Class VI Injection Well: Quality Assurance and Surveillance Plan

February 8, 2024

Kern River Eastridge CCS

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Title and Approval Sheet

This Quality Assurance and Surveillance Plan (QASP) is approved for use and implementation at Kern River Eastridge CCS. The signatures below denote the approval of this document and intent to abide by the procedures outlined within it.

Signature
David Wessels
Project Manager

12/12/2023
Date

Distribution List

The following project participants will receive the completed Quality Assurance and Surveillance Plan (QASP) and all future updates for the duration of the project.

Name	Organization	Project Role	Business Address
David Wessels	Chevron	Project Manager	9525 Camino Media, Bakersfield, CA 93311 David.wessels@chevron.com 661-412-6039

Glossary of Terms:

Acronym or Abbreviation	Name and Comment
Δz	Thickness
ΔSh	Horizontal stress
Δz	Thickness
°	Degree
°C	Degree, Celsius
°F	Degree, Fahrenheit
µm	Micron (micrometer)
3D	Three-dimensional
AGA	American Gas Association
AMS	Accelerator Mass Spectrometer
APHA	American Public Health Association
APHA SM	American Public Health Association Standard Method
API	American Petroleum Institute
ASTM	American Society of Testing Materials
CCS	Carbon Capture & Sequestration
CEMS	Continuous Emission Monitoring Systems
CFR	Code of Federal Regulations
CF-IRMS	Continuous-Flow Isotope Ratio Mass Spectrometry
CO_2	Carbon Dioxide
Cogen	Cogeneration facility
CRDS	Cavity Ring-Down Spectroscopy
DAS	Distributed Acoustic Sensing
DIC	Dissolved Inorganic Carbon
EPA	United States Environmental Protection Agency

Acronym or Abbreviation	Name and Comment
ft	Foot or feet
g	Gravitational acceleration (9.8 m^2/s)
g/cm^3	Grams per cubic centimeter
GPA	Gas Processors Association
HPLC	High-Performance Liquid Chromatography
ICP	Inductively Coupled Plasma
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
IRMS	Isotope Ratio Mass Spectrometry
Mg/l	Milligrams per liter
MDL	Method Detection Limit
meq	Milliequivalents
MIT	Mechanical Integrity Test
NACE	National Association of Corrosion Engineers
pH	Potential of Hydrogen
PLC	Programmable Logic Controllers
PNL	Pulse Neutron Log
ppm	Parts per million
psi	Pound per square inch
psi/ft	Pressure per square inch per foot
psi/sec	Pressure per square inch per second
psi/yr	Pressure per square inch per year
psia	Pound per square inch, absolute
psig	Pound per square inch at gage
QA	Quality Assurance
QASP	Quality Assurance and Surveillance Plan
QC	Quality Control

Acronym or Abbreviation	Name and Comment
RL	Reporting Limits
RSK-175	Describes a procedure particular at the. R.S. Kerr USEPA Laboratory in Ada, OK
SCADA	Supervisory Control and Data Acquisition
SOP	Standard Operating Procedure
SOX	Sulfur Oxide
TDS	Total Dissolved Solids, in mg/l or ppm
UIC	Underground Injection Control
USDW	Underground Source of Drinking Water
VSP	Vertical Seismic Profile
WAN	Wide Area Network
Wt%	Percent Weight

A. Project Management

A.1. Project/Task Organization

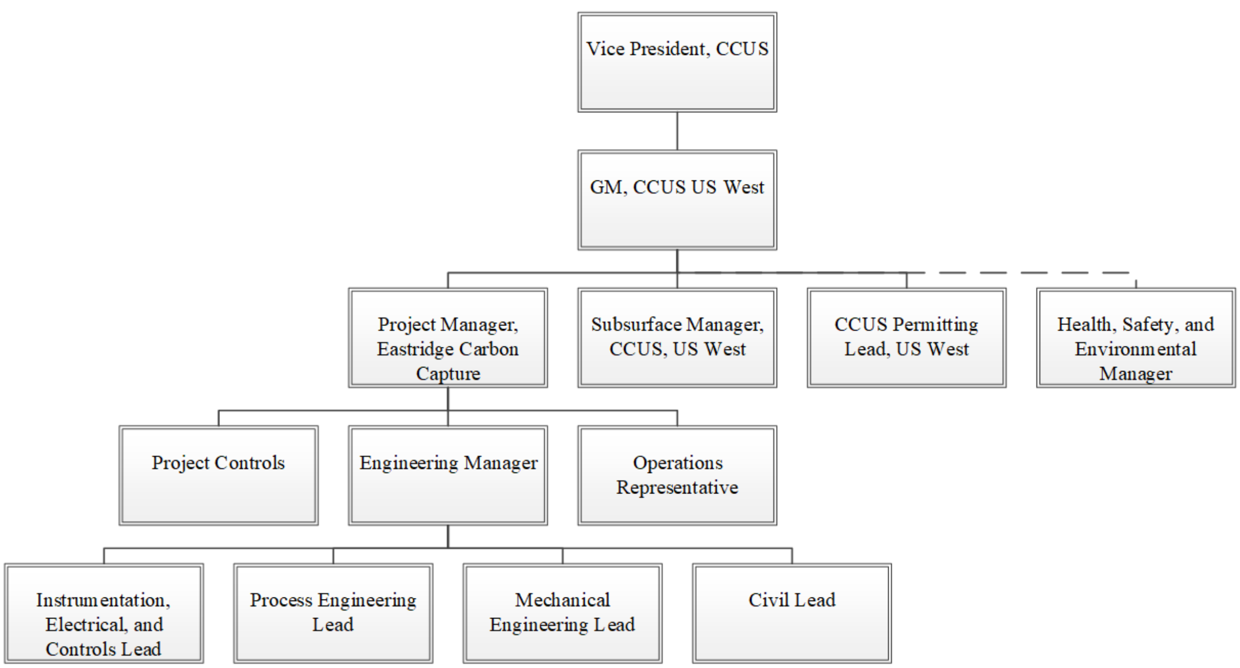
A.1.a/b. Key Individuals and Responsibilities

The Kern River Eastridge CCS Project (Project), owned and operated by Chevron U.S.A., Inc. (Chevron), includes participation from several subcontractors. Chevron will share testing and monitoring responsibilities with designated subcontractors. These testing and monitoring activities will be broadly divided into:

1. Groundwater Sampling and Analysis
2. Well Logging
3. Mechanical Integrity Testing
4. Injection Monitoring
5. Geophysical Monitoring

Figure 1 shows the organizational structure for the project. Although not all these roles have been filled because the project is not operational, the chart shows the breakdown in responsibilities for future positions.

Figure 1. Organization Structure for the Project



Roles are defined below in **Table 1**.

Table 1. Roles & Responsibilities of Key Project Personnel.

Role	Responsibility
VP, Carbon Capture Utilization and Storage (CCUS)	Leads Chevron's CCUS division.
GM, CCUS US West	Leads overall CCUS activities for West Coast of United States.
Health, Safety, and Environmental (HSE) Manager	Advises on all HSE aspects for the project.
Project Manager	Responsible for the overall coordination and administrative aspects of the project. Responsible for planning, funding, schedules, and controls needed to implement project plans and ensure that project participants adhere to the plan.
Subsurface Manager	Leads a team of earth scientists, and engineers. Responsible for subsurface aspects of the project.
CCUS Permitting Lead, US West	Responsible for permitting guidance and communication with Environmental Protection Agency (EPA).
Operations Representative	Provides operator viewpoint to guide overall project design and installation. Will oversee the data handling, management, and assessment process.
Project Controls	Responsible for cost and schedule reporting.
Engineering Manager	Leads team of discipline specific engineers related to the project. Responsible for above ground facilities design of the project.
Instrumentation, Controls, and Electrical (IC&E) Lead	Responsible for IC&E aspects of the project.
Process Engineering Lead	Responsible for process engineering aspects of the project.
Mechanical Engineering Lead	Responsible for mechanical engineering aspects of the project.
Civil Lead	Responsible for civil engineering aspects of the project.

A.1.c. Independence from Project QA Manager and Data Gathering

Most of the physical samples collected, and data gathered as part of the testing and monitoring program will be analyzed, processed, or witnessed by independent third parties outside of the project management structure. Chevron will furnish a final list of vendors, subcontractors, and independent testing labs that will have access to the monitoring data generated for the Project.

A.1.d. QA Project Plan Responsibility

Chevron will be responsible for maintaining and distributing the official approved Quality Assurance and Surveillance Plan (QASP). Chevron will periodically review this QASP and consult with the underground Injection Control (UIC) Program Director if/when changes to the plan are warranted.

A.2. Problem Definition/Background

A.2.a. Reasoning

The objective of Chevron's testing and monitoring program is to demonstrate that Project activities comply with 40 CFR 146.90, while protecting human and natural resources in the project Area of Review (AoR). To help achieve this goal, this Quality Assurance Surveillance Plan (QASP) has been developed to define the quality and standards of the testing and monitoring program and to specifically meet the requirements set forth in Section 40 CFR 146 of the UIC regulations.

A.2.b. Reasons for Initiating the Project

Chevron believes Carbon Capture and Storage (CCS) technologies, both novel and traditional, will be essential to accelerating the lower carbon ambitions of our company and customers. Chevron is working to advance these technologies, and the domestic CCS industrial ecosystem, by partnering with the United States Department of Energy (DOE) to scale viable lower carbon solutions across the value chain.

Chevron, in collaboration with carbon capture technology providers, skilled design, engineering and construction firms, and local community support from California State University, Bakersfield (Team1), aims to demonstrate the safe capture, transport, and permanent storage of CO_2 from an existing combined heat and power natural gas electric generation facility (Facility) located in the Kern River field in Kern County (Project).

The Project will capture, transport, and sequester a full exhaust CO_2 stream from 2 GE LM2500 gas turbines (46MW[e]) at its Facility to demonstrate decarbonization for the critical high efficiency, heavy industrial gas turbine sector using conventional amine solvent technology.

The expected CO_2 capture rate is 200,000 - 300,000 metric tonnes per annum of 3-4% CO_2 concentration with at least a 90% CO_2 capture efficiency.

A.2.c. Regulatory Information, Applicable Criteria, Action Limits

Owners or operators of CO_2 injection wells are required to perform several types of activities during the lifetime of the project to assess that the injection well maintains its mechanical integrity, that fluid migration and the extent of pressure elevation are within the limits described in the permit application, and that underground sources of drinking water (USDW's) are not endangered. Specific monitoring procedures include internal and external well mechanical integrity tests (MITs), injection well pressure, temperature, and rate monitoring during operation, monitoring of ground water quality, and tracking of the CO_2 plume and associated pressure front. This QASP discusses methods of measurement as well as the steps Chevron will take to assess that the quality of all the gathered data provides confidence that the project is constructed and operated safely.

A.3. Project/Task Description

A.3.a/b. Summary of Work to be Performed

Table 2 and **Table 3** below describe the testing and monitoring tasks, reasoning, and techniques.

Table 2. Summary of Testing and Monitoring

Activity	Location(s)	Method	Analytical Technique	Lab/Custody	Purpose
Carbon dioxide stream analysis	Downstream of CO_2 capture facility	Online analyzer	Direct Measurement	N/A	Monitor CO_2 stream chemical composition
Injection rate and volume	Upstream of Injection Wellhead (ANO9004INJ and MC19001INJ)	Coriolis flow meter or equivalent flow meter	Direct Measurement	N/A	Monitor injection rate and volume
Injection pressure/temperature	Injection Wellhead (ANO9004INJ and MC19001INJ)	Pressure gauge	Direct Measurement	N/A	Monitor injection pressure and temperature
Annular pressure	Injection wellhead & above injection packer (ANO9004INJ and MC19001INJ)	Pressure gauge	Direct Measurement	N/A	Monitor annular pressure and wellbore integrity
Annular Volume	Injection wells (ANO9004INJ and MC19001INJ)	Volumetric calculation	Direct Measurement	N/A	Monitor fluid volume added to the annulus
Downhole pressure	Injection wells (ANO9004INJ and MC19001INJ)	Downhole pressure gauge	Direct Measurement	N/A	Monitor bottomhole injection pressure
Corrosion monitoring	Upstream of injection well wellhead, along injection well wellbore (ANO9004INJ and MC19001INJ)	Coupons in corrosion loops. Wireline logs (if determine necessary based on coupons).	Physical Analysis	N/A	Monitor well integrity

Activity	Location(s)	Method	Analytical Technique	Lab/Custody	Purpose
External mechanical integrity	Injection wells (ANO9004INJ, MC19001INJ)	Oxygen Activation Wireline Log	Wireline Log Analysis	N/A	Monitor well integrity
Internal mechanical integrity	Injection wells (ANO9004INJ and MC19001INJ)	Standard Annulus Pressure Test	Direct Measurement	N/A	Monitor well integrity
CO_2 Plume Monitoring	Injection & deep monitoring wells (ANO9004INJ, MC19001INJ, RCA9001OB, COR9001OB, HK_9001OB, DDA9001OB)	Vertical Seismic Profile (VSP) survey via Distributed Acoustic Sensing (DAS) fiber	Seismic Analysis	N/A	Monitor CO_2 plume migration
	Deep monitoring wells (RCA9001OB, COR9001OB, HK_9001OB, DDA9001OB)	Pulsed Neutron Wireline Log	Wireline Log Analysis	N/A	Monitor CO_2 plume migration
Pressure Fall Off Test	Injection wells (ANO9004INJ and MC19001INJ)	Downhole pressure gauge	Pressure Transient Analysis	N/A	Reservoir Characterization

Activity	Location(s)	Method	Analytical Technique	Lab/Custody	Purpose
Groundwater Sampling	Shallow monitoring wells and select deep monitoring wells (ANO9003OB, GW_9002OB, IR_9001OB, KER9001OB, ANO9001OB, GW_9001OB, HK_0991OB, and COR9001OB)	U-tube sampling system or wireline/coil fluid sampler	Chemical analysis	CA certified lab	Monitor for CO_2 contamination
Reservoir Pressure	Deep monitoring wells (DDA9001OB, HK9001OB, COR9001OB, RCA9001OB)	Array sensor system	Direct Measurement	N/A	Monitor reservoir pressure

Table 3. Instrumentation Summary

Monitoring Location	Instrument Type	Monitoring Target (Formation or Other)	Data Collection Location(s)	Explanation
CO_2 Facility	Online Analyzer	CO_2 Stream	Downstream of CO_2 capture facility	Measures CO_2 stream composition prior to injection
Deep Monitoring Wells	DAS fiber optic	Vedder	Fiber optics run on long string of casing (DDA9001OB, HK9001OB, COR9001OB, RCA9001OB)	CO_2 plume migration
	Array sensor system	Vedder	Casing conveyed across Vedder (DDA9001OB, HK9001OB, COR9001OB, RCA9001OB)	Measures pressure across cement barrier and into the reservoir, direct measure of pressure front
	Fluid Sampling Tool	Olcese	U-tube sampling system or fluid sampling tool deployed on tubing, wireline, or coil (HK9001OB, COR9001OB)	Collects fluid samples from Olcese
Shallow Monitoring Wells	Fluid Sampling Tool	Santa Margarita/Olcese	U-tube sampling system or fluid sampling tool deployed on tubing, wireline, or coil (ANO9003OB, GW_9002OB, IR_9001OB, KER9001OB, ANO9001OB, GW_9001OB)	Collects fluid samples from Olcese or Santa Margarita, depending on the well
Injection Wells	DAS fiber optic	All formations across wellbore path	Fiber optics run on long string of casing (ANO9004INJ and MC19001INJ)	CO_2 plume migration
	Dual Transducer Pressure Gauge	Vedder & annular pressure	Above injection packer (ANO9004INJ and MC19001INJ)	Bottomhole injection pressure, annual pressure, bottomhole injection temperature
	Pressure/ Temperature Gauge	Injection stream	Wellhead (ANO9004INJ and MC19001INJ)	Injection surface pressure

A.3.c. Geographic Locations

Figure 2 below shows the locations of the injection and monitoring wells which will support collection of the various characterization and monitoring measurements needed to track development of the CO_2 plume within the injection zone and identify/quantify any potential release of CO_2 from containment that may occur.

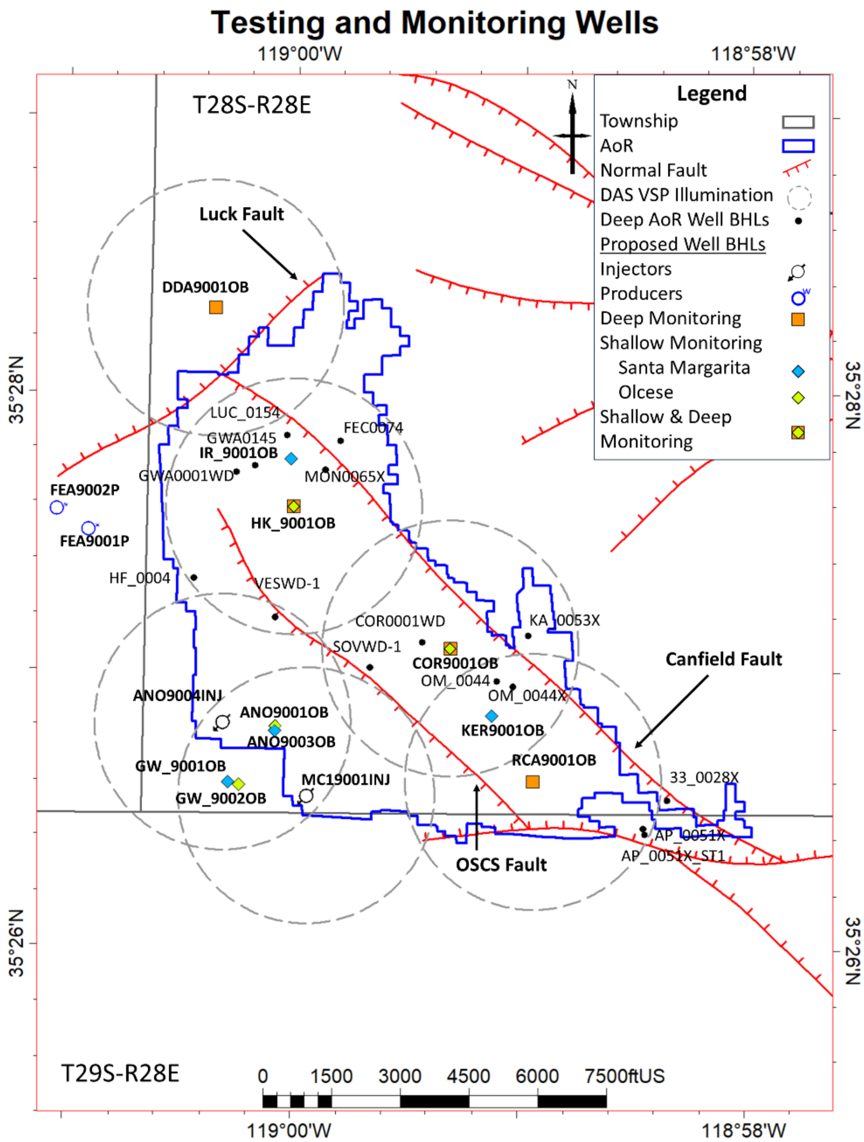


Figure 2. Location of Monitoring Wells

A.3.d. Resource and Time Constraints

No resource or time constraints have been identified for this project.

A.4.Quality Objectives and Criteria

A.4.a. Performance/Measurement Criteria

Table 4. Summary of Analytical and Field Parameters for Fluid Samples in the Vedder Sand

Parameters	Analytical Methods[1]	Detection Limit/Range	Typical Precisions	QC Requirements
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, Sr, Tl, Zn	ICP-MS[2], EPA Method 6020B	MDL (0.001-0.006 mg/L) RL (0.002-0.10 mg/L)	± 20%	Frequent calibration, Method blank, lab control samples, matrix spikes and sample duplicate
Cations: Ca, Fe, K, Mg, Na, S, and Si	ICP, EPA Method 6010B	MDL (0.02-0.6 mg/L) RL (0.05-1.2 mg/L)	± 20%	Frequent calibration, Method blank, lab control samples, matrix spikes and sample duplicate
Anions: Br, Cl, F, I, NO_3, NO_2, SO_4, PO_4	Ion chromatography, EPA Method 300.0	MDL (0.02-0.1 mg/L) RL (0.4 mg/L)	± 20%	Frequent calibration, Method blank, lab control samples, matrix spikes and sample duplicate
Total Alkalinity	Standard Method 2320B	20.0 mg/L	± 20%	Frequent calibration, Method blank, lab control samples, matrix spikes and sample duplicate
Total dissolved solids	Standard Method 2540C	6.0/10.0 mg/L	± 10%	Frequent calibration, Method blank, lab

				control samples, matrix spikes and sample duplicate
Water density (lab)	Density Meter (ASTM D4052/D5002)	0.0001-0.1 g/cc	± 6%	Frequent calibration and sample duplicate
pH (lab)	EPA 9040B	0.05 pH units	± 10%	Frequent calibration and sample duplicate
Temperature (field)	Field instrument	Per manufacturers specs	Per manufacturers specs	Daily field calibration.
Dissolved Inorganic Carbon (DIC)	Standard Method 5310B	1.0 mg/L	± 20%	Frequent calibration, Method blank, lab control samples, matrix spikes and sample duplicate
$\delta^{18}O$ and $\delta^{2}H$ of H_2O	Analyzed via CRDS	N/A	$\delta^{18}O$: 0.10 per mil, $\delta^{2}H$: 2.0 per mil	20% of all analyses are either check/reference standards or duplicate analyses.
$\delta^{13}C$ of DIC	Gas Bench/CF-IRMS	Depends on available sample volume	0.20 per mil	20% of all analyses are either check/reference standards or duplicate analyses.
H2S headspace	ASTM D5623	Depends on available sample volume	± 20%	Frequent calibration and sample duplicate

Sulfide (Total)	EPA 9034	1.0/2.0 mg/L	± 20%	Frequent calibration and sample duplicate
Turbidity (lab)	United States Environmental Protection Agency (U.S. EPA) Method 180.1 (Same as APHA SM 2130B)	Depends on available sample volume	± 20%	Frequent calibration and sample duplicate
Conductivity (lab)	U.S. EPA Method 120.1 (Same as APHA SM 2510B and ASTM D1125-95(A)).	Depends on available sample volume	± 20%	Frequent calibration and sample duplicate
Dissolved CO_2, N_2, Ar, O_2, He, C1-C6+, by headspace	Lab in-house SOP, similar to RSK-175	Lowest quantifiable limits 1-100 ppm, varies by component	C1-C4: ± 5% C5-C6+: ± 10%	20% of all analyses are either check/reference standards or duplicate analyses.
$\delta^{13}C$ of dissolved Methane, Ethane, Propane, and CO_2, $\delta^{2}H$ of Methane	High precision (offline) analysis via Dual Inlet IRMS	Varies by component	$\delta^{13}C$: 0.1 per mil $\delta^{2}H$: 3.5 per mil	20% of all analyses are either check/reference standards or duplicate analyses.
Organic Acids (Acetate, Propionate, Butyrate)	APHA SM 5560B	Acetate: 0.663/4.0 mg/L Propionate: 0.758/4.0 mg/L Butyrate: 0.940/4.0 mg/L	± 20%	Frequent calibration and sample duplicate

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.

Table 5. Summary of Analytical and Field Parameters for Fluid Samples in Olcese and Santa Margarita.

Parameters	Analytical Methods[1]	Detection Limit/Range	Typical Precisions	QC Requirements
Cations: Al, Ba, Mn, As, Cd, Cr, Cu, Pb, Sb, Se, Sr, Tl, Zn	ICP-MS[2], EPA Method 6020B	MDL (0.001-0.006 mg/L) RL (0.002-0.10 mg/L)	± 20%	Frequent calibration, Method blank, lab control samples, matrix spikes and sample duplicate
Cations: Ca, Fe, K, Mg, Na, S, and Si	ICP, EPA Method 6010B	MDL (0.02-0.6 mg/L) RL (0.05-1.2 mg/L)	± 20%	Frequent calibration, Method blank, lab control samples, matrix spikes and sample duplicate
Anions: Br, Cl, F, I NO_3, NO_2, SO_4, PO_4	Ion chromatography, EPA Method 300.0	MDL (0.02-0.1 mg/L) RL (0.4 mg/L)	± 20%	Frequent calibration, Method blank, lab control samples, matrix spikes and sample duplicate
Total Alkalinity	Standard Method 2320B	20.0 mg/L	± 20%	Frequent calibration, Method blank, lab control samples, matrix spikes and sample duplicate
Total dissolved solids	Standard Method 2540C	6.0/10.0 mg/L	± 10%	Frequent calibration, Method blank, lab control samples, matrix spikes and sample duplicate
Water density (lab)	Density Meter (ASTM D4052/D5002)	0.0001-0.1 g/cc	± 6%	Frequent calibration and sample duplicate

Water density (field)	Sigma is Calculated from Salinity, Temperature, and Pressure	0.0 to 5.0 sigma	Dependent on salinity, temperature, and Pressure sensors	Daily field calibration.
pH (lab)	EPA 9040B	0.05 pH units	± 10%	Frequent calibration and sample duplicate
pH (field)	Field instrument	Per manufacturers specs	Per manufacturers specs	Daily field calibration.
Specific conductance (field)	Field instrument	Per manufacturers specs	Per manufacturers specs	Daily field calibration.
Specific conductance (lab)	U.S. EPA Method 120.1 (Same as APHA SM 2510B and ASTM D1125-95(A)).	Depends on sample volume	± 20%	Frequent calibration and sample duplicate
Temperature (field)	Field instrument	Per manufacturers specs	Per manufacturers specs	Daily field calibration.
Turbidity (field)	Field instrument	Per manufacturers specs	Per manufacturers specs	Daily field calibration.
Turbidity (lab)	U.S. EPA Method 180.1 (Same as APHA SM 2130B)	Depends on available sample volume.	± 20%	Frequent calibration and sample duplicate

Oxidation-Reduction Potential (field)	Field instrument	Per manufacturers specs	Per manufacturers specs	Daily field calibration.
Dissolved Oxygen (field)	Field instrument	Per manufacturers specs	Per manufacturers specs	Daily field calibration.
Dissolved Inorganic Carbon (DIC)	Standard Method 5310B	1.0 mg/L	± 20%	Frequent calibration, Method blank, lab control samples, matrix spikes and sample duplicate
$^{228}Ra/^{226}Ra$; $^{87}Sr/^{86}Sr$	EPA Method 901.1; ICP-MS	50.0 pCi/L; 0.02-4 ppb	± 25%; ± 0.00005 ppm	Frequent calibration, Method blank, lab control samples, matrix spikes and sample duplicate; At least one secondary standard is measured with each sample batch and approx. 10% of samples submitted are prepared and measured a second time.

$\delta^{18}O$ and $\delta^{2}H$ of H_2O	Analyzed via CRDS	N/A	$\delta^{18}O$: 0.10 per mil, $\delta^{2}H$: 2.0 per mil	20% of all analyses are either check/reference standards or duplicate analyses.
$\delta^{13}C$ of DIC	Gas Bench/CF-IRMS	Depends on available sample volume	0.20 per mil	20% of all analyses are either check/reference standards or duplicate analyses.
^{14}C of DIC	AMS	Depends on available sample volume	+/- 1-2 pMC	Daily monitoring of instrumentation and chemical purity in additional to extensive computer and human cross-checks.
Dissolved CO_2, N_2, Ar, O_2, He, C1-C6+, by headspace	Lab in-house SOP, similar to RSK-175	Lowest quantifiable limits 1-100 ppm, varies by component	C1-C4: ± 5% C5-C6+: ± 10%	20% of all analyses are either check/reference standards or duplicate analyses.
$\delta^{13}C$ of dissolved Methane, Ethane, Propane, and CO_2, $\delta^{2}H$ of Methane	High precision (offline) analysis via Dual Inlet IRMS	Varies by component	$\delta^{13}C$: 0.1 per mil $\delta^{2}H$: 3.5 per mil	20% of all analyses are either check/reference standards or duplicate analyses.
Sulfide (Total)	EPA 9034	1.0/2.0 mg/L	± 20%	Frequent calibration and sample duplicate

Total Petroleum Hydrocarbons	EPA 8015B	0.050 mg/L	± 20%	Frequent calibration and sample duplicate
Ammonium as N	SM 4500 NH3D	0.07/0.14 mg/L	± 20%	Frequent calibration and sample duplicate
Acetate	Sub High-Performance Liquid Chromatography (HPLC)	0.663/4.0 mg/L	± 20%	Frequent calibration and sample duplicate
Propionate	Sub HPLC	0.758/4.0 mg/L	± 20%	Frequent calibration and sample duplicate
Butyrate	Sub HPLC	0.940/4.0 mg/L	± 20%	Frequent calibration and sample duplicate
$^3He/^4He$	Noble gas mass spectrometry	1e-8 – 1e-5 (isotope ratio)	2%	Crimped copper tube sample
Helium	Noble gas mass spectrometry	4e-11 – 2e-7 mol/L	2%	Crimped copper tube sample
Neon	Noble gas mass spectrometry	2e-10 – 1e-7 mol/L	2%	Crimped copper tube sample
Argon	Noble gas mass spectrometry	4e-7 – 2e-4 mol/L	3%	Crimped copper tube sample
Krypton	Noble gas mass spectrometry	1e-10 – 6e-8 mol/L	3%	Crimped copper tube sample
Xenon	Noble gas mass spectrometry	2e-11 – 9e-9 mol/L	3%	Crimped copper tube sample

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.

Note 2: AMS = accelerator mass spectrometer; CRDS= cavity ring-down spectroscopy; ICP = inductively coupled plasma; IRMS = isotope ratio mass spectrometry; MS = mass spectrometry.
Note 3: All analyses will be performed by accredited laboratories in [State] or by the International Organization of Standardization (ISO).

Table 6. Summary of Analytical Parameters for CO_2 Stream.

Parameters	Analytical Methods[1]	Detection Limit/Range	Typical Precisions	QC Requirements
CO_2, N_2, O_2, Ar	Gas chromatography	CO_2: 50 ppm N_2 and O_2: 100 ppm	for CO_2 (> 1.5%) ±0.6% (of measured value) for CO_2 (< 0.05%) ±1.7% (of measured value) for N_2 and O_2 (>10%) ±0.5% (of measured value)	At a rate of 20% of the samples analyzed: A lab check standard, or sample duplicate is analyzed every 5th run with a lab standard being run first every day. QC method based on ASTM D1945.
CH_4, C1-C5	Gas chromatography	CH_4: 2 ppm C2 - C6+: 1ppm	CH_4: ±0.4 to 1% (of measured value) C2 - C4: ±0.4 to 1% (of measured value)	At a rate of 20% of the samples analyzed: A lab check standard, or sample duplicate is analyzed every 5th run with a lab standard being run first every day. QC method based on ASTM D1945.

			C5 - C6+: ±2 to 4% (of measured value)	
δ^{13}C of CO_2 and CH_4	High precision, dual inlet IRMS	CO_2 and CH_4: 0.25%	CO_2 and CH_4: ±0.1%	At a rate of 20% of the samples analyzed: A lab check standard, or sample duplicate is analyzed every 5th run with a lab standard being run first every day. Method similar to Edman, J.D., 2007, Newsletter of the Rocky Mountain Association of Geologists, v. 56, no. 8.
δD of CH_4	High precision, dual inlet IRMS	CH_4: 0.5%	CH_4: ±3.5%	At a rate of 20% of the samples analyzed: A lab check standard, or sample duplicate is analyzed every 5th run with a lab standard being run first every day. Method similar to Edman, J.D., 2007, Newsletter of the Rocky Mountain Association of Geologists, v. 56, no. 8.
^{14}C of CO_2	Accelerator mass spectrometry	0.44 pMC/ 0.44 pMC – 198 pMC	0.02 pMC - 0.5 pMC	NIST suite, IAEA standards, AMS wheel, and QA report

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.

Table 7. Summary of Analytical Parameters for Corrosion Coupons.

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Mass	NACE RP0775-91	0.0001 g	+/- 2%	Annual Calibration of Scale, QC checks done weekly
Thickness	NACE RP0775-91	0.001 mm	+/- 0.005 mm	Factory Calibration

Table 8. Summary of Measurement Parameters for Field Gauges.

Parameters	Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Compressor discharge pressure	Bourdon tube	0 – 6,000 psi	+/- 0.5%	Annual Calibration
Injection tubing temperature	Piezo Transducer	-20 °F – 130°F	0.1 °F	Annual Calibration
Annulus pressure	Quartz pressure/temperature sensor	0 – 10,000 psi	1.2 psi	Upon installation only
Injection tubing pressure	Dual-quartz pressure transducer	0 – 15,000 psi	0.01 psi	Annual Calibration
Wellhead pressure	Dual-quartz pressure transducer	0 – 15,000 psi	0.01 psi	Annual Calibration
Downhole temperature	Quartz pressure/temperature sensor	0 - 392 degrees Fahrenheit	0.9 degrees Fahrenheit	Upon installation only
Injection mass flow rate	N/A	0.1% of flow rate	.0001 lb/hr	Annual Calibration

Table 9. Actionable Testing and Monitoring Outputs.

Activity or Parameter	Project Action Limit	Detection Limit	Anticipated Reading
External mechanical integrity (oxygen activation wireline log)	Action will be taken when fluid movement is observed out of injection zone	Fluid velocities between 2 and 120 feet per minute	Baseline will be developed prior to injection. Significant deviation could indicate a potential mechanical integrity issue.
Internal mechanical integrity (standard annulus pressure test)	Pressure decreases by more than 10% of test pressure within a 30-minute test.	0.1 psi	Above -10% of test pressure within a 30-minute test.
Surface pressure	Action will be taken when surface pressure is outside of expected or modeled range	0.01 psi	Within proposed operating pressure range
Downhole pressure	Action will be taken when surface pressure is outside of expected or modeled range	0.006 psi	Within proposed operating pressure range
Water quality (Santa Margarita and Olcese)	Action will be taken when fluid samples differ from baseline samples and indicate movement of other fluids into these zones	Variable based on parameter (see **Table 5**)	Baseline will be developed prior to injection.

A.4.b. Precision

For groundwater sampling, data accuracy is evaluated by the collection and analysis of field blanks to test sampling procedures and matrix spikes to test lab procedures. Field blanks will be acquired no less than one per sampling event to spot check for sample bottle contamination. Duplicate water samples will also be taken in the field and tested in the laboratory to verify precision. Assessment of analytical precision will be the responsibility of the individual laboratories.

Precision information for direct pressure and temperature monitoring are found in the tables below.

A.4.c. Bias

Assessment of analytical bias is evaluated by individual laboratories, as documented in their standard operating procedures and analytical methodologies. For direct pressure, temperature or logging measurements, there is no bias.

A.4.d. Representativeness

Data representativeness is 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. The Chevron sampling network is designed to provide data representative of site-specific conditions. For analytical results of individual groundwater samples, representativeness is estimated by ion and mass balances. Ion balances with ±10% error or less is considered valid. Mass balance assessment is used in cases where the ion balance is greater than ±10% to help identify 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

Data completeness is a measure of the quantity 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 groundwater 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 is the confidence with which one data set may be compared to another. The data sets generated by the Eastridge project will be comparable to future data sets, due to the use of standard methods and the application of quality assurance/quality control (QA/QC) procedures. Groundwater sampling will occur, to the best of the project's ability, in similar weather conditions at which previous groundwater sampling has occurred to facilitate comparability of sample datasets. If historical groundwater quality data becomes available from other sources, their applicability to the project and level of quality will be assessed prior to utilization with data collected by Chevron. Direct continuous pressure, temperature, and logging measurements will be directly comparable to previously obtained data by following manufacturer calibration frequencies.

A.4.g. Method Sensitivity

The following tables provide gauge technical specifications. Values may change depending on service providers, suppliers, and specific technology chosen when gauges are installed.

Table 10. Pressure and Temperature—Downhole Gauge Specifications.

Parameter	**Value**
Calibrated working pressure range	0 – 10,000 psi
Initial pressure accuracy	1.5 psi over full scale
Pressure resolution	<0.006 psi/sec at <1 second sample rate
Pressure drift stability	+/- 2 psi/ year
Calibrated working temperature range	0 to 392 degrees Fahrenheit
Initial temperature accuracy	0.9 degrees Fahrenheit
Temperature resolution	.009 degrees Fahrenheit/second
Temperature drift stability	0.18 degrees Fahrenheit/year
Max temperature	392 degrees Fahrenheit
Instrument calibration frequency	Upon installation only

Table 11. Representative Logging Tool Specifications

Parameter	**Pulsed Neutron/Oxygen Activation**	**Ultrasonic Casing & Cement Evaluation**	**Cement Bond Log**
Logging speed	Up to 30 ft/hr (pulsed neutron) Variable depending on well conditions (oxygen activation)	Up to 4500 ft/hr	Recommended 3600 ft/hr
Vertical resolution	30 inches	Up to 6 inches	3 ft
Investigation	Formation fluid saturations, CO_2 plume migration, mechanical integrity	Casing properties, casing to cement bond, annular cement coverage	Cement bond to casing and formation
Temperature rating	325°F	350°F	350°F
Pressure rating	15,000 psi	20,000 psi	20,000 psi

Table 12. Pressure Field Gauge - Compressor Discharge Pressure

Parameter	Value
Calibrated working pressure range	0 – 6,000 psi
Initial pressure accuracy	+/- 0.5%
Pressure resolution	0.016667 psi
Pressure drift stability	0.1 psi/year

Table 13. Temperature Field Gauge – Surface Injection Tubing Temperature

Parameter	Value
Calibrated working temperature range	-20°F to 130°F
Initial temperature accuracy	4 °F
Temperature resolution	0.1 °F
Temperature drift stability	0.3 °F/ 6 months

Table 14. Pressure Field Gauge—Surface Injection Tubing Pressure and Wellhead Pressure

Parameter	Value
Calibrated working pressure range	0-15,000 psi
Initial pressure accuracy	≤ 1.5 psi
Pressure resolution	0.01 psi
Pressure drift stability	0.1 psi/year

Table 15. Pressure Field Gauge—Annulus Pressure.

Parameter	Value
Calibrated working pressure range	0 – 10,000 psi
Initial pressure accuracy	1.5 psi
Pressure resolution	<0.006 psi/sec
Pressure drift stability	2 psi/year at maximum temperature and pressure (392°F and 10,000 psi)

Table 16. Temperature Field Gauge—Injection Downhole Temperature.

Parameter	Value
Calibrated working temperature range	0 – 392 degrees Fahrenheit
Initial temperature accuracy	+/- 1.8 degrees Fahrenheit
Temperature resolution	0.018 degrees Fahrenheit
Temperature drift stability	0.09 degrees Fahrenheit/year

Table 17. Mass Flow Rate Field Gauge—CO_2 Mass Flow Rate.

Parameter	Value
Calibrated working flow rate range	6000 ft^3/day -12,000 ft^3/day
Initial mass flow rate accuracy	+/- 0.1% of rate
Mass flow rate resolution	0.0001 lb/hr
Mass flow rate drift stability	0.05% of rate

A.5. Special Training/Certifications

A.5.a. Specialized Training and Certifications

All specialized equipment at the storage site (drilling, geophysical survey, completions, wireline, and other) will be operated by trained, qualified and certified personnel, according to the service company providing the equipment. Subsequent data collected will be processed and analyzed by qualified and technically skilled personnel according to industry standards. Groundwater sampling and laboratory chemical analysis will be evaluated by qualified and experienced personnel who understand and regularly follow environmental sampling/chemical analysis procedures, standard operating procedures (SOPs) and quality control protocols using the established sampling/chemical analysis method. Chevron will furnish relevant certifications for all vendor/subcontractor staff upon request.

A.5.b/c. Training Provider and Responsibility

Personnel will be trained by the service providers responsible for data collection.

A.6. Documentation and Records

A.6.a. Report Format and Package Information

Chevron will submit semi-annual reports, annual reports, necessary notices, project operations, and ongoing monitoring results pursuant to 40 CFR 146.91. Chevron will provide written notification to the UIC Program Director with the required amount of notice before select testing occurs (e.g., MIT demonstration).

All quarterly, semi-annual, and annual reports from Chevron to U.S. 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 other formats as required by the UIC Program Director. Reports from Chevron to the UIC Program Director will be submitted online electronically according to specified reporting frequencies. **Table 18** summarizes the reporting frequencies for Chevron monitoring pursuant to 40 CFR 146.91.

Reports of other frequencies follows: An initial report including the results of a pressure fall-off test within 30 days following the test, an intent to demonstrate mechanical integrity at least 30 days prior to such demonstration, and an amended testing and monitoring plan once every five years unless it can be demonstrated that no amendment is necessary.

Table 18. Reporting Frequencies of Monitoring-Related Data Acquired during Operational Phase

Monitoring Category	Monitoring Method		UIC Reporting Frequency
Monitoring Plan Update	Reviewed every 5 years. Updated as required		Every 5 years, reported within 1 year of amended monitoring plan 40 CFR 146.90(j)
CO_2 Injection Stream Analysis	CO_2 Stream Analysis		Semi-annual 40 CFR 146.91(a)(1)
CO_2 Injection Monitoring	Injection rate and volume		Semi-Annual Report 40 CFR 146.91(a)
	Injection Pressure; annulus pressure and volume		Semi-Annual Report 40 CFR 146.91(a)
Hydrogeologic Testing	Injection well pressure fall-off testing		Report sent to Program Director 30 days following test; Amended in Semi-Annual annual report once every 5 years 40 CFR 146.91(b)(1)
Injection Well Mechanical Integrity Testing	*Internal*	Continuous annulus pressure monitoring of pressurized annulus	Report sent to Program Director 30 days following test; Amended in Semi-Annual annual report once every 5 years 40 CFR 146.91(b)(1)
	External	Oxygen Activation Wireline Log	
Corrosion Monitoring	Corrosion coupon testing (Well and pipeline materials)		Semi-Annual 40 CFR 146.91(a)
Above-Zone Aqueous Geochemistry	Above-Zone & Shallow Groundwater Fluid sampling		Semi-Annual 40 CFR 146.91(a)
Direct Pressure Monitoring	Pressure Array Sensors		Semi-Annual 40 CFR 146.91(a)
Direct & Indirect Plume Monitoring Techniques	*Wireline*	Pulsed Neutron Logging	Reported in semi-annual report at a frequency of once per year 40 CFR 146.91(a)
	Seismic	Timelapse 3D DAS-VSP Surveys	Reported in semi-annual report at a frequency of once per every five years 40 CFR 146.91(a)

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 stored and maintained 10 years post site closure and provided at the request of the UIC Program Director pursuant to 40 CFR 146.91(f).

A.6.c/d. Data Storage and Duration

Chevron or a designated contractor will store and maintain the required project data as outlined in the Class VI permit.

A.6.e. QASP Distribution Responsibility

Chevron will maintain a staffing position that will distribute the most current copy of the approved QASP.

B. Data Generation and Acquisition

B.1. Sampling Process Design

B.1.a. Design Strategy

CO_2 Stream Monitoring Strategy

Chevron will monitor the CO_2 stream continuously via an online analyzer, continuous emissions monitoring system (CEMS), or similar device. This monitoring device will be located at a point after the CO_2 stream discharges from the compressor. No other equipment will act on the CO_2 stream at this point. Therefore, the analyzer will be exposed to the same CO_2 stream as the wellhead, any downhole equipment, and formation solids and fluids.

Shallow & Deep Groundwater Monitoring Strategy

The shallow monitoring wells are designed to monitor the first permeable zone above the caprock (i.e., Olcese Sand) for early detection of loss of containment and to monitor the lowermost USDW (i.e., Santa Margarita Sandstone) to establish the non-endangerment of USDWs. While maintaining reservoir pressure of the sample, the wells will sample the groundwater using a U-tube tubing-conveyed sampling system or via a fluid sampling tool deployed on coil tubing or wireline or an equivalent technology. Chevron plans to have four sampling locations for the Santa Margarita and four sampling locations for the Olcese. For each zone, two of the four well locations are updip and downdip of the CO_2 injection wells, respectively, and two of the four well locations are located within the AoR near faults and well penetrations. All four Santa Margita sampling locations are in dedicated shallow monitoring wells (IR_9001OB, KER9001OB, ANO9001OB, and GW_9001OB). Two Olcese sampling locations are in dedicated shallow monitoring wells (ANO9003OB and GW_9002OB), and two sampling locations are in two of the deep monitoring wells (HK_9001OB and COR9001OB).

The deep monitoring wells will be cased through the injection zone (i.e., there will be no perforations across the injection zone), and the shallow perforated intervals will be isolated via packers. All wells will use the same sampling technologies as described above. Monitoring well locations were determined based on the site-specific focus areas discussed in the testing and monitoring plan. The wells are located near major faults within the AoR (e.g., Canfield, Omar Sterling Cortez South, Luck) and wells penetrations within the AoR.

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

Please refer to **Table 2** for sampling activities.

B.1.c. Site/Sampling Locations

Please refer to **Figure 2** (Location of Monitoring Wells).

B.1.d. Sampling Site Contingency

All testing and monitoring techniques will take place on the private property of the project stakeholders.

B.1.e. Activity Schedule

Table 19. Monitoring methodologies and monitoring frequencies for baseline, injection, and post-injection phases.

Monitoring Category	Monitoring Method		Baseline Frequency (1 year)	Injection Phase Frequency (20 years)*	Post-Injection Frequency (50 years)*
Monitoring Plan Update	Reviewed every 5 years. Updated as required		N/A	As required	As required
CO_2 Injection Stream Analysis	Continuous monitoring of injection stream composition		N/A	Continuous	N/A
CO_2 Injection Process Monitoring	Continuous monitoring of injection process (e.g., injection rate, pressure, and temperature; annulus pressure)		N/A	Continuous	N/A
Hydrogeologic Testing	Injection well pressure fall-off testing		1 Prior to injection	1 per every 5 years	N/A
Injection Well Mechanical Integrity Testing	*Internal*	Continuous annulus pressure monitoring of pressurized annulus	1 after well completion *(injectors)*	Continuous *(injectors)*	1 prior to abandonment
	External	Oxygen activation log	1 after well completion *(injectors)*	Annual *(injectors)*	1 prior to abandonment *(injectors)*
Corrosion Monitoring	Corrosion Loop (well and pipeline materials)		N/A	Quarterly	N/A
Groundwater Quality and Geochemistry Monitoring (Above-Zone)	Above-Zone & Shallow Groundwater Fluid sampling		Quarterly, 1 yr. prior to injection	Quarterly	Annual
Direct Pressure Monitoring	Pressure array sensors in deep monitoring wells		1 yr. prior to injection	Monthly	1 per every 5 years
Direct & Indirect Plume Monitoring Techniques	*Wireline*	PNL	1 prior to injection	Annual	1 per every 5 years
	Seismic	Timelapse 3D DAS-VSP Surveys	1 prior to injection	1 per every 5 years	10, 30, & 50 years post injection

*Monitoring technologies and monitoring and reporting frequencies provided in this permit may change, pursuant to EPA approval, based on monitoring data and/or regulatory changes.

B.1.f. Critical/Informational Data

Detailed field and laboratory documentation will be recorded in field and laboratory forms and notebooks, and chain of custody forms will be used during groundwater sampling and analytical efforts. Critical information to be documented includes time and date of activity, person performing activity, location of activity (well/field sampling) or instrument (lab analysis), instrument calibration data, field parameter values. For laboratory analyses, critical data is generated during the analysis process and provided to end users.

B.1.g. Sources of Variability

Several potential sources of variability related to monitoring activities exist including:

- Natural variation in formation pressure and temperature, ground water fluid quality, seismic activity, and reservoir properties
- Natural variation in the in the groundwater fluid chemistry and quality from climate change due to anthropogenic causes.
- Variation in fluid quality, formation pressure and temperature, and seismic activity as a result of project operations
- Changes in recharge due to precipitation (rainfall, drought, and snowfall)
- Changes in instrument calibration during sampling or analytical activity
- Different personnel collecting or analyzing samples
- Variation in environmental conditions during field sampling
- Changes in analytical data quality during life of project
- Data entry errors

Variability related to monitoring activities may be reduced or reconciled via the following methods:

- Gathering baseline data to observe and document natural variation in monitoring parameters
- Evaluating data in a timely manner after collection to observe anomalies that can be addressed by resampling or reanalyzing
- Conducting statistical analysis of data to determine whether variability is the result of natural variation or project activities
- Maintaining weather-related data using on-site data or data collected from nearby locations (such as local airports)
- Verifying instrument calibration before, during and after sampling and analysis
- Provide appropriate training for staff
- Performing laboratory quality assurance checks using third party reference materials, and/or blind and/or replicate sample checks
- Utilizing a systematic review process of data that may include sample-specific data quality checks

B.2. Sampling Methods

B.2.a/b. Sampling SOPs

Groundwater Sampling

Groundwater samples will be collected into pressurized sample containers using a U-tube sampling system or via a fluid sampling tool deployed on coil tubing or wireline. The U-tube sampling system is described in Freifeld, 2009. The selected sampling system will be capable of collecting a sufficient volume of fluid as required by the laboratories to complete all the analyses listed in **Table 5**. Given the depths of the Olcese and Santa Margarita, the primary preservation technique is to preserve reservoir pressure in the sample containers. It may not be practicable to use chemical preservatives or field filter the pressurized samples which may reduce hold times in which case Chevron will coordinate with the laboratories to expedite the shipping and analysis.

Prior to taking a groundwater sample, monitoring wells will be purged to verify that samples are representative of formation water quality. Refer to **Table 20** below for stabilization criteria during well purging. These parameters will be measured using portable probes in the field which will be calibrated at the beginning of each sampling day. However, alternative protocols for assessing well purging may be developed for pressurized sample collection.

Table 20. Stabilization Criteria of Water Quality Parameters During Shallow Well Purging.

Field Parameter	**Stabilization Criteria**
pH	±0.2 units
Temperature	±1 ºC
Specific conductance	±3% of reading in μS/cm
Dissolved oxygen	±10% of reading or 0.3 mg/L whichever is greater
Turbidity	Three sequential samples with values within +/- 2%

B.2.c. In-situ Monitoring

In-situ monitoring of water samples is not planned.

B.2.d. Continuous Monitoring

DAS Fiber Optic

DAS technology will continuously collect acoustic data along a fiber-optic line which will be run along the outside of the injection-string of casing on CO_2 injection and deep monitoring wells. The DAS will be used for VSP seismic surveys to indirectly monitor the location of the CO_2 plume.

Pressure Gauges

Downhole pressure gauges will be installed tubing-conveyed in the injection wells to continuously measure bottomhole pressures and annular pressures. This pressure data will confirm internal casing integrity on injection wells.

Array Sensors

Array pressure sensor technology will be installed along the outside of the injection string of casing across the Vedder in the deep monitoring wells. This technology reads across the cement barrier and will directly measure reservoir formation pressures.

Injection Parameters

Data related to operational processes (injection rate and volume, annular pressure and volume) will be continuously monitored via surface gauges and mass flowmeters installed at injection well wellheads. This data will be utilized to verify that injection operations are running safely and efficiently.

B.2.e. Sample Homogenization, Composition, Filtration

Described in section B.2.b.

B.2.f. Sample Containers and Volumes

For groundwater sampling events, pressurized containers will be used to preserve reservoir pressure during shipment to the laboratories.

B.2.g. Sample Preservation

For groundwater samples, pressurized containers will be used to preserve reservoir pressure during shipment to the laboratories.

B.2.h. Cleaning/Decontamination of Sampling Equipment

Each groundwater monitoring well will have its own U-tube sampling system to reduce the likelihood of cross contamination between wells. Any wireline sampling tool will be decontaminated prior to performing any sampling activity.

B.2.i. Support Facilities

When sampling of groundwater, the following equipment is needed: Compressed nitrogen tanks and analytical meters (pH, specific conductance, etc.). Field analyses are usually conducted in field vehicles and portable laboratory trailers located on site.

Deployment and retrieval of well gauges will be conducted via procedures and equipment recommended by the vendor, subcontractor, or standard industry practice.

B.2.j. Corrective Action, Personnel, and Documentation

Field staff will be responsible for testing equipment properly and conducting corrective actions on broken or malfunctioning field equipment. All surface wellheads and valves will be inspected, and leak inspection results maintained. If corrective action cannot be completed in the field, the equipment will be returned to the manufacturer for repair or equipment replaced. Substantial corrective actions that may impact analytical results will be documented in field notes.

B.3. Sample Handling and Custody

Geophysical logging, continuous monitoring, and pressure/temperature monitoring are not relevant to this section, and therefore, are omitted.

To preserve samples after collection, they will be placed in ice chests in the field and maintained at approximately 4°C until analysis. The samples will be kept at their preservation temperature and sent to the selected laboratory within 24 hours of collection. Analysis of the samples will be completed within the holding time specified in **Table 21**. As needed, alternative sample containers and preservation techniques will be used to meet analytical requirements with approval from the UIC Program Director.

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

See **Table 21**.

B.3.b. Sample Transportation

See description above.

B.3.c. Sampling Documentation

Field documentation will be compiled for all groundwater samples collected. Field notes will be archived for future reference. Groundwater sampling personnel are responsible for the sample documentation.

B.3.d. Sample Identification

Waterproof labels will be attached to all sample bottles containing information denoting project, sampling date, sampling location, sample identification number, sample type (freshwater or brine), analyte, volume, filtration used (if any), and preservative used (if any). An example of a sample bottle label is displayed in **Figure 3**.

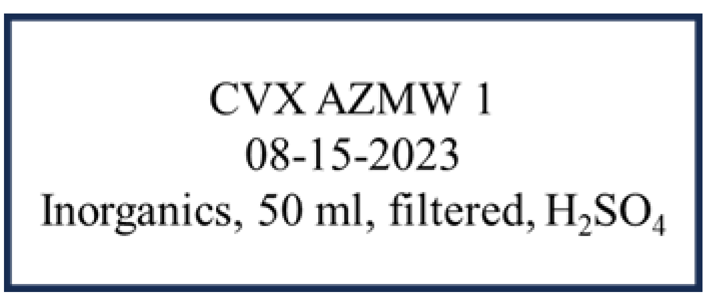


Figure 3. Example Label for Groundwater Sample Bottles.

Table 21. Summary of Sample Containers, Preservation Treatments, and Holding Times for CO_2 Gas Stream Analysis

Sample	Volume/Container Material	Preservation Technique	Sample Holding time (max)
CO_2 gas stream	75cc stainless steel gas cylinder	None	5 days

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

A standardized form will be used to document groundwater sample chain-of-custody. The form is displayed in **Figure 4**. A copy of the form will be provided to the person or laboratory receiving the samples as well as the person or laboratory transferring the samples. These forms will allow simplified tracking of sample status and will be archived. The groundwater sampling personnel are responsible for the chain-of-custody forms and record maintenance.

CHAIN OF CUSTODY RECORD (Page __ of __)

Kern River Eastridge CCS Project

	MGSC ID	ISGS MVA ID	Matrix	Date Collected	Time Collected	Sampling Team	Circle analyses to be performed
1							anions, cations, TDS, alk, NH_3, NVOC
2							anions, cations, TDS, alk, NH_3, NVOC
3							anions, cations, TDS, alk, NH_3, NVOC
4							anions, cations, TDS, alk, NH_3, NVOC
5							anions, cations, TDS, alk, NH_3, NVOC
6							anions, cations, TDS, alk, NH_3, NVOC
7							anions, cations, TDS, alk, NH_3, NVOC
8							anions, cations, TDS, alk, NH_3, NVOC
9							anions, cations, TDS, alk, NH_3, NVOC
10							anions, cations, TDS, alk, NH_3, NVOC
11							anions, cations, TDS, alk, NH_3, NVOC
12							anions, cations, TDS, alk, NH_3, NVOC
12							

CHAIN OF CUSTODY		
Relinquished by:	Print Name:	Date and Time:
Received by:	Print Name:	Date and Time:
General Remarks: - Field parameters are to be recorded on separate sheets by sampling teams. - Any special laboratory instructions or remarks should be made below.		
Data Contacts:	Fund:	
Billing Contact:	Billing Address:	
Send Data To:		

Remarks:

Rev. Oct. 2011 (RL)

Figure 4. Example Chain of Custody Form to be used for Laboratory Sampling Handling.

B.4. Analytical Methods

B.4.a. Analytical SOPs

Upon selection of a contact laboratory, other laboratory-specific SOPs will be identified. Chevron will provide the agency with all laboratory SOPs developed for specific parameters using the standard methods, upon request. The laboratory technicians performing the analyses on the samples will be trained on the SOP developed for each standard method. Technician's training certifications will be included with the biannual report.

B.4.b. Equipment/Instrumentation Needed

See **Table 21**.

B.4.c. Method Performance Criteria

It is not anticipated that nonstandard method performance criteria will be needed for this project.

B.4.d. Analytical Failure

The laboratory carrying out the analyses in the above tables will be responsible for properly addressing analytical failure according to their respective SOPs.

B.4.e. Sample Disposal

Proper sample disposal is the responsibility of each laboratory performing the analyses listed in the above tables.

B.4.f. Laboratory Turnaround

Fluid sample analysis turnaround time varies by laboratory. A turnaround of verified analytical results within approximately two months is anticipated to meet project needs.

B.4.g. Method Validation for Nonstandard Methods

The need for nonstandard methods is not anticipated for this project. If nonstandard methods are needed or proposed in the future, the U.S. EPA will be consulted to determine additional actions that shall be undertaken.

B.5. Quality Control

B.5.a. QC activities

Blanks

Field blanks will be utilized for both shallow and deep groundwater sampling to identify potential contamination due to the collection and transportation process. Field blanks will be collected and analyzed for the inorganic analytes at a frequency of 10% or more. The field and transport conditions for field blanks will be the same as those of the groundwater samples.

Duplicates

During each round of shallow groundwater sampling, a second groundwater sample is collected from one well, selected based on a rotating schedule. These duplicate samples are collected from the same source and at the same time as the original sample in a different, yet identical sample container. Duplicate samples are processed as all other samples and are used to determine sample heterogeneity and analytical precision.

B.5.b. Exceeding Control Limits

If the sample analytical results do not fall within control limits, further examination of the analytical results will be done as outlined in Section B.5.c below. The method indicates whether cation or anion analyses should be considered suspect based on the mass balance ratio. Suspect ion analyses are then compared to historical data and interlaboratory results, if available. The resulting analyses are then brought to the attention of the analytical laboratory for confirmation and/or reanalysis. The ion balance is then recalculated and verified. If the discrepancy is still not resolved, suspect data are noted, and may be given less importance in data interpretations.

B.5.c. Calculating Applicable QC Statistics

Charge Balance

To determine correctness of the groundwater analyses, the analytical results are evaluated based on the anion-cation charge balance calculation. All potable waters are electrically neutral; thus, the chemical analyses should produce similar negative and positive ionic activity. The anion-cation charge balance will be calculated using the formula:

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

where the sums of the ions are given in milliequivalents (meq) per liter, and the acceptable charge balance is ±10%.

Mass Balance

If the charge balance acceptance criteria are not acceptable, the ratio of the measured TDS to the calculated TDS will be calculated using the formula:

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

with anticipated values between 1.0 and 1.2.

Outliers

A determination of potential statistical outliers is essential before the statistical evaluation of groundwater. The project will refer to the U.S. EPA's Unified Guidance (March 2009) for the selection of recommended statistical methods to identify outliers in groundwater chemistry data sets as appropriate. These methods in the document include Probability Plots, Box Plots, Dixon's test, and Rosner's test. The EPA-1989 outlier test may also be used as an additional screening tool to identify potential outliers.

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

1. Vendor will maintain DAS according to manufacturer standards.
2. Vendor will maintain P/T gauges according to manufacturer standards.
3. Vendor will maintain logging tool equipment will be maintained as per wireline industry best practices.
4. For groundwater sampling, field equipment will be maintained, factory serviced, and factory calibrated per manufacturer's recommendations. Spare parts that may be needed during sampling will be included in supplies on-hand during field sampling.
5. For all laboratory equipment, testing, inspection, and maintenance will be the responsibility of the analytical laboratory per standard practice, method-specific protocol, or NELAP requirement.

B.7. Instrument/Equipment Calibration and Frequency

B.7.a. Calibration and Frequency of Calibration

All field and downhole gauges will be calibrated prior to use by the equipment supplier. Logging tool calibration will be conducted as per the standards of the service company providing the equipment. Calibration frequency will be determined by standard industry practices.

Portable field meters or multiprobe sondes used to determine field parameters of groundwater samples (e.g., pH, temperature, specific conductance, dissolved oxygen) are calibrated according to manufacturer recommendations and equipment manuals (Hach, 2006) before each sample collection. Recalibration is performed if any components fail to meet calibration standards, or do not stabilize during sampling.

Distributed Acoustic Sensing (DAS) lines will be tuned with auto calibration software after all the fiber connections have been performed on site. The depth will be calibrated and aligned to measured well depth.

B.7.b. Calibration Methodology

Logging tool calibration methodology will follow standard industry practices. Calibration of all field and downhole gauges, gas chromatographs, and mass flow meters will be conducted by the respective manufacturers/suppliers as per their normal procedures.

Groundwater sampling calibration standards typically require 7 and 10 for pH, a potassium chloride solution with a value of 1413 microsiemens per centimeter (µS/cm) at 25°C for specific conductance, and a dissolved oxygen calibration to a 100% dissolved O_2 solution. Calibration for the pH meters is performed according to the manufacturer's specifications, using a 2-point calibration bounding the range of the sample. For coulometry, sodium carbonate standards with a concentration of 4,000 mg CO_2/L are routinely analyzed to calibrate instrument.

B.7.c. Calibration Resolution and Documentation

Logging tool recalibration and documentation will be conducted as needed by the logging company, following standard industry practices.

Groundwater sampling equipment calibration occurs regularly, and values are recorded in sampling records, with any errors in calibration noted. For parameters where calibration resolution is not feasible, redundant equipment may be used so loss of data is minimized.

B.8. Inspection/Acceptance for Supplies and Consumables

B.8.a/b. Supplies, Consumables, and Responsibilities

Individual vendors selected and approved by Chevron are responsible for ensuring that all supplies and consumables for field and laboratory operations are inspected, and acceptable for data collection activities. Procurement of supplies and consumables related to groundwater analyses will be the responsibility of the laboratory conducting water analyses, in accordance with established standard methodology and operating procedures.

B.9. Nondirect Measurements

B.9.a. Data Sources

Plume development will also be monitored via 3D VSP and pulsed neutron logging techniques. Pulsed neutron logging detects CO_2 concentration in a well and repeat logging runs will be compared to the baseline run conducted before injection operations being. Distributed acoustic sensing fiber measures acoustic waves passing through/near the fiber optic cable ran along the long-string casing and can act as downhole VSP geophones. This technology can be used to generate 3D VSP surveys to track the CO_2 plume.

Repeatability of subsequent seismic surveys is crucial for accurate comparison. Therefore, to verify survey quality, the locations for shots and receivers and procedure of acquisition of sequential surveys must be consistent. Seismic surveys will be compared to a baseline survey collected prior to injection operations to track and monitor plume growth and movement.

B.9.b. Relevance to Project

Time-lapse seismic surveys and scheduled pulsed neutron logging will be used to track movement and growth of the CO_2 plume in the subsurface. After initial baseline testing is conducted prior to injection, processing and comparing subsequent surveys will allow project managers to monitor the extent of the plume. Numerical modeling will be conducted throughout the project to predict the CO_2 plume growth and migration over time by combining the processed seismic data with the existing geologic model.

B.9.c. Acceptance Criteria

Seismic data acquisition will be completed using standard industry practices. Seismic data acquisition quality assurance checks will be conducted throughout the acquisition of subsequent surveys to verify repeatability and consider parameters such as ground conditions, source/receiver locations and source frequency.

Seismic data processing will be completed using standard industry practices. Seismic data processing quality assurance checks will be conducted throughout each stage of processing to verify correct phase, noise removal and usability of amplitudes.

B.9.d. Resources/Facilities Needed

Chevron will subcontract all necessary resources and facilities for seismic monitoring, in-zone pressure monitoring, groundwater sampling, and other required monitoring equipment and services.

B.9.e. Validity Limits and Operating Conditions

Intraorganizational verification by trained and experienced personnel will ensure that all seismic surveys and numerical modeling are conducted according to standard industry practices.

B.10. Data Management

B.10.a. Data Management Scheme

Data will be maintained internally by Chevron and backed up on and/or held on secured servers.

B.10.b. Recordkeeping and Tracking Practices

All records of collected data will be securely kept and properly labeled for auditing purposes. Various end devices will be collected and stored in a data center locally and then on a separate system for archiving and reporting.

B.10.c. Data Handling Equipment/Procedures

All data storage equipment will be properly maintained and operated according to Chevron technical standards. The center point of the field devices will be the Programmable Logic Controllers (PLC) or similar. PLCs will sit on a hardened network, secured from the office/data network, and talk to end devices (flow computers, sensors, pump motors, valves, compressors, chromatographs, monitoring site equipment, etc.). A Wide Area Network (WAN) or similar will connect to each location's local network including the secured network. The WAN is comprised of leased circuits, cellular networks and satellites all connected to the internet (some sites may have multiple connection types for redundancy). Each site on the WAN will communicate through a secure virtual private network (VPN) tunnel to a central location or hub. A Communication Manager Software will communicate with the field devices (primarily the PLCs) to poll data for both real time, control room monitoring and/or historical or measurement data. This tool may also talk directly to Flow Computers and Chromatographs for historical (measurement) data collection. Chevron will implement Supervisory Control and Data Acquisition (SCADA) Software that will communicate with the Communication Manager software to collect data required to monitor and control the system. Field devices will be monitored and controlled by PLCs. Ticketing or measurement software will also talk to the Communication Manager Software to retrieve historical data for measurement purposes. Reporting software will also talk to the Communication Manager Software for both historical data and in some instances real time data for reporting purposes.

Meter data is captured via a gas calculating program. This software calculates the data from the measurement equipment, allowing for reports such as System balancing, Monthly Close, Sarbanes-Oxley (SOX) audit requirements, customer reporting, and quality management. This software uses standard calculations from American Petroleum Institute (API), American Gas Association (AGA), and Gas Processors Association (GPA), and uses the SCADA systems to integrate from upstream to downstream customer. Metered data will be gathered at each flow computer site and brought back to SCADA. Data from all monitoring devices will be historized in Chevron historian and is governed by Chevron data retention policy.

B.10.d. Responsibility

The primary Chevron project manager will be responsible for ensuring proper data management is maintained.

B.10.e. Data Archival and Retrieval

All data will be compiled and stored by Chevron. This data will be maintained for auditing purposes as described in section B.10.a.

B.10.f. Hardware and Software Configurations

All Chevron and third-party hardware and software configurations will interface appropriately.

B.10.g. Checklists and Forms

Checklists and forms will be generated and completed, as necessary.

C. Assessment and Oversight

C.1. Assessments and Response Actions

C.1.a. Activities to be Conducted

Please refer to **Table 2** and **Table 19** for a summary of work to be performed and proposed work schedule. After completion of groundwater sample analysis, the results will be reviewed for QC criteria as noted in section B.5 above. If the data fails to meet the quality criteria set in section B.5, samples will be reanalyzed while still within the sample holding time. If sample holding time has expired, additional samples may be collected, or sample results may be excluded from data evaluations and interpretations. An evaluation of data consistency will be performed according to procedures described in the U.S. EPA 2009 Unified Guidance (U.S. EPA, 2009).

C.1.b. Responsibility for Conducting Assessments

Each organization gathering data will be responsible for conducting their own internal assessments. All stop work orders will be handled internally within each individual organization.

C.1.c. Assessment Reporting

All assessment information will be reported to the Chevron project manager specified in A.1.a/b.

C.1.d. Data Corrections

All corrections shall be addressed and documented by Chevron. Integration of information from multiple monitoring sources (operational, in-zone monitoring, above-zone monitoring) may be required to determine whether data and/or measurement method corrections are required, as well as the most cost-efficient and effective action to implement.

C.2. Reports to Management

C.2.a/b. QA status Reports

QA status reports are not required unless there are significant adjustments to the methods and procedures listed above. If any testing or monitoring techniques are changed, this document will be reviewed, and appropriately updated after consultation with the UIC Program Director. Revised QASPs will be distributed by Chevron to the full distribution list noted at the beginning of this document.

D. Data Validation and Usability

D.1. Data Review, Verification, and Validation

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

Validation of data will include a review of concentration units, sample holding times, and a review of duplicate, blank and other QA/QC results. Chevron will hold copies of all laboratory analytical test results and/or reports. Analytical results will be reported regularly, based on the approved permit frequency conditions. In these periodic reports, data will be presented in either graphical and tabular formats as appropriate to represent general groundwater quality and CO_2 stream quality coming into the AoR, and to identify variability in each groundwater monitoring well with time. All groundwater and CO_2 stream quality results will be documented in a database or spreadsheet with regular data review and analysis. After sufficient data have been collected, additional methods, such as those described in the U.S. EPA 2009 Unified Guidance (U.S. EPA, 2009), will be used to evaluate well variations, to determine if significant changes have occurred which could result from CO_2 or brine seepage beyond the anticipated storage reservoir.

D.2. Verification and Validation Methods

D.2.a. Data Verification and Validation Processes

Verification will include a review of the following:

- Documentation and maps to verify the boundaries of the project, including the location of monitoring and measurement equipment, and procedures for data quality assurance and quality control; and
- All plans, assessments, and reports for conformance with the UIC Regulation and the requirements of the UIC regulation.

See sections D.1.a. and B.5.

Appropriate statistical software will be utilized to determine data consistency.

D.2.b. Data Verification and Validation Responsibility

Chevron will designate a subcontractor who will verify and validate sampling and monitoring data.

D.2.c. Issue Resolution Process and Responsibility

Chevron will designate an Operations Representative, who will oversee the data handling, management, and assessment process. All staff involved with these procedures will consult with the Operations Representative to determine required actions to resolve issues.

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

Checklists and forms shall be specifically developed to meet permit requirements. These checklists will be dependent on the parameters that are being tested as well as standard operating procedures of the subcontractors and labs that will be gathering samples and conducting the analyses. Chevron will provide these forms and checklists to the UIC Program Director upon request.

D.3. Reconciliation with User Requirements

D.3.a. Evaluation of Data Uncertainty

Statistical software will be used to verify data consistency using methods consistent with U.S. EPA 2009 Unified Guidance (USEPA, 2009).

D.3.b. Data Limitations Reporting

Chevron will use the current operating procedure for the use, sharing, and presentation of data for the Eastridge project. This procedure has been developed to verify quality and internal consistency, and to facilitate tracking and record keeping of data, end users, and all associated publications.

References

Freifeld, Barry. (2009). The U-tube: A New Paradigm for Borehole Fluid Sampling. Scientific Drilling. 8. 10.2204/iodp.sd.8.07.2009.

Hach Company, February 2006, Hydrolab DS5X, DS5, and MS5 Water Quality Multiprobes User Manual, Hach Company, 73 p.

U.S. Environmental Protection Agency (U.S. EPA) 2009, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, U.S. EPA Cincinnati, OH, EPA-530/R-09-007.

U.S. Environmental Protection Agency (U.S. EPA) 2009, Data Quality Assessment: Statistical Methods for Practitioners, U.S. EPA Cincinnati, OH, EPA-QA/G-9S.

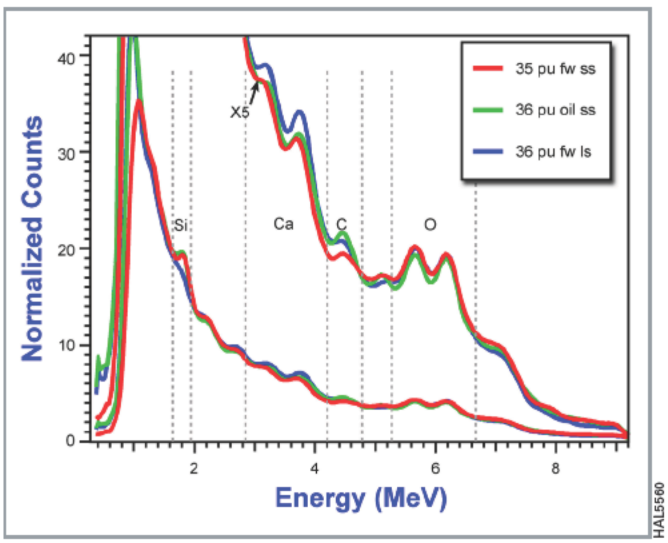
Appendices

Attachments included
Pulsed Neutron/Oxygen Activation Log (RMT-I in attachments)
CBL
Ultrasonic Casing & Cement Evaluation (for corrosion baseline log)
Array – deep monitoring casing conveyed pressure sensors
DAS surface integrator

Reservoir Monitor (RMT™i) Tool

The Industry's Most Accurate and Repeatable Slim-Hole Through-Tubing Carbon/Oxygen Logging System

The Halliburton RMT™i tool is a slim-hole pulsed neutron logging system for monitoring and managing the production of hydrocarbon reserves. This unique through-tubing carbon/oxygen (C/O) system has two to three times higher measurement resolution than other systems. Its high-density bismuth germanium oxide (BGO) detectors let the RMTi tool achieve resolutions previously available only with larger-diameter C/O systems. The RMTi tool can even be conveyed into a well with tubing completions unlike larger diameter C/O systems that can only log through casing.



RMTi Inelastic Spectra – the highest spectral peak resolution of any through-tubing C/O system

Increase Production, Save on Cost

Because the RMTi tool can accurately evaluate the time-lapse performance of hydrocarbon-producing reservoirs without pulling tubing from the well, it can help operators to:

- Increase production more cost effectively
- Monitor changing conditions and fluid movements
- Tap into bypassed hydrocarbon reserves
- Optimize, manage, and produce reservoirs more efficiently
- Increase production to take advantage of increasing oil prices
- Avoid production problems through enhanced diagnostics
- Make faster decisions on workovers and completions

The RMTi tool can also help eliminate:

- The cost of killing the well
- The cost of pulling tubing out of the well
- Operational cost and lost production revenue from additional workovers
- Potential production losses due to formation damage from well kill fluids
- The cost of recompleting the well by re-running tubing

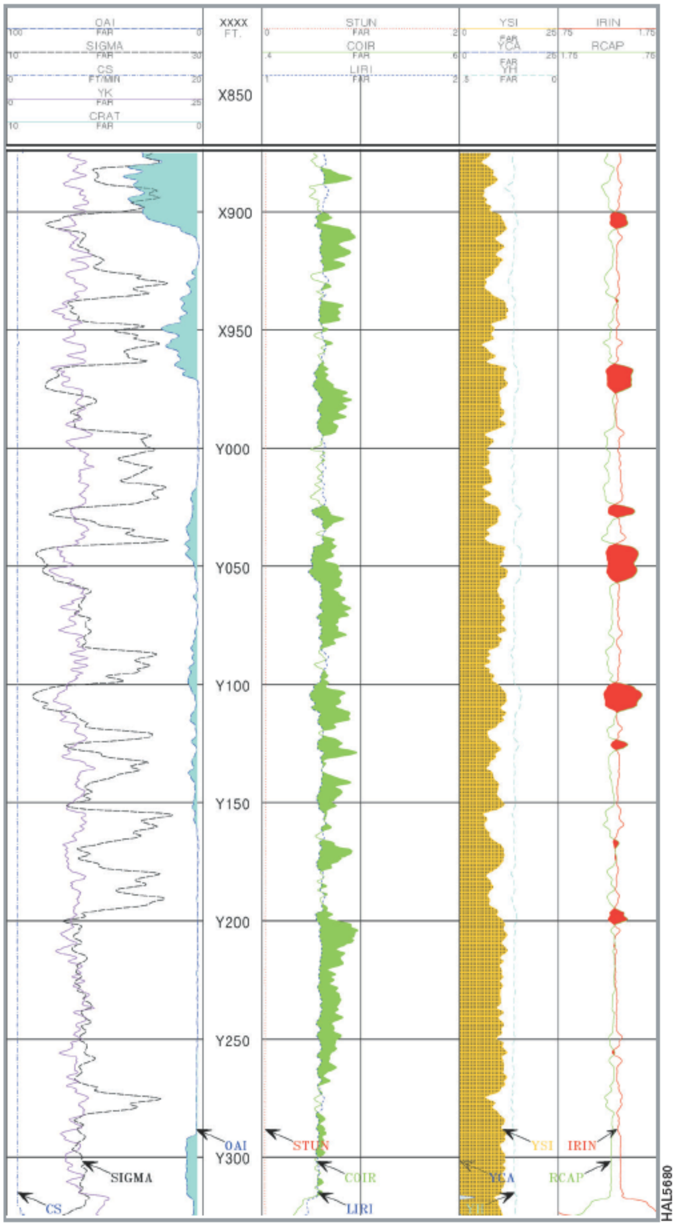
Faster Logging Speeds, More Accurate Results

Halliburton's RMTi tool can provide accurate and precise results that help operators to achieve logging speeds two to five times faster than any other competing systems. This blazing combination of speed and precision helps enable the RMTi tool to:

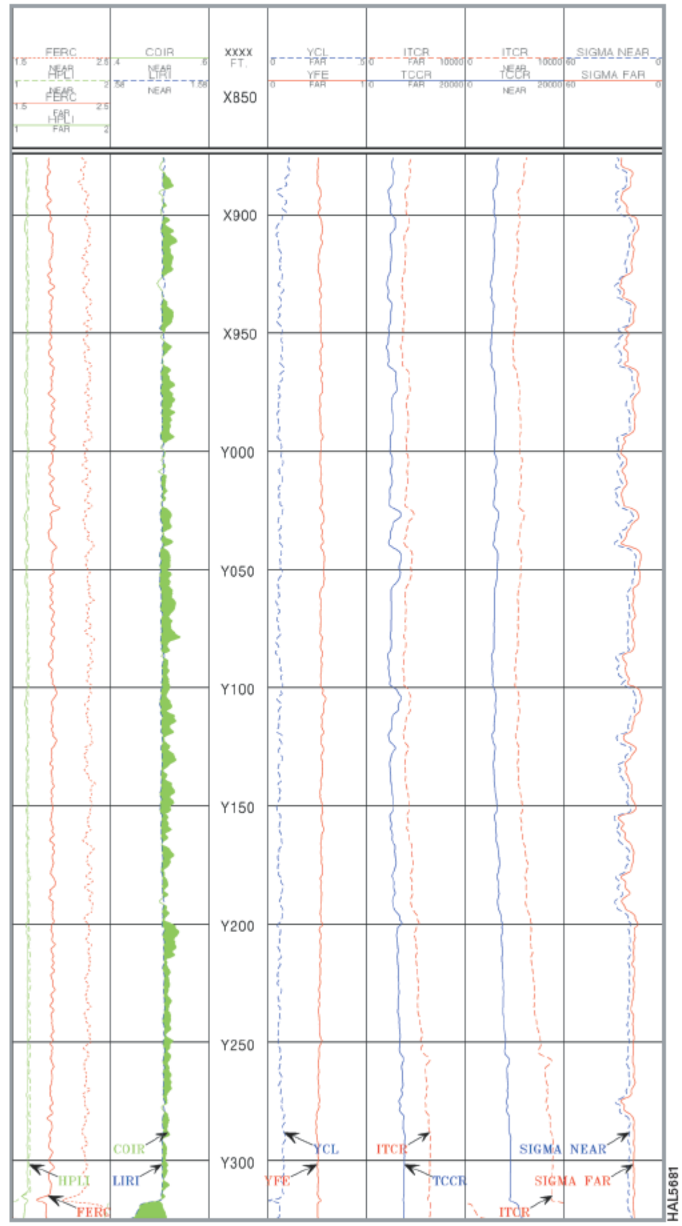
- Accurately determine oil and gas saturations in high-salinity or freshwater formations
- Identify bypassed reserves
- Pinpoint formation fluid contacts
- Identify lithologies and mineralogies
- Provide porosity information within the completion interval
- Evaluate gravel packs and lithology via silicon activation
- Detect water flow inside or outside the pipe

Advanced Modular Design

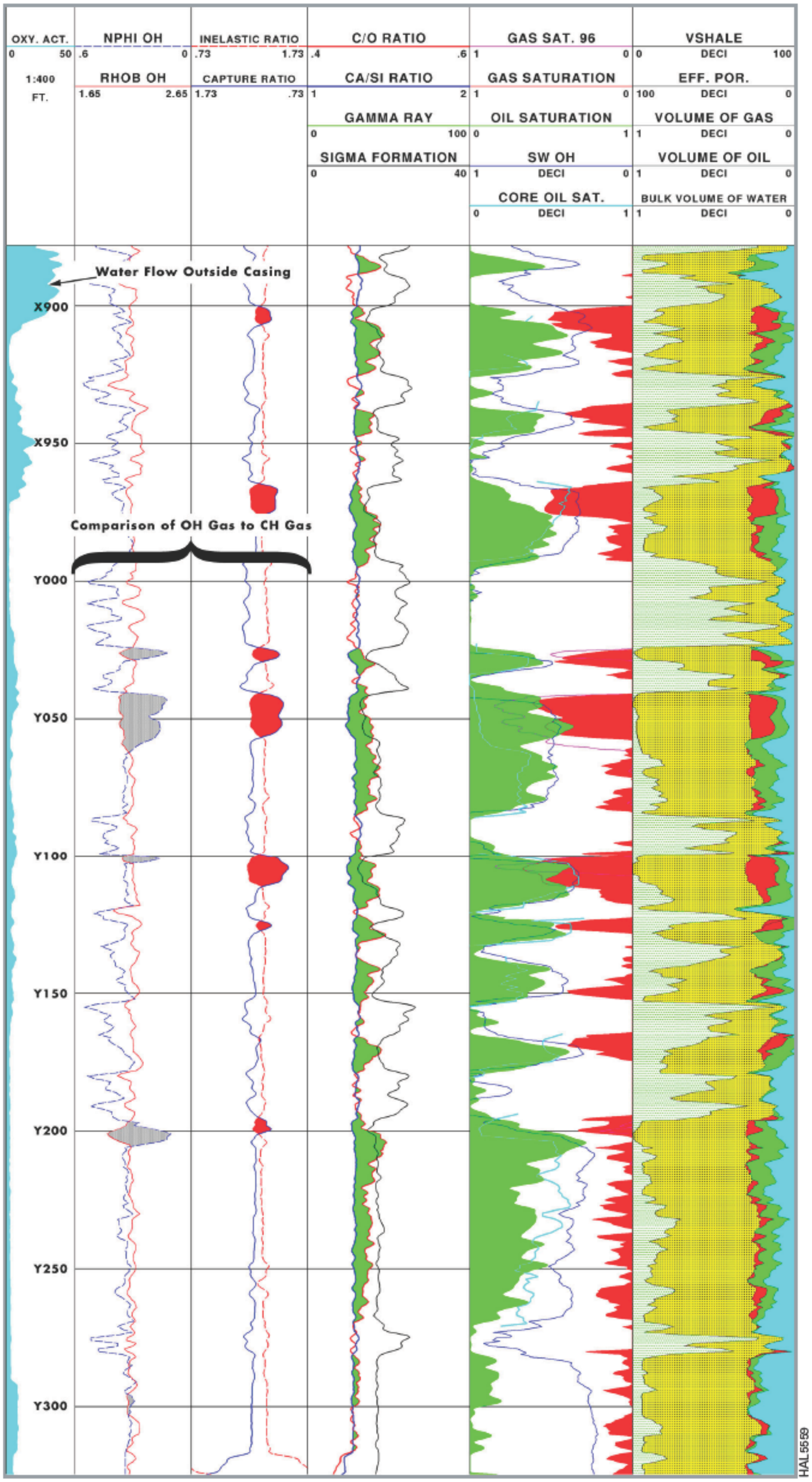
The Halliburton RMTi tool modular hardware design provides a highly versatile system that has multiple operating modes and capabilities, enabling operators to make simultaneous C/O, sigma, and water flow measurements. Because the system is modular, it can be combined with a complete string of production-logging tool sensors for detailed production analysis.



RMT Primary Log Presentation – Track 1 of the display is used for plotting basic correlation curves. In this example, the simultaneously recorded formation sigma (SGSM) and the potassium yield curve (YK) are plotted. Also plotted in the track is the Oxygen activation curve (OAI), which is used to detect water flow. Track 2 of the log is used to display the raw Carbon to Oxygen ratio (COIR) and the Calcium to Silicon ratio (LIRI). The green shading between the curves is a quick-look representation of hydrocarbons. Track 3 of the log displays yield curves computed from the capture spectra for Silicon (YSi), Calcium (YCa) and Hydrogen (YH). Track 4 displays inelastic and capture near-to-far detector ratio curves. These curves are used to identify gas in the formation (shaded in red).



RMT Quality Log Presentation – Track 1 of the presentation are curves that represent the accuracy of spectral gain stabilization measured from ratios of the iron edge (FERC) and the hydrogen peak (HPLI). Track 2 is a plot of the COIR and LIRI from the near space detector. Track 3 is used to plot additional yield curves computed from the capture spectra. Plotted on this example are the Iron yield (YFe) and the Chlorine yield (YCl). Tracks 4 and 5 are used to plot the total inelastic and capture count rates for the near and far detectors. Track 6 is used to plot the simultaneous measured near-formation sigma (SGFN) and the far-formation sigma (SGFF).



KernSat Interpretation Example –
This well, located in Kern County, California in the Kern River Field, is in an active steam-flood hydrocarbon recovery project. The log displayed to the left is an example of our customized interpretation model KernSat.

Track 4 of the example displays the computed oil saturation (shaded in green) and the gas saturation (shaded in red). These saturations were computed by using a combination of Carbon Oxygen ratio and formation sigma.

Track 3 displays the Carbon Oxygen and the Calcium Silicon ratio curves. The green shading between the two curves indicates hydrocarbons in the formation. Also displayed in the track are the natural gamma ray measurement and the simultaneous recorded formation sigma.

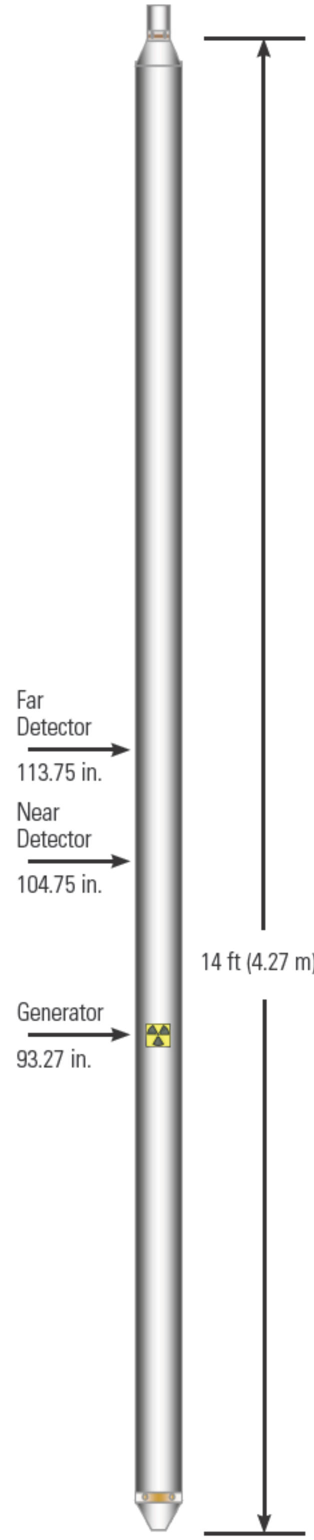
Tracks 1 and 2 display a comparison of the open hole density and neutron porosities and the porosity ratio indicators measured by the RMT logging tool. Track 1 is the open hole density neutron porosity. Steam measured in the formation at the time of the log is indicated by the gray shading between the curves. Track 2 displays the inelastic and capture ratios measured from the RMT logging tool. The red shading indicates the current location of steam in the reservoir. This example indicates that the steam chest has changed when compared to the original formation contacts.

The depth track recorded at the far left side of the log displays water flow measured by the RMT logging tool outside the casing.

RMTi Reservoir Monitor Tool

Dimensions and Ratings		
Maximum OD	2.125 in.	
Maximum Pressure	15,000 psi (103.4 Mpa)	
Maximum Temperature	325°F (162.8°F)	
Minimum Csg/Tbg ID	2.388 in.	
Maximum Csg/Tbg ID	9.625 in.	
Weight	with Gamma Ray and Telemetry	137 lb (62.1 kg)
Length	with Gamma Ray and Telemetry	23.3 ft (7.1 m)
Hardware Characteristics		
Source Type	14-MeV Neutron Generator	
Sensor Type	2 BGO Scintillators	
Firing Rate (C/O)	One 30 μs burst every 100 μs; One 5 ms background pause burst every 25 ms	
Firing Rate (Sigma)	One 80 μs burst every 1250 μs; One 5 ms background pause burst every 25 ms	
Sample Rate	4 or 10 samples per ft	
Combinability	SBSAT, RCBL, PLT, PAL, CAST-M™* tool	
Measurement		
Principle	Neutron-induced Gamma Ray Spectroscopy Induced capture Gamma Die-away	
Vertical Resolution	(90%) 30 in.	
Depth of Investigation	(50%) 6 in. inelastic; 12 in. capture	
Precision (C/O) Ratio	1.5% (1 SD) at 5 ft/min, (C/O) mode	
Precision (Ca/Si) Ratio	1.5% (1 SD) at 5 ft/min, (C/O) mode	
Precision (SGFF)	2% (1 SD) at 20 ft/min, Sigma mode	
Primary Curves (C/O)	C/O ratio, Ca/SI ratio, Near/Far Capture CR, Near/Far Inelastic CR, Inelastic/Capture ratio, Si yield, Ca yield, H yield, Cl yield, K yield, Fe yield	
Primary Curves (Sigma)	SGFF, SGBN, Near/Far Capture CR, Near/Far Inelastic CR, Inelastic/Capture ratio, Near CR, Far CR, Inelastic CR	
Secondary Curves (C/O)	S yield, Ti yield, H peak ratio, Fe edge ratio, C/O ratio uncertainty, Capture CR, Inelastic CR, O activation CR, SGFF	
Secondary Curves (Sigma)	SGFN, SGBF, Decay Curve fit error, O activation CR, Near/Far Amplitude ratio, Near Amplitude	
Calibration		
Primary	HES calibration pits, Houston Tool Response and Characterization Laboratory (TRAC Lab)	
Secondary	Horizontal water tank	
Maximum Logging Speed	5 ft/min (C/O mode), 30 ft/min (sigma mode)	

*TBA



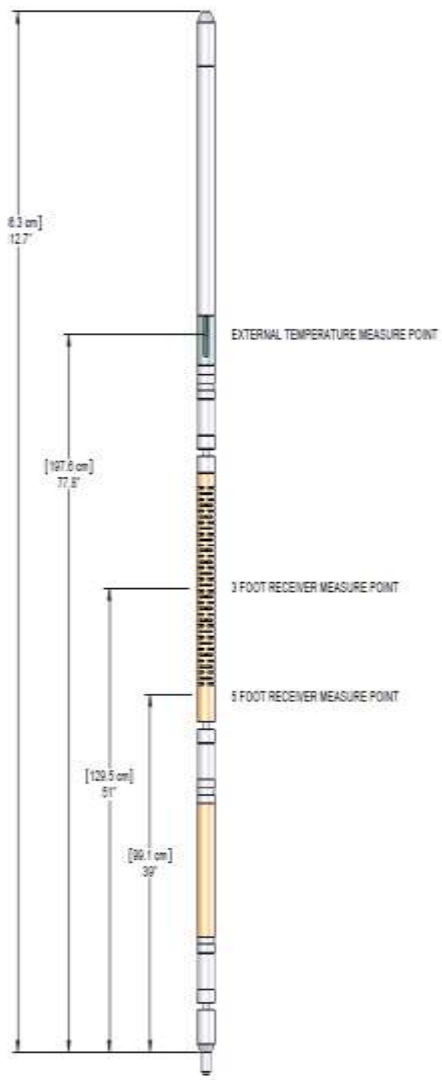
For more information, contact your local Halliburton representative.

H02621 6/14

HALLIBURTON
Wireline & Perforating

2 ¾" Dual Receiver RADII Cement Bond Tool w/ Temperature (RCBS-P4)

Tool Part Number: 101941615, TOT LLT6FO0031, File Code 4.06.01.25



DIMENSIONS AND RATINGS

Max Temp:	350°F *(177°C)*	Max Press:	20,000 psi *(137,895 Kpa)*
Max OD:	2.75 in. *(6.985 cm)*	Min Csg/Tbg ID:	3.50 in. *(8.89 cm)*
Length*:	9.39 ft *(2.862 m)*	Max Csg/Tbg OD:	11.6 in. *(29.50 cm)*
		Weight:	116 lb *(52.66 kg)*
The length does not include centralizers.			

BOREHOLE CONDITIONS

Borehole Fluids: *Salt* ■ *Fresh* ■ *Oil* ■ *Air* □
Recommended Logging Speed: 60 ft *(18.2m)*/min. Maximum Logging Speeed: 100 ft *(30.5m)*/min. @ 0.08 ft *(0.02m)* sample rate
Tool Positioning: *Centralized* ■ *Eccentralized* □

HARDWARE CHARACTERISTICS

Source Type:	One *piezoelectric crystal fired at 50 msec interval*
Sensor Type:	*3' Radial Receiver 20kHz piezoelectric* *(Amplitude, Travel Time, 8 Sector Curves)* *5' Omni Receiver 20 kHz piezoelectric (MSG)* *Temperature Probe = Platinum Resistance*
Sensor Spacings:	*Omni Receivers = 5 ft (1.5 m)* *Radial Receivers = 3 ft (.914m).*
Firing Rate:	*20/sec*
Recording Time:	*1300µ for each receiver, 250µ for each sector*
Combinability:	*CCL, GR, Single or Dual Spaced Neutron*

MEASUREMENT

	Sonic Waveform	**E_1 Peak Amplitude**
Principle	*Sonic Wavetrain Attenuation*	
Range	*200 to 1500µs*	*200 to 1500µs*
Vertical Resolution	*5 ft (1.5 m)*	*3 ft (.9 m)*
Depth of Investigation	*NA*	*NA*
Precision (1 SD)	*NA*	*< 1mV*
Accuracy	*NA*	*±2%*
Primary Curves	*Amplitude (3ft (.9 m),Radial 1-8),TT (3ft) (.9 m), MSG(5ft) (1.5 m), Amplitude Map*	
Secondary Curves	*External Temperature, Head Voltage, Internal Temperature*	

CALIBRATION

Primary:	*5.5 in.(13.97 cm) – Pressurized Calibration Tank*
Wellsite Verifier:	*Free Pipe, Stored Calibration Tank Waveforms on Demand*

PHYSICAL STRENGTHS*

Hardware	**Tension**	**Compression**	**Torque**
Tool Joints	*50,000*	*35,000*	*NA*
Other	*50,000*	*35,000*	*NA*
* *Strengths apply to new tools at 70°F (21°C) and 0 psi.*			

MEASURE POINTS

Measurement	**Measure Point** (Referenced from bottom of tool)
Ampliture, TT	51.0 in *(129.5 cm)*
MSG, Signature	39.0 in *(99.1 cm)*
External Temperature	77.8 in *(197.6 cm)*

CAST-M™

Mono-Conductor Electric Line Conveyed Simultaneous Ultrasonic Casing and Cement Evaluation

The Halliburton CAST-M™ tool provides the same simultaneous ultrasonic casing and cement evaluation capabilities as the FASTCAST™ service, but in a smaller diameter tool and on mono-conductor e-line. With the CAST-M tool, the industry-leading cement and casing evaluation service can now be acquired in 4-1/2-in. through 9-5/8-in. casing, and deployed on light-duty cased hole logging units.

The CAST-M tool provides high-resolution cement and casing evaluation images oriented with respect to high side-low side of the wellbore, enabling identification of both internal and external casing wear, erosion, corrosion, or mechanical damage. The CAST-M tool is also combinable with a 2-3/4-in.- OD cement bond tool.

The 2D and 3D image presentation provides accurate measure of casing properties, and helps determine bonding and image channels in the cement sheath directly outside the casing.

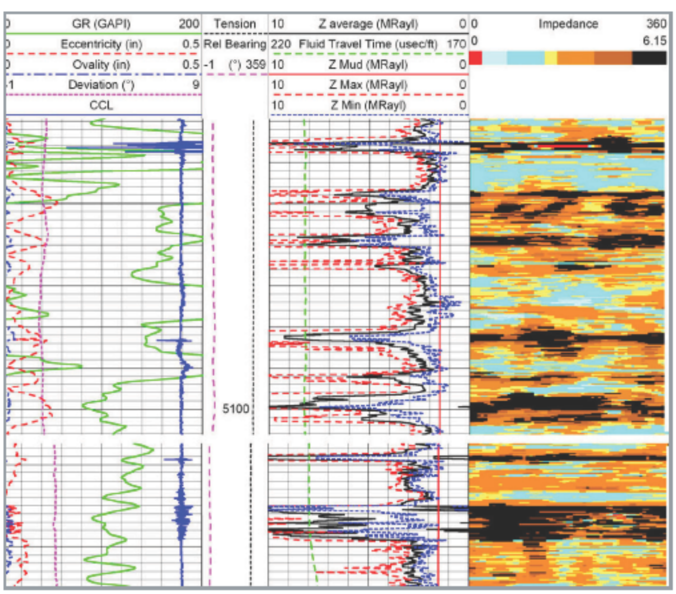
The CAST-M tool is fully programmable to optimize logging speeds up to 75 ft/min in 4-1/2-in. casing, and provides 100% casing wall coverage, reducing non-productive time (NPT) with efficient operation.

Benefits

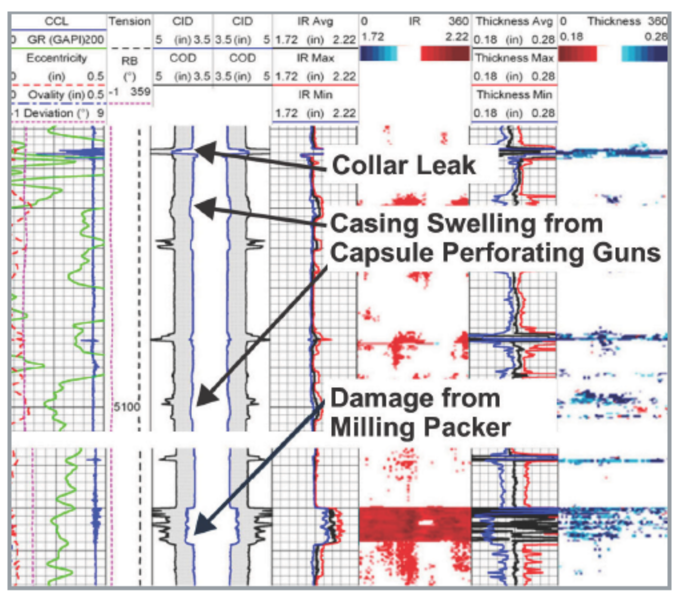
- Reveals bonding and image channels in the cement sheath directly outside the casing
- Measures casing properties such as thickness, internal, and external diameters
- Accurately evaluates foam cements and other lightweight complex cement slurries using Halliburton ACE™ processing
- Reduces NPT with fast logging speeds
- Combinable with 2-3/4-in.-OD cement bond tool
- Can be tractor or e-coil conveyed for high angle and horizontal well applications

Features

- Fully programmable to optimize logging speeds, with 100% casing wall coverage
- Integral in-line bottom roller centralizer improves centralization
- Continuous measurement of borehole fluid for accurate casing diameter
- Deploys on mono-conductor cable traditional cased hole units and rig-less operations
- Traditional cased hole pressure controls equipment compared to 7 conductor cables



CAST-M Wellsite 4-1/2-in. Cement Evaluation



CAST-M Wellsite 4-1/2-in. Casing Inspection

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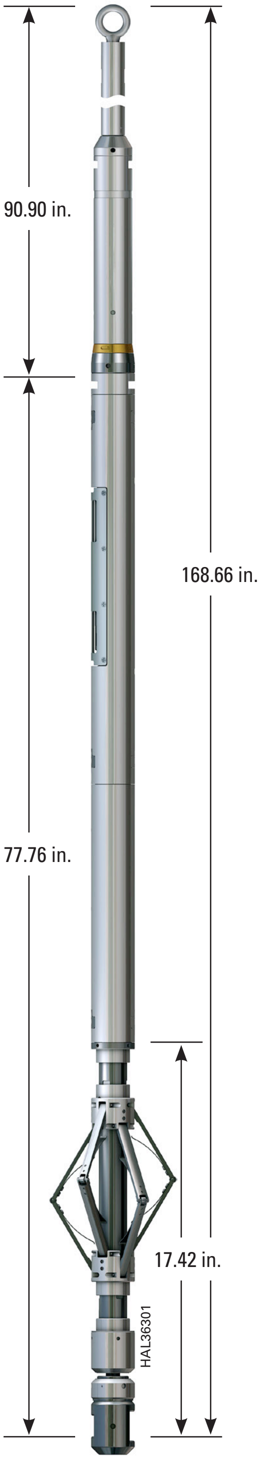
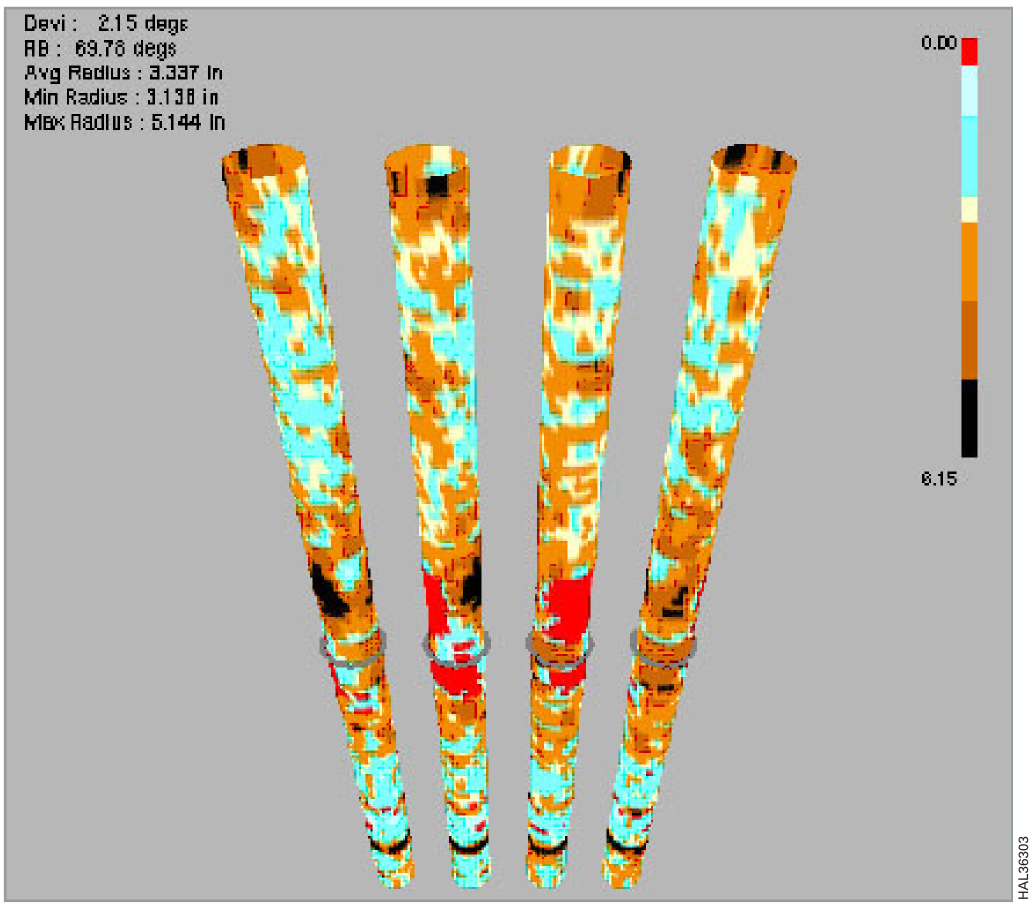


CAST-M Tool Specifications

Feature	Imperial Units	Metric Units
Length	168.55 in.	428.1 cm
Maximum OD-built-in centralizer	9 in.	228.6 mm
Tool OD	2.75 in. tool body 3.125 in. at transducer	698 mm 794 mm
Minimum Casing ID	3.9 in.	99.1 mm
Maximum Casing ID	12.9 in.	32.77 cm
Maximum Pressure*	20,000 psi	1,379 bar
Temperature	350°F	177°C
Weight	182 lb	82.5 kg
Borehole Fluid	WBM/OBM/Brine/Water	WBM/OBM/Brine/Water
Logging Speed 4-1/2 in. casing	75 ft/min 4,500 ft/hr	23 m/min 1,372 m/hr
Logging Speed 9-5/8 in. casing	33 ft/min 1,980 ft/hr	10 m/min 600 m/hr

*With TTTC-U telemetry pressure rating 15,000 psi, 1,032 bars

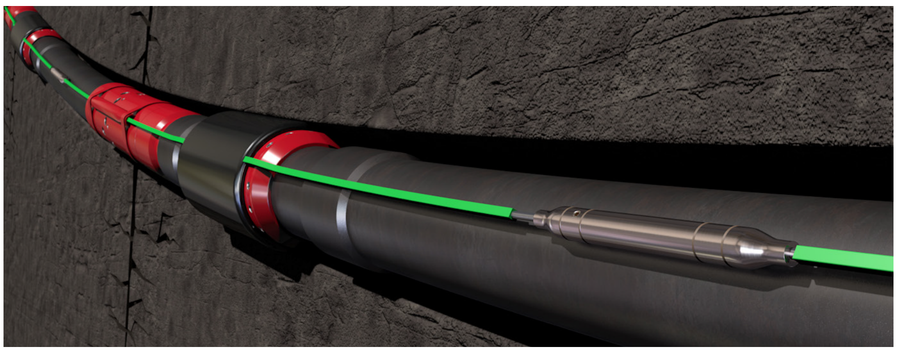


3D image of foam cement evaluation

H08628 4/14

DataSphere™ Array System

RELIABLE MULTI-POINT RESERVOIR MONITORING



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OVERVIEW

The DataSphere™ array system is the next step in the evolution of Halliburton Permanent Monitoring solutions. The technology is built upon the reliability of ROC™ gauge hybrid technology and provides greater system customization by deploying multiple discrete sensors across challenging wellbore regions.

A system comprised of conventional gauges can communicate with multiple array sensor systems distributed across different wellbore intervals. Each array system provides discrete real-time annular downhole data in distributed multi-point temperature and pressure monitoring applications. The array system incorporates no cable terminations, which reduces installation time and eliminates risks associated with multiple terminations. In addition, the array system uses internal short-circuit protection circuitry that minimizes system line takedowns.

Based on an industry-standard, field-proven resonating quartz crystal sensor, the DataSphere array system can be used for distributed, single zone, or multi-zone monitoring applications.

In distributed monitoring, the use of Halliburton conventional downhole gauges can be enhanced by the array system, allowing operators greater visibility into their operations efficiency.

APPLICATIONS

- Inflow Control Device efficiency monitoring
- Production monitoring
- Injection monitoring
- Field reservoir monitoring
- SmartWell® completion system optimization
- Artificial lift/gas lift optimization

FMJ CABLE TERMINATION

When connected to a conventional gauge, the DataSphere array system uses a high-performance cable termination that uses a sealing arrangement based on our highly reliable, field-proven, intelligent completion FMJ connector. This cable termination incorporates a pressure-testable dual metal-to-metal ferrule seal arrangement for isolating the downhole cable outer metal sheath from the well fluid.

BENEFITS

- Quartz-sensors provide high accuracy and resolution and low drift
- Can be deployed across the sandface for greater reservoir inflow/outflow understanding
- Reduces rig time through faster installation times (up to eight hours saved per gauge)
- Reduces need for cable terminations
- Eliminates requirement for gauge mandrels in annular sensing applications
- Validates/disproves reservoir models
- Tool head voltage and gauge current measurement for diagnostics
- Reduces potential leak points by minimizing system connections

FEATURES

- Can be deployed standalone
- Up to 50 sensors can be deployed
- ROC-MODBUS communication protocol
- Designed for harsh environments up to 30,000 psi and 200°C
- AWES qualified
- Reduced OD design
- Multi-drop capability on single core tubing encased conductor (TEC)
- Available as Temperature only, or both Pressure and Temperature
- Hermetically sealed electron beam-welded design
- Application Specific Integrated Chip (ASIC) technology
- Uses industry-leading FMJ connections
- Increased capabilities such as fault protection per sensor
- Designed for a 20-year life

TESTING

The individual sensor design has gone through the Design for Reliability process, which includes a Highly Accelerated Lifetime Test (HALT) program. This program is a series of controlled environmental stresses designed to ensure that stringent criteria are met for thermal shock, mechanical shock, vibration and thermal aging. During manufacture, all gauges are also subjected to Environmental Stress Screening (ESS) to highlight any defect in functionality prior to installation at the well site. This method of screening has proven to be far more effective than "burn-in" techniques.

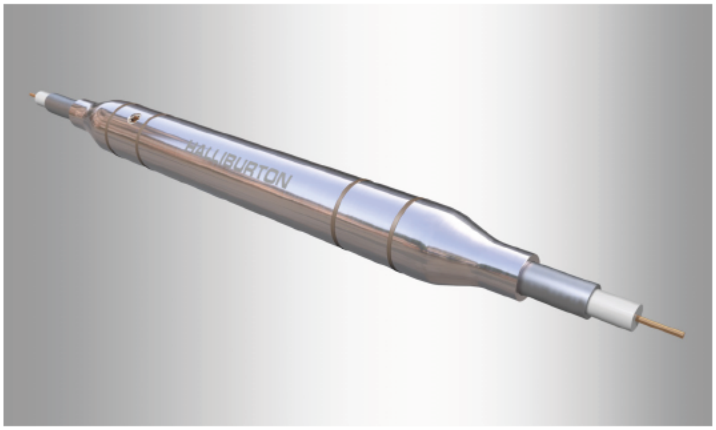
All of the individual sensors that make up the DataSphere array system are independently calibration-checked in our manufacturing facility. During Factory Acceptance Testing (FAT), the DataSphere array sensor welds are pressure tested for integrity as the array is being built and spooled onto the final drum.

DataSphere™ Array System - Temperature Performance

Accuracy (°C)	0.5
Typical Accuracy (°C)	0.15
Achievable Resolution (°C/sec)	< 0.005
Repeatability (°C)	< 0.01
Drift at 177°C (°C/year)	< 0.1

DATASPHERE ARRAY SYSTEM DESIGNS

- Quartz transducer and hybrid technology
- ASIC technology
- Maximum 200°C operating temperature
- Multi-drop capability – up to 50 sensor gauges at 30,000 ft max depth
- Can be used in conjunction with existing gauges
- Improved shock and vibration performance
- 0.625-in. OD ultra slim design
- Less than 7-in. length per sensor
- Does not need a gauge mandrel to be deployed
- Short-circuit protection per sensor, prevents line takedowns



Temperature and Pressure Sensor > The DataSphere™ array system is comprised of multiple ultra slim, highly accurate quartz-based temperature and pressure sensors.

DataSphere™ Array System - Pressure Performance

Pressure Range (psi / bar)	0 to 10,000 / 0 to 690	0 to 16,000 / 0 to 1,100	0 to 30,000 / 0 to 2,070
Accuracy (% FS)	0.015	0.02	0.025
Typical Accuracy (% FS)	0.012	0.015	0.02
Achievable Resolution (psi/sec)	< 0.006	< 0.008	< 0.010
Repeatability (% FS)	< 0.01	< 0.01	< 0.01
Response Time to FS Step (for 99.5% FS)	< 1 sec	< 1 sec	< 1 sec
Acceleration Sensitivity (psi/g – any axis)	< 0.02	< 0.02	< 0.02
Drift at 14 psi and 25°C (%FS/year)	Negligible	Negligible	Negligible
Drift at Max. Pressure and Temperature (%FS/year)	0.02	0.02	0.025

For more information, contact your local Halliburton representative or visit us on the web at www.halliburton.com

FiberWatch® DAS Interrogator System

DISTRIBUTED ACOUSTIC SENSING INTERROGATOR 4400

OVERVIEW

The FiberWatch® DAS interrogator family reigns in the latest technology evolutions for Rayleigh-based time domain sensing. The offering consists of a high-performance phase-sensitive, "coherent" DAS interrogator capable of covering a wide range of applications for distributed dynamic sensing. These units are highly configurable and provide for optimal interrogation performance for sensors ranging from 1 km to 10+ km.

HAL124225

FIBERWATCH DAS SYSTEM OFFERINGS

DAS Interrogator Technical Specifications

Configurability	
Sensor Range	1 to 10 km (capable of longer with de-rated performance)
Interrogation Rate	2.5 to 100 kHz
Spatial Resolution	2.5 m, 5 m, 15 m, 25 m as gauge length (GL)
Pulse Width	10 ns to 350 ns
Optical Gain	Programmable, both for outgoing pulse and sensor return
Time Stamp / Active Test	"Data markers" time stamping or active test
Clock / Sample Trigger / Synchronization	Clock versatility / Frame synchronization (API function calls)
Performance	
Self Noise Per SEAFOM MSP-02	GL@ 5 m (7 p□/rt-Hz)
Rayleigh Fading	≤ 0.2%
Specifications	
Operational / Storage Temperature / Humidity	0°C to 40°C (32°F to 113°F) / 20°C to 70°C (-4°F to 158°F) / < 90% RH @ 30°C (86°F) (no condensation)
Altitude	3048 m (10,000 ft)
Signal Outputs (Analog 100 MHz)	+/-1.7V into 50W, 4-channel (2 pair I&Q)
Optical Wavelength	1549.32 nm (ITU 35) – 1547.72 (ITU37)
Fiber Compatibility	Single Mode Telco G.652, G.657.B2, G657.B3
Optical Interface	Diamond E-2000PS connector
Laser Safety	Class 1 to IEC60825-1:2014 / EX op pr
Power (AC) / Fuse	100 to 240 VAC: 50W peak, 33W Typical / Fuse: 1A/250V 5X20 mm SLO-BLO
Weight / Dimensions	18.6 kg (41 lb) / 3U, Rackmount, w x d x h: 482 x 508 x 133 mm (19 x 20 x 5.25 in.)

Software and Communications

Software	Interrogator control API and interrogator control application
Communication Port	USB 2.0
Remote Access	Yes, through operator host system
Diagnostics	Power supply status and temperature of active optical elements and controller

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Optical *E-2000PS to sensor (1),* ***USB*** *Control Interface (1),* ***Signal Out*** *shown for DP1 (4), Two quadrature pairs I & Q*
Data Markers In *(2), Used for GPS time stamp or test tones* ***Sample Trigger Out*** *(1), DAQ trigger for data frame*
Clk In/Out, Aux In/Out, Start In/Out *(5), Used to synchronize to Host DAQ or other DAS interrogators* ***Safety Interlock In*** *(1)*

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