from the guidelines given here may occur. These deviations may not affect the validity of the data collected, but they could reduce the ability to check that validity.

Catherine MacGregor
President, Wireline

Schlumberger

# Introduction

Data is a permanent asset of energy companies that may be used in unforeseen ways. Schlumberger is committed to and accountable for managing and delivering quality data. The quality of the data is the cornerstone of Schlumberger products and services.

## Data quality

Quality is conformance to predefined standards with minimum variation. This document defines the standards by which the quality of the data of Schlumberger wireline logs is determined. The attributes that form the data quality model are

- accuracy
- repeatability
- integrity
- traceability
- timeliness
- relevance
- completeness
- sufficiency
- interpretability
- reputation
- objectivity
- clarity
- availability
- accessibility
- security.

### Accuracy

Accuracy is how close to the true value the data is within a specified degree of conformity (e.g., metrology and integrity). Accuracy is a function of the sensor design; the measurement cannot be made more accurate by varying operating techniques, but it can fail to conform to the defined accuracy as a result of several errors (e.g., incorrect calibration).

### Repeatability

Repeatability of data is the consistency of two or more data products acquired or processed using the same system under the same conditions. Reproducibility, on the other hand, is the data consistency of two or more data products acquired or processed using different systems or under different conditions. The majority of wireline measurements have a defined repeatability range, which is applicable only when the measurement is conducted under the same conditions. Repeatability is used to validate the measurement acquired during the main logging pass, as well as identify anomalies that may arise during the survey for relogging.

### Integrity

The integrity of data is essential for the believability of data. Data with integrity is not altered or tampered with. There are situations in which data is altered in a perfectly acceptable manner (e.g., applying environmental corrections, using processing parameters for interpretation). Any such changes, which involve an element of judgment, are not done to intentionally produce results inconsistent with the measurements or processed data and are to the best and unbiased judgment of the interpreter. Results of interpretation activities are auditable, clearly marked, and traceable.

### Traceability

Traceability of data refers to having a complete chain defining a measurement from its point of origin (sensor) to its final destination (formation property). At each step of the chain, appropriate measurement standards are respected, well documented, and auditable.

### Timeliness

Timeliness is the availability of the data at the time required. Timeliness ensures that all tasks in the process of acquiring data are conducted within the time window defined for such tasks (e.g., wellsite calibrations and checks are done within the time window defined).

### Relevance

Relevance is the applicability and helpfulness of the acquired dataset within the business context (e.g., selection of the right service for the well conditions). Most services have a defined operating envelope in which the measurement is considered valid. Measurements conducted outside their defined envelope, although the measurement process may have been completed satisfactorily, are almost always irrelevant (e.g., recording an SP curve in an oil-base mud environment).

### Completeness

Completeness ensures that the data is of sufficient breadth, depth, and scope to meet predefined requirements. This primarily means that all required measurements are available over the required logging interval, with no missing curves or gaps in curves over predefined required intervals of the log.

### Sufficiency

Sufficiency ensures that the amount of data that is acquired or processed meets the defined objectives of the operation. For example, when the defined objective is to compute the hole volume of an oval hole, a four-arm caliper service—at minimum—must be used. Using a single-arm caliper service would not provide sufficient information to achieve the defined objective and would inadvertently result in overestimation of the hole volume.

### Interpretability

Interpretability of data requires that the measurement is specified in appropriate terminology and units and that the data definitions are clear and documented. This is essential to ensure the capability of using the data over time (i.e., reusability).

### Reputation

Reputation refers to data being trusted or highly regarded in terms of its source, content, and traceability.

### Objectivity

The objectivity of data is an essential attribute of its quality, unbiased and impartial, both at acquisition and at reuse.

### Clarity

Clarity refers to the availability of a clear, unique definition of the data by using a controlled data dictionary that is shared. For example, when "NPHI" is referred to, it must be understood by all that NPHI is the thermal neutron porosity in porosity units ($m^3/m^3$ or $ft^3/ft^3$), computed from a thermal neutron ratio that is calibrated using a single-point calibration mechanism (gain only), and is the ratio of counts from a near and a far receiver, with the counts corrected only for hole size and not corrected for detector dead time.

Clarity ensures objectivity and interpretability over time.

### Availability

Availability of data ensures the distribution of data only to the intended parties at the requested time (i.e., no data is disclosed to any other party than the owner of the data without prior written permission).

### Accessibility

Accessibility ensures the ease of retrievability of data using a classification model. Wireline data are classified into three datasets:

- Basic dataset is a limited dataset suitable for quicklook interpretation and transmission of data.
- Customer dataset consists of a complete set of data suitable for processing (measurements with their associated calibrations), recomputing (raw curves), and validating (log quality control [LQC] curves) the measurements of the final product delivered. The customer dataset includes all measurements required to fully reproduce the data product with a complete and auditable traceability chain.
- Producer dataset includes Schlumberger-proprietary data, which are meaningful only to the engineering group that supports the tool in question (e.g., the 15th status bit of ADC015 on board EDCIB023 in an assembly).

### Security

The security of data is essential to maintain its confidentiality and ensure that data files are clean of malware or viruses.

## Calibration theory

The calibration of sensors is an integral part of metrology, the science of measurement. For most measurements, one of the following types of calibrations is employed:

- single-point calibration
- two-point calibration
- multiple-point calibration.

Because most measurements operate in a region of linear response, any two points on the response line can be compared with their associated calibration references to determine a gain and an offset (two-point calibration) or a gain (single-point calibration). The gain and offset values are used in the calibration value equation, which converts any measured value to its associated calibrated value.

There are three events that measurements may have one or more of:

- Master calibration: Performed at the shop on a quarterly or monthly basis, a master calibration usually comprises a primary measurement done to a measurement standard and a reference measurement that serves as a baseline for future checks. The primary measurement is the calibration of the sensor used for converting a raw measurement into its final output.
- Wellsite before-survey calibration or check: Measurements that have a master calibration are normally not calibrated at the wellsite; rather, the reference measurement conducted in the master calibration is repeated at the wellsite before conducting the survey to ensure that the tool response has not changed. Measurements that do not have a master calibration may employ a wellsite calibration that is conducted prior to starting the survey.
- Wellsite after-survey check: Some measurements employ an after-survey check (optional for most measurements) to ensure that the tool response has not changed from before the survey.

All such events are recorded in a calibration summary listing (CSL) (Fig. 1).

The calibration summary listing contains an auditable trail of the event:

- equipment with serial numbers
- actual measurement and the associated range (minimum, nominal, and maximum)
- time the event was conducted.

For the event to be valid, the measurement must fall within the defined minimum and maximum limits, using the same equipment (verified through the mnemonics and serial numbers), and performed on time (verified through the time stamp on the summary listing).

More details on the calibrations associated with the wide range of Schlumberger wireline measurements are in the *Logging Calibration Guide*, which is available through your local Schlumberger representative.

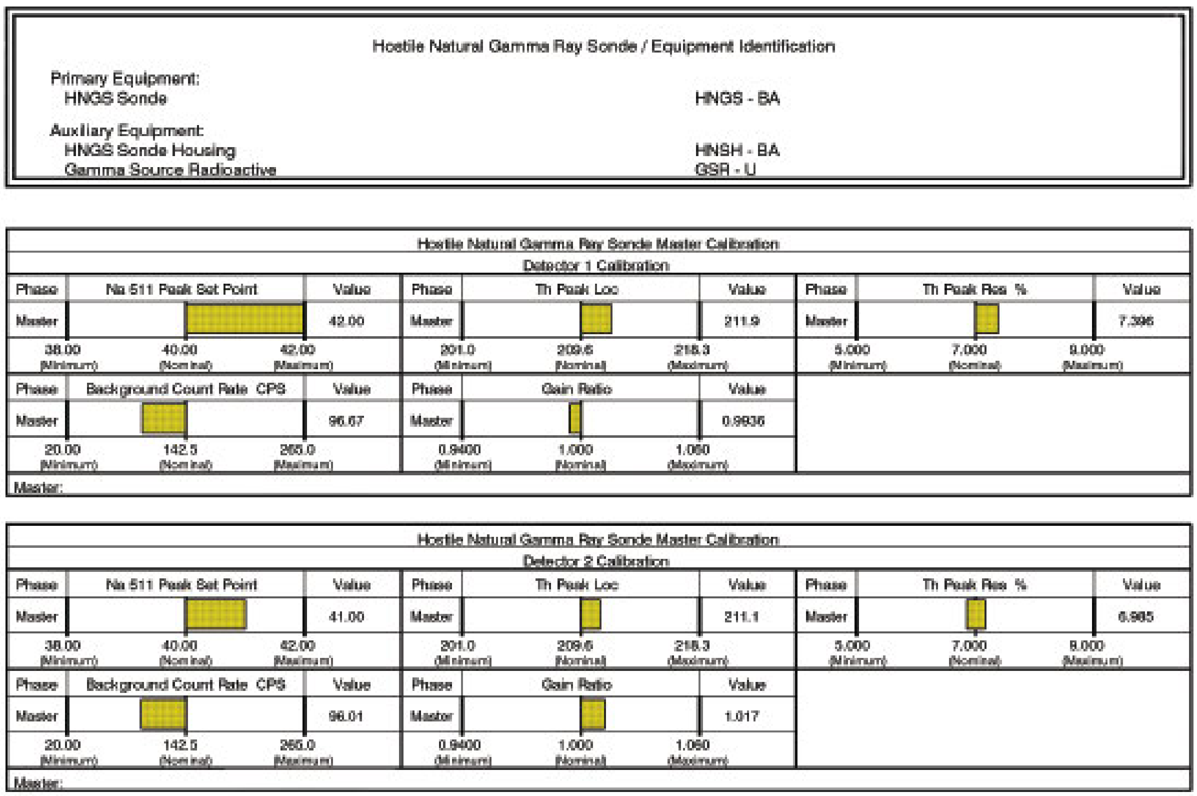


*Figure 1. Example of a master calibration.*

Schlumberger

# Depth Control and Measurement

## Overview

Depth is the most fundamental wireline measurement made; therefore, it is the most important logging parameter. Because all wireline measurements are referenced to depth, it is absolutely critical that depth is measured in a systematic way, with an auditable record to ensure traceability.

Schlumberger provides through its wireline services an absolute depth measurement and techniques to apply environmental corrections to the measurement that meet industry requirements for subsurface marker referencing.

The conveyance of tools and equipment by means of a cable enables the determination of an absolute wellbore depth under reasonable hole conditions through the strict application of wellsite procedures and the implementation of systematic maintenance and calibration programs for measurement devices. The essentials of the wireline depth measurement are the following:

- Depth is measured from a fixed datum, termed the depth reference point, which is specified by the client.
- The Integrated Depth Wheel (IDW) device (Fig. 1) provides the primary depth measurement, with the down log taken as the correct depth reference.
- Slippage in the IDW wheels is detected and automatically compensated for by the surface acquisition system.
- The change in elastic stretch of the cable resulting from changing direction at the bottom log interval is measured and applied to the log depth as a delta-stretch correction.
- Other physical effects on the cable in the borehole, including changes in length owing to wellbore profile, temperature, and other hole conditions, are not measured but can be corrected for after logging is complete.
- Subsequent logs that do not require a primary depth measurement are correlated to a reference log specified by the client, provided that enough information exists to validate the correctness of the depth measured on previous logs.
- Traceability of the corrections applied should be such that recovery of absolute depth measurements is possible after logging, if required.

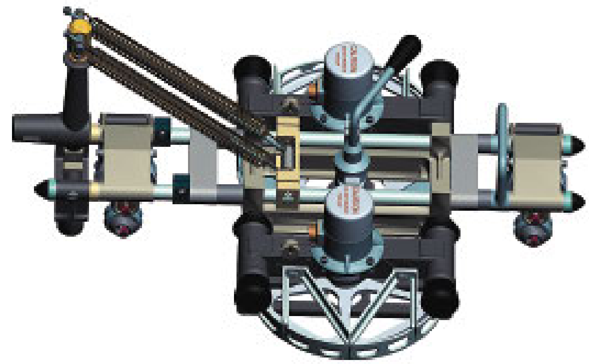

*Figure 1. Integrated Depth Wheel device.*

By strict application of this procedure, Schlumberger endeavors to deliver depth measurement with an accuracy of ±5 ft per 10,000 ft and repeatability of ±2 ft per 10,000 ft [±1.5 m and ±0.6 m per 3,050 m, respectively] in vertical wells.

## Specifications

| Measurement Specifications | |
|---|---|
| Accuracy | ±5 ft per 10,000 ft [±1.5 m per 3,050 m] |
| Repeatability | ±2 ft per 10,000 ft [±0.6 m per 3,050 m] |

## Calibration

The IDW calibration must be performed every 6 months, after 50 wellsite trips, or after 500,000 ft [152,400 m] have passed over the wheel, whichever comes first. The IDW device is calibrated with a setup that is factory-calibrated with a laser system, which provides traceability to international length standards.

Tension devices are calibrated every 6 months for each specific cable by using a load cell.

For more information, refer to the *Logging Calibration Guide*, which is available through your local Schlumberger representative.

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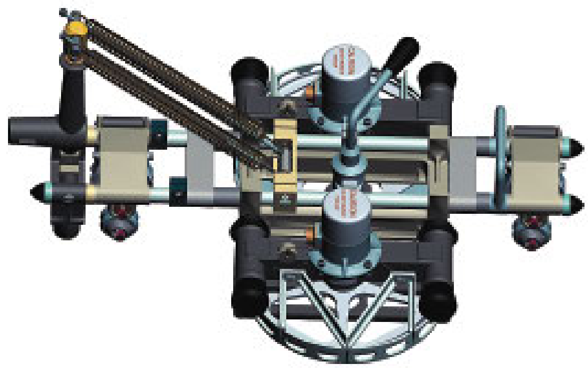

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The high-precision IDW device uses two wheels that measure cable motion at the wireline unit. Each wheel is equipped with an encoder, which generates an event for every 0.1 in [0.25 cm] of cable travel. A wheel correction is applied to obtain the ideal of one pulse per 0.1 in of cable travel.

Integration of the pulses results in the overall measured depth, which is the distance measured along the actual course of the borehole from the surface reference point to a point below the surface.

A tension device, commonly mounted on the cable near the IDW device, measures the line tension of the cable at the surface.

## Depth control procedure

On arrival at the wellsite, the wireline crew obtains all available information concerning the well and the depth references (wellsite data) from the client's representative. Information related to the calibrations of the IDW device and the tension device is entered in the surface acquisition system.

### First trip

#### First log

The procedure for the first log in a well consists of the following major steps:

1. Set up the depth system, and ensure that wheel corrections are properly set for each encoder.
2. Set tool zero (Fig. 2) with respect to the client's depth reference.
3. Measure the rig-up length (Fig. 3) between the IDW device and the rotary table at the surface. Investigate, and correct as necessary, any significant change in the rig-up length from that measured with the tool close to the surface.
4. Run in the hole with the toolstring.
5. Measure the rig-up length (Fig. 3) between the IDW device and the rotary table at bottom.
6. Correct for the change in elastic stretch resulting from the change in cable or tool friction when logging up.
7. Record the main log.
8. Record one or more repeat sections for repeatability analysis.†
9. Pull the toolstring out of the hole and check the depth on return to surface.

To set tool zero on a land rig, fixed platform, or jackup, the toolstring is lowered a few feet into the hole and then pulled up, stopping when the tool reference is at the client's depth reference point (Fig. 2).


*Figure 2. Tool zero.*

†Operational considerations may dictate a change in the order of Steps 6–8.

The following procedure for setting tool zero is used on floating vessels, semisubmersible rigs, and drillships equipped with a wave motion compensator (WMC):

1. With the WMC deactivated, stop the tool reference at the rotary table, and set the system depth to zero.
2. Lower the tool until the logging head is well below the riser slip joint, then flag the cable at the rotary table and record the current depth.
3. Have the driller pull up slowly on the elevators, until the WMC is stroking about its midpoint.
4. Raise or lower the tool until the cable flag is back at the rotary table.
5. Set the system depth to the depth recorded in Step 2.

Measuring the cable rig-up length ensures that the setup has not changed while running in the well (e.g., slack in the logging cable, movement of the logging unit, the blocks, or the sheaves). The following procedure is used to measure the rig-up length of the cable (Fig. 3):

1. Run in the hole about 100 ft [30 m], flag the cable at the IDW device, and note the depth.
2. Lower the toolstring until the flag is at the rotary table. Subtract the depth recorded in Step 1 from the current depth. The result is the rig-up length at surface (RULS).
3. Record RULS.

The speed used to proceed in the hole should avoid tool float (caused by excessive force owing to mud viscosity acting on the tool) or birdcaging of the cable. To the extent possible and operational considerations permitting, a constant speed should be maintained while running downhole. At the bottom of the hole, the measurement process is conducted to obtain the rig-up length at bottom (RULB), which is also recorded. If RULB differs from RULS by more than 1 ft [0.3 m], the rig-up has changed and the cause of the discrepancy must be investigated and eliminated or corrected for.

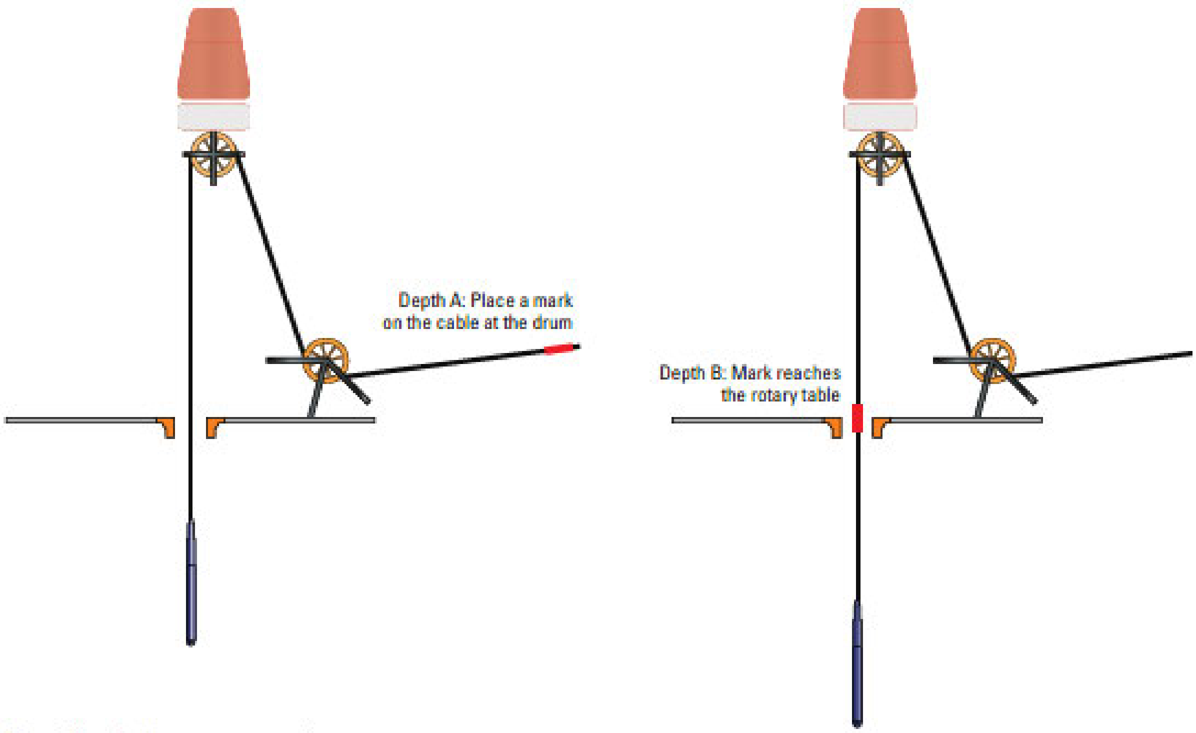


*Figure 3. Rig-up length measurement procedure.*

The rig-up length correction (RULC = RULS – RULB) is applied by adding RULC to the system depth. RULC is recorded in the Depth Summary Listing (Fig. 5).

To correct for the change of elastic stretch, the log-down/log-up method (Fig. 4) is applied as close as is reasonable to the bottom log interval:

1. Continue toward the bottom of the well at normal speed.
2. Log down a short section (minimum 200 ft [60 m]) close to the bottom, making sure to include distinctive formation characteristics for correlation purposes.
3. At the bottom, open calipers (if applicable) and log up a section overlapping the down log obtained in Step 2.
4. Using the down log as a reference, adjust the up-log depth to match the down log.
5. The adjustment is the stretch correction (SCORR) resulting from the change in tension. SCORR should be added to the hardware depth before logging the main pass.
6. Record SCORR and the depth at which it was determined in the Depth Summary Listing (Fig. 5).

If it is determined to be too risky to apply the delta-stretch correction before starting the log, the log can be recorded with no correction and then depth-shifted after the event with a playback. This procedure must be documented clearly in the Depth Summary Listing remarks. Such a procedure is justified when the well is excessively hot or sticky, and following the steps previously outlined could lead to a significant risk of tool problems or failure to return to bottom (and thus to loss of data).

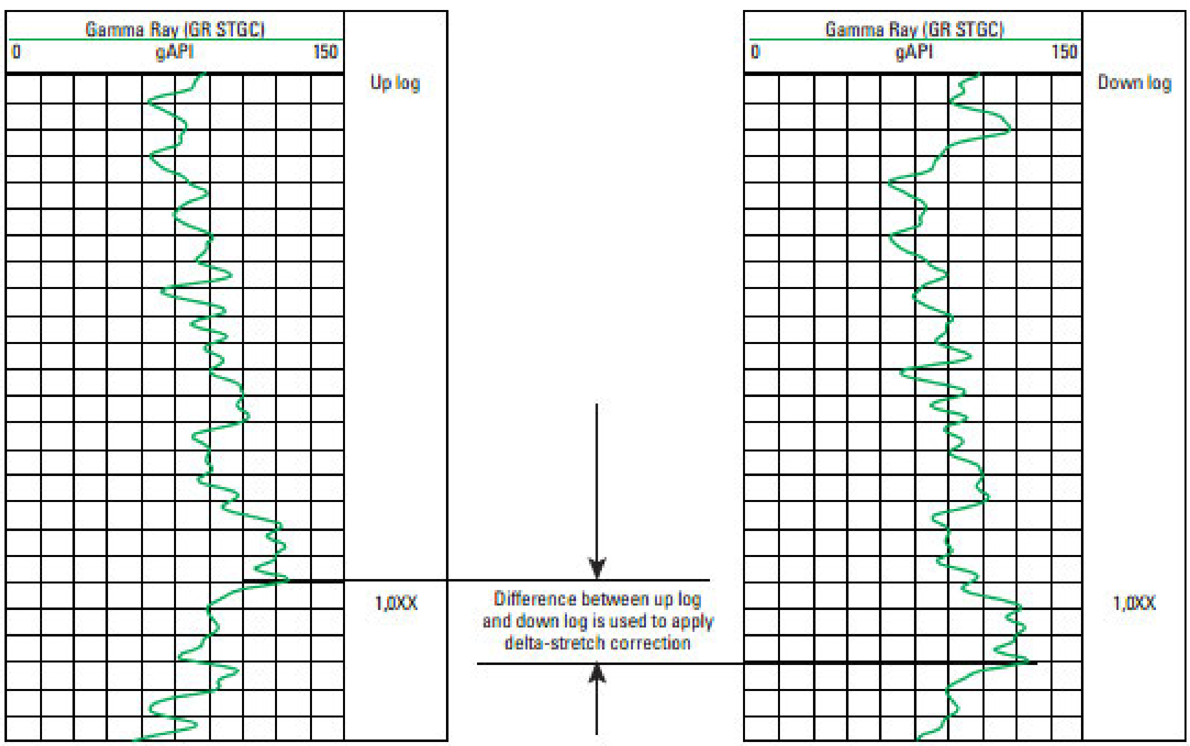


*Figure 4. Stretch correction.*



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After pulling out of the hole, tool zero is checked at the surface, as was done before running in the hole, and the difference is recorded in the Depth Summary Listing (Fig. 5). In deviated wells in particular, environmental effects may lead to a re-zero error, with the depth system reading other than zero when the tool reference is positioned opposite the log reference point after return to the surface. Recording this difference is an essential step in controlling the quality of any depth correction computed after the log, because that depth correction process should include an estimate of the expected re-zero error.

All information related to the procedure followed for depth control should be recorded in the Depth Summary Listing (Fig. 5) for future reference.

**DEPTH SUMMARY LISTING**

Date Created: 10-Dec-20XX 12:09:15

**Depth System Equipment**

| Depth Measuring Device | | Tension Device | | Logging Cable | |
|---|---|---|---|---|---|
| Type : | IDW-B | Type : | CMTD-B/A | Type : | 7-46P |
| Serial Number: | 4XX | Serial Number: | 82XXX | Serial Number: | 83XX |
| Calibration Date: | 10-Dec-20XX | Calibration Date: | 10-Dec-20XX | Length: | 18750 FT |
| Calibrator Serial Number: | 15XX | Calibrator Serial Number: | 98XX | Conveyance Method: | Wireline |
| Calibration Cable Type: | 7-46P | Number of Calibration Points: | 10 | Rig Type: | LAND |
| Wheel Correction 1: | -3 | Calibration RMS: | 11 | | |
| Wheel Correction 2: | -2 | Calibration Peak Error: | 15 | | |

**Depth Control Parameters**

| | |
|---|---|
| Log Sequence: | First Log in the Well |
| Rig Up Length At Surface: | 352.00 FT |
| Rig Up Length At Bottom: | 351.00 FT |
| Rig Up Length Correction: | 1.00 FT |
| Stretch Correction: | 5.00 FT |
| Tool Zero Check At Surface: | 0.50 FT |

**Depth Control Remarks**

1. Subsequent trip to the well. Downlog correlated to reference log XXX by YYY company dated DD-MM-YYYY.
2. Non-Schlumberger reference log. Full 1st trip to the well depth control procedure applied, which required the addition of XX ft to the down log.
3. Delta-stretch correction was conducted at 12XXX ft and applied to depth prior to recording the main log.
4. Z-chart used as a secondary depth check.

*Figure 5. Depth Summary Listing for the first trip, first log in the well.*

**Subsequent logs**

The depth of subsequent logs on the same trip is tied into the first log using the following procedure:

1. Properly zero the tool as for the first log.
2. The rig-up length does not need to be measured if the setup has not changed since the previous log.
3. Match depths with the first log by using a short up-log pass.
4. Run the main log and repeat passes as necessary.
5. Record the re-zero error in the Depth Summary Listing. This is part of the traceability that makes possible the determination of absolute depth after the event, if required.

Subsequent logs should be on depth with the first log over the complete interval logged. However, particularly when toolstrings of different weights are run in deviated wells, the relative depths of the logs can change over long logging intervals. Subsequent correction should enable removing all discrepancies.

The amount and sign of the correction applied and the depth at which it was determined must be recorded in the Depth Summary Listing. For any down log made, the delta-stretch correction should also be recorded, as well as the depth at which it was determined.

All information related to the procedure followed for depth control of subsequent logs of the first trip should be recorded in the Depth Summary Listing (Fig. 6).

**DEPTH SUMMARY LISTING**

Date Created: 10-Dec-20XX 14:38:50

Depth System Equipment

| Depth Measuring Device | | Tension Device | | Logging Cable | |
|---|---|---|---|---|---|
| Type : | IDW-B | Type : | CMTD-B/A | Type : | 7-46P |
| Serial Number: | 4XX | Serial Number: | 82XXX | Serial Number: | 83XX |
| Calibration Date: | 10-Dec-20XX | Calibration Date: | 10-Dec-20XX | Length: | 18750 FT |
| Calibrator Serial Number: | 15XX | Calibrator Serial Number: | 98XX | Conveyance Method: | Wireline |
| Calibration Cable Type: | 7-46P | Number of Calibration Points: | 10 | Rig Type: | LAND |
| Wheel Correction 1: | -3 | Calibration RMS: | 11 | | |
| Wheel Correction 2: | -2 | Calibration Peak Error: | 15 | | |

Depth Control Parameters

| | |
|---|---|
| Log Sequence: | Subsequent trip In the Well |
| Reference Log Name: | AIT-GR |
| Reference Log Run Number: | 1 |
| Reference Log Date: | 10-Dec-20XX |

Depth Control Remarks

1. Subsequent log on 1st trip correlated to first log in the well from XX000 to XX200 ft
2. Speed correction not applied.
3. Z-chart used as a secondary depth check.
4. Correction applied to match reference log = XX ft, determined at depth XXX00 ft.
5. No rigup changes from previous log.

*Figure 6. Depth Summary Listing for first trip, subsequent logs.*

### Subsequent trips

If there is not enough information in the Depth Summary Log from previous trips to ensure that correct depth control procedures have been applied, subsequent trips are treated as a first trip, first log in the well.

If sufficient information from previous trips was recorded to show that correct depth control procedures were applied, the previous logs can be used as a reference. The subsequent trips proceed as if running the initial trip with the following exceptions:

1. In conjunction with the client, decide which previous log to use as the downhole depth reference. Ensure that a valid copy of the reference log is available for correlation purposes. If the depth reference is a wireline log from a oilfield service provider other than Schlumberger, proceed as for the first log in the well, and investigate and document any discrepancies found with respect to the reference log.
2. Run in the hole and record a down log across an overlap section at the bottom of the reference log. If the overlap section is off by less than 5 ft per 10,000 ft, adjust the depth to match the current down log with the reference log. This adjustment ensures that the down section of the current log is using the same depth reference as the correlation log. Record any corrections made as the subsequent trip down log correction.
3. If the overlap log is off by more than 5 ft per 10,000 ft, investigate and resolve any problems. Record any depth discrepancies. Consult with the client to decide which log to use as the depth reference.
4. Run down to the bottom of the well at a reasonable speed so that the tool does not float.
5. Log main and repeat passes, correcting for stretch following the first trip procedure.
6. The logging pass should overlap with the reference log by at least 200 ft, if possible. The depth should match the reference log. Any discrepancies should be noted in the Depth Summary Listing or the log remarks.

All information related to the depth control procedure followed should be recorded in the Depth Summary Listing (Fig. 7).

**DEPTH SUMMARY LISTING**

Date Created: 10-Dec-20XX 14:26:56

**Depth System Equipment**

| Depth Measuring Device | | Tension Device | | Logging Cable | |
|---|---|---|---|---|---|
| Type : | IDW-B | Type : | CMTD-B/A | Type : | 7-46P |
| Serial Number: | 4XX | Serial Number: | 82XXX | Serial Number: | 83XX |
| Calibration Date: | 10-Dec-20XX | Calibration Date: | 10-Dec-20XX | Length: | 18750 FT |
| Calibrator Serial Number: | 15XX | Calibrator Serial Number: | 9851 | Conveyance Method: | Wireline |
| Calibration Cable Type: | 7-46P | Number of Calibration Points: | 10 | Rig Type: | LAND |
| Wheel Correction 1: | -3 | Calibration RMS: | 11 | | |
| Wheel Correction 2: | -2 | Calibration Peak Error: | 15 | | |

**Depth Control Parameters**

| | |
|---|---|
| Log Sequence: | Subsequent trip to the well |
| Reference Log Name: | AIT-GR |
| Reference Log Run Number: | 1 |
| Reference Log Date: | 10-Dec-20XX |
| Subsequent Trip Down Log Correction: | 1.00 FT |

**Depth Control Remarks**

1. Subsequent trip to the well.
2. Down pass correlated to reference log within +/- 0.05%.
3. Correlation to reference log performed from XX000 to XX200 ft.
4. Correction applied to match reference log = XX ft, determined at depth XXX00 ft..
5. Z-chart used as a secondary depth check.

*Figure 7. Depth Summary Listing for subsequent trips.*

### Spudding

Spudding is not a recommended procedure, but it is sometimes necessary to get past an obstruction in the borehole. It generally involves making multiple attempts from varying depths or using varying cable speed to get past an obstruction.

If the distance pulled up is small, the error introduced is also small. In many cases, however, the tool is pulled back up for a considerable distance (i.e., increasing cable over wheel) in an attempt to change its orientation. Then, the correction necessary to maintain proper depth control becomes sizeable.

If multiple attempts are made, the correction necessary to maintain proper depth control also becomes sizeable.

When possible, log data is recorded over the interval where spudding occurs in case consequent damage occurs to the equipment that prevents further data acquisition. If it is not possible to pass an obstruction in the well, data is recorded while pulling out of the hole for remedial action.

## Absolute depth

Measurements made with wireline logs are often used as the reference for well depth. However, differences are usually noted between wireline depth and the driller's depth. Which one is correct? The answer is neither. For more information, refer to SPE 110318, "A Technique for Improving the Accuracy of Wireline Depth Measurements."

Wireline depth measurement is subject to environmental corrections that vary with many factors:

- well profile
- mud properties
- toolstring weight
- cable type
- temperature profile
- wellbore pressure
- logging speed.

All these effects may differ from one well to another, so the depth corrections required also differ. Because of the number of factors involved, the corrections can be applied through a numerical model.

### Logging down

Any short element of cable that is spooled off the winch drum as a tool is lowered downhole takes up a tension sufficient to support the weight of the tool in the well plus the weight of the cable between the winch and the tool, minus any frictional force that helps support the tool and cable. This prestretched cable passes the IDW device and its length is thus measured in the stretched condition. When this element of cable is downhole, the tension at the surface can be quite different. However, the tension on this element remains the same because it is still supporting the weight of the tool plus the weight of the cable between itself and the tool minus the frictional force.

If it is assumed that the frictional force is constant and that temperature and pressure do not affect the cable length, the tension on the cable—and thus the cable length—stays constant as the tool is lowered in the hole. Considering that all such elements remain at constant length once they have been measured, it follows that the down log is on depth. This means that the encoder-measured depth incorporates the stretched cable length, and no additional stretch correction is required.

### Logging up

When the tool reaches the bottom of the well, the winch direction is reversed. This has the effect of inverting the sign of the frictional component acting on the tool and cable. In addition, if a caliper is opened, the magnitude of the frictional force can change. As a result, the cable everywhere in the borehole is subject to an increase in tension, and thus an increase in stretch.

For the surface equipment to track the true depth correctly, a delta-stretch correction must be added to compensate for the friction change (Fig. 4). Once the correction has been applied, the argument used while running in hole is again applicable, and the IDW correctly measures the displacement of the tool provided there are no further changes in friction.‡

### Deviated wells

In deviated wells, the preceding depth analysis applies only to the vertical section of the well. Once the tool reaches the dogleg, lateral force from the wellbore supports part of the tool weight. The tool is thus shallower than the measured depth on surface; i.e., the recorded data appear deeper than the actual tool position. This is commonly referred to as tool float.

### Correction modeling

Correction modeling software estimates the delta-stretch correction to be applied at the bottom of the well, as well as the expected tool re-zero depth upon return to the surface. This software can be used to correct the depth after logging. Contact your local Schlumberger representative for more information.

‡The main assumptions remain that the friction is constant (other than the change due to reversal of direction of cable motion), and that temperature and pressure effects on the cable may be ignored.