BELL CREEK TEST SITE – SITE CLOSURE PLAN

Plains CO_2 Reduction (PCOR) Partnership Phase III
Task 10 – Deliverable D54

Prepared for:

William Aljoe

National Energy Technology Laboratory
U.S. Department of Energy
626 Cochrans Mill Road
PO Box 10940
Pittsburgh, PA 15236-0940

DOE Cooperative Agreement No. DE-FC26-05NT42592

Prepared by:

Kyle A. Glazewski
Barry W. Botnen
Kerryanne M. Leroux
Nicholas S. Kalenze
Ryan J. Klapperich
William I. Wilson
John A. Hamling
Charles D. Gorecki

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

December 2017
2017-EERC-12-11 Approved

EERC DISCLAIMER

LEGAL NOTICE This research report was prepared by the Energy & Environmental Research Center (EERC), an agency of the University of North Dakota, as an account of work sponsored by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL). Because of the research nature of the work performed, neither the EERC nor any of its employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement or recommendation by the EERC.

ACKNOWLEDGMENTS

This work was performed under DOE NETL Cooperative Agreement No. DE-FC26-05NT42592. The EERC would like to thank Denbury Resources Inc. (Denbury) for providing necessary data to perform this work. Special thanks go to the members of Denbury's Bell Creek team for their valuable input and fruitful discussions.

DOE DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government, nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

TABLE OF CONTENTS

LIST OF FIGURES

BELL CREEK TEST SITE – SITE CLOSURE PLAN

EXECUTIVE SUMMARY

As part of a Plains CO_2 Reduction (PCOR) Partnership Phase III demonstration project, the Energy & Environmental Research Center (EERC) has partnered with Denbury Onshore LLC to study associated CO_2 storage incidental to a commercial enhanced oil recovery (EOR) project at the Bell Creek oil field. The PCOR Partnership demonstration activities are integrated with commercial EOR operations; however, the commercial EOR project will continue to operate, and subsequent site closure will occur, far beyond the scope and time frame of the PCOR Partnership Phase III effort. This site closure report (D54) provides a summary of relevant field-based demonstration, research, and monitoring activities that were conducted as part of PCOR Partnership Phase III efforts at Bell Creek. Also included is a closure/decommissioning plan and associated time line for the closeout of field-based operations and data collection activities being conducted at Bell Creek by the PCOR Partnership.

The EERC is working with the host site operator (Denbury Onshore LLC) and pertinent landowners to repurpose, transfer ownership and operations, or abandon locations and installed systems in-place where practical, prudent, and cost-effective to do so or to remove and remediate when necessary. Closure activities related to Bell Creek research efforts began in July 2016 (FY16). Field office support services, including satellite Internet and portable facilities (i.e., sanitation), were canceled and removed from the field site. A passive seismic array deployed in the dedicated 04-03 OW (observation well) monitoring well was powered down and idled in anticipation of decommissioning. Two groundwater monitoring wells completed into the lowermost underground source of drinking water were idled and abandoned in place, effectively transferring operations to the associated landowner while maintaining access rights for future fluid sampling. A casing-conveyed pressure and temperature gauge system and a distributed temperature system installed at the 05-06 OW well was put into a minimum maintenance acquisition mode in anticipation of relinquishing operations to the site operator. Ten soil gas profile stations were idled in anticipation of either transferring operations to the site operator or removal and remediation. A decommissioning plan/schedule for EERC mobile operations support trailers located in the field was developed. Progress of ongoing site-closure activities will be reported to the U.S. Department of Energy Project Manager in future quarterly reports, with all activities anticipated to be completed by the end of Task 10 (currently scheduled for December 31, 2018).

The learnings derived from the field-based activities being conducted through the PCOR Partnership Bell Creek Phase III demonstration project will have direct application to site operation and closure for future CO_2 storage projects within the PCOR Partnership region. While D54 will serve as a functional site closure plan for project activities, a companion report (D73 – Monitoring and Modeling Fate of CO_2) is being concurrently developed to assess and report the relevant

learnings and results of modeling and monitoring efforts demonstrated through the PCOR Partnership Bell Creek Phase III activities. The relevancy of modeling and monitoring strategies which were demonstrated at Bell Creek and their applicability to commercial storage sites during the injection, postinjection, and postclosure time period will be considered and reported in the companion document D73.

BELL CREEK TEST SITE – SITE CLOSURE PLAN

INTRODUCTION

The Plains CO_2 Reduction (PCOR) Partnership, led by the Energy & Environmental Research Center (EERC), is working with Denbury Onshore LLC (Denbury) to study associated carbon dioxide (CO_2) storage incidental to a commercial enhanced oil recovery (EOR) project at the Denbury-operated Bell Creek oil field. As part of this Phase III demonstration project, field-based sampling, data acquisition, and support systems were installed in support of several monitoring activities. These monitoring activities include reservoir-level monitoring (e.g., temperature/pressure, passive seismic) via observation wells, groundwater monitoring, and shallow-zone soil gas monitoring via soil gas profile stations.

Commercial CO_2 injection and oil production operations will continue at Bell Creek beyond the current PCOR Partnership effort. Likewise, commercial reservoir surveillance will continue to monitor flood performance and inform operations of the commercial CO_2 EOR project. This report **ONLY** covers site closure operations for PCOR Partnership field efforts and does **NOT** address the commercial EOR operation. As PCOR Partnership field efforts are completed, the EERC is working with the host site operator (Denbury) and pertinent landowners to repurpose, transfer ownership and operations, or abandon installed systems in-place where practical, prudent, and cost-effective to do so or to remove and remediate when necessary. This report details the planned site closure activities. Progress of ongoing PCOR Partnership site closure activities will be reported to the U.S. Department of Energy (DOE) Project Manager in future quarterly reports, with all activities anticipated to be completed by the end of Task 10 (currently scheduled for December 31, 2018).

FIELD SYSTEMS

The PCOR Partnership Phase III Bell Creek characterization and monitoring effort included drilling two observation wells (05-06 OW and 04-03 OW) and installing associated data acquisition systems, installation of two dedicated groundwater monitoring wells (MW0504 and MW3312), and installation of ten soil gas profile stations (SGPSs) (Figure 1). Two EERC trailers served as mobile field offices to support research and field operations. The following sections describe the field-based sampling, data acquisition and support systems, and related PCOR Partnership site closure activities.

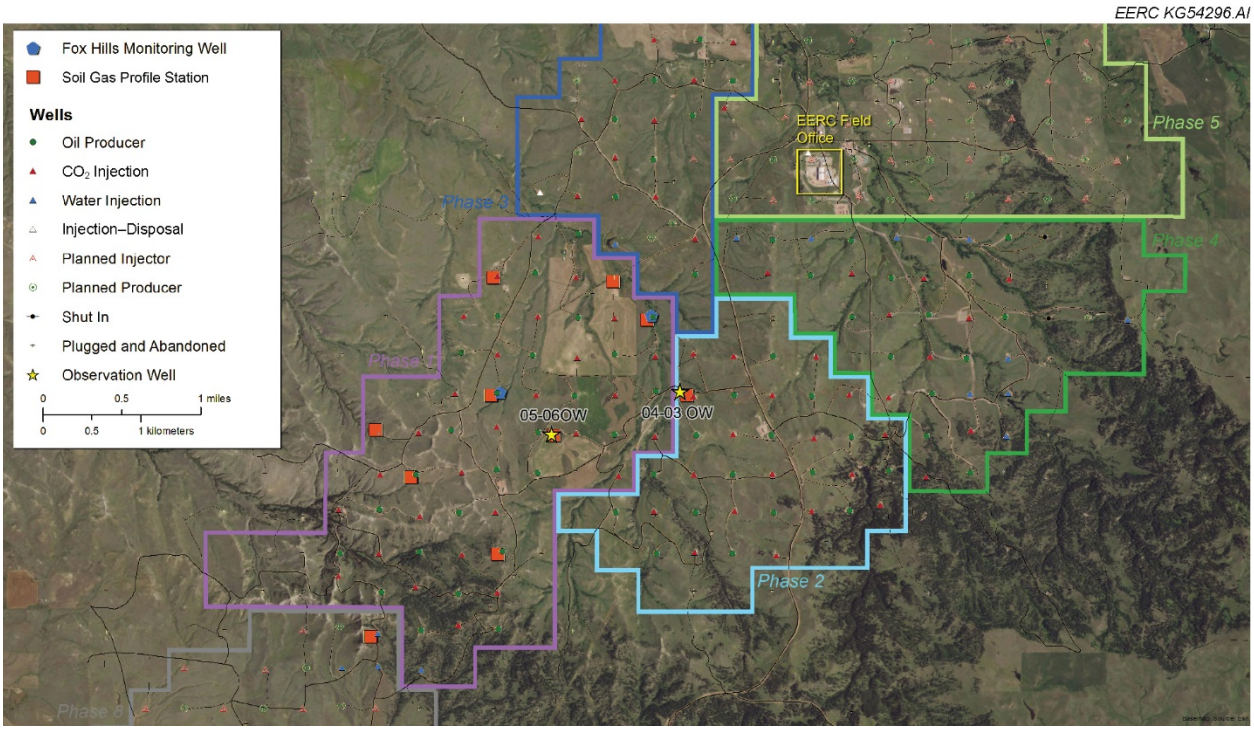

Figure 1. Location field systems within the Bell Creek oil field.

Observation and Monitoring Wells

05-06 OW

In December 2011, the 05-06 OW observation well was drilled to a depth of 4856 ft in order to collect characterization data, including core and well logs, and to provide a means of acquiring monitoring data (e.g., vertical seismic profiles [VSP], pulsed-neutron logs [PNL], etc.) in a manner not intrusive to commercial EOR operations (Heebink and others, 2014). Three permanently installed casing-conveyed pressure and temperature gauges (PTGs: two in the reservoir and one in an above-zone monitoring interval) and a distributed temperature system (DTS) were installed as part of the well completion to provide real-time pressure and temperature date for both the reservoir and for the above-zone monitoring intervals (Figure 2). Surface systems included an environmental enclosure connected to the electrical grid, a DTS data interrogator and data logger, a PTG interrogator and data logger, and a battery backup system (see the *Installing a Casing-Conveyed Permanent Downhole Monitoring System* video for details: http://undeerc.org/pcor/Documentary/PDM.aspx) (Figures 3 and 4). The system has been operational nearly continuously since April 2012.

The 05-06 OW well was bonded and permitted and is operated by Denbury (Heebink and others, 2014). As part of an agreement with Denbury, the EERC is able to access the well for data collection and monitoring activities related to the PCOR Partnership Bell Creek Demonstration Project. As a practical, prudent, and cost-effective measure and so as not to compromise the ability

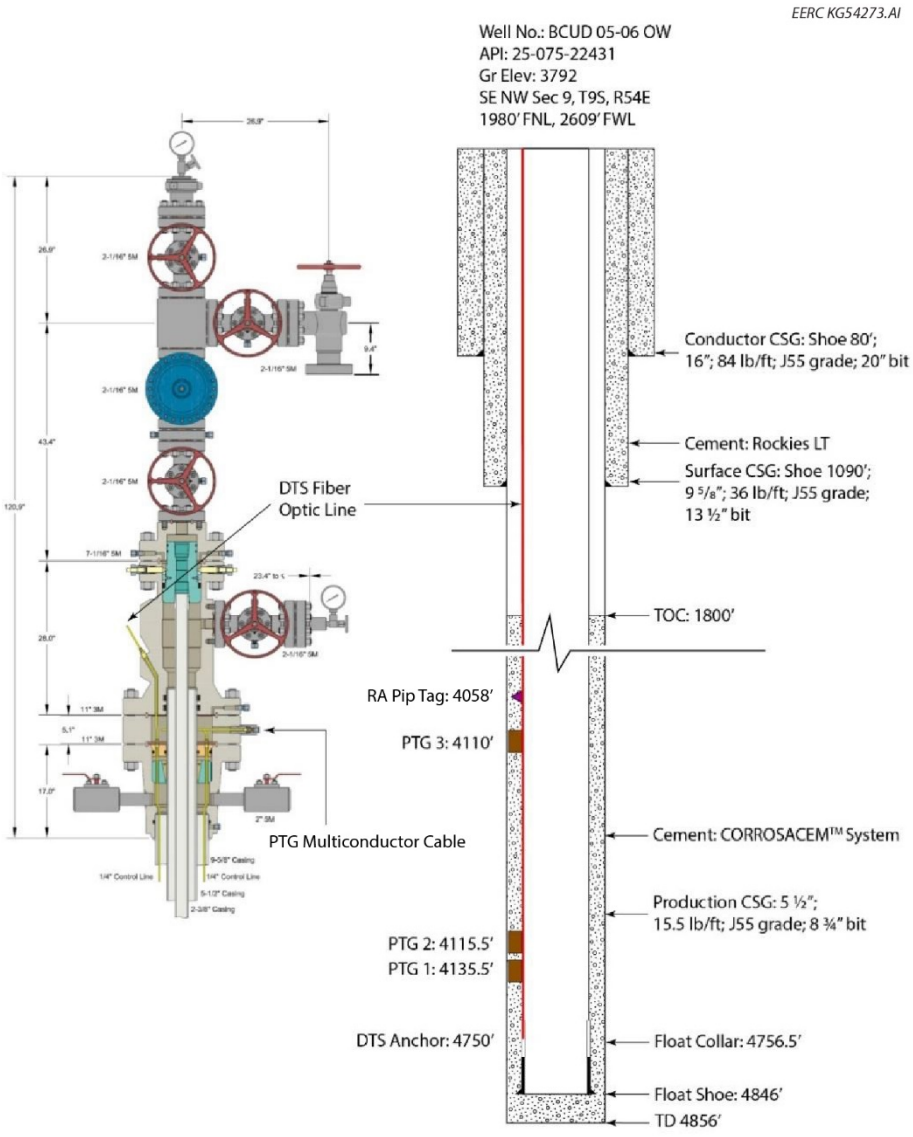

Figure 2. Wellbore schematic for 05-06 OW.

to operate the system, the EERC plans to decommission the 05-06 OW site by transferring full operation of the monitoring surface systems to Denbury. In exchange, the EERC will negotiate for continued access and use of the well for project monitoring work and for access to the pressure/temperature data for an agreed-upon time or until the system degrades to the point that it becomes inoperable and not practical to repair.

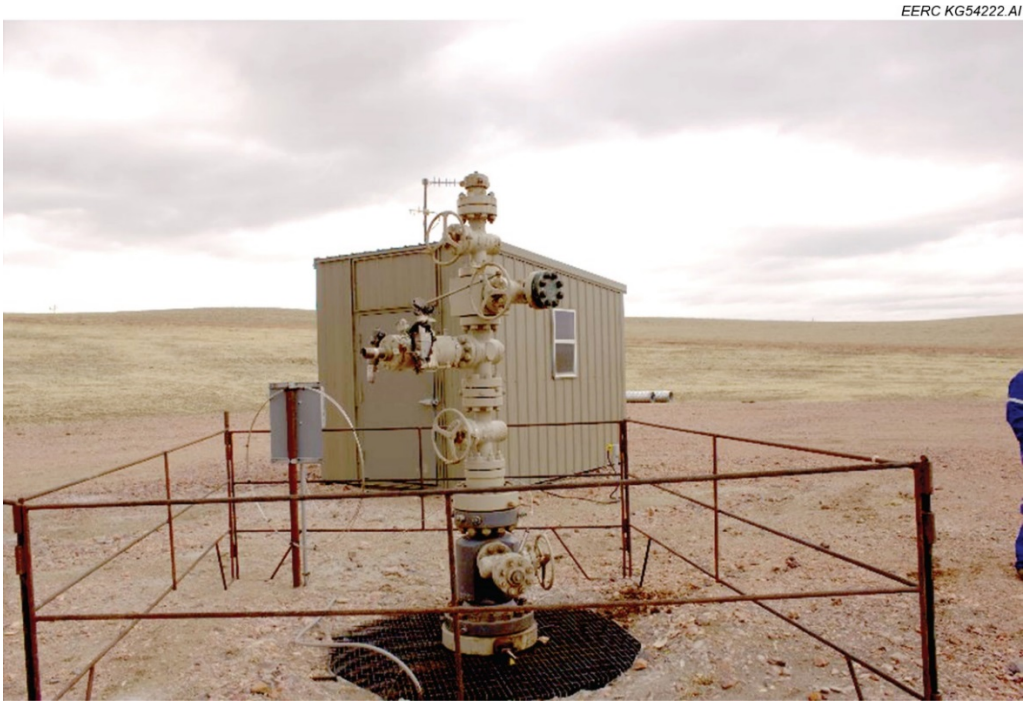

Figure 3. 05-06 OW wellhead and environmental enclosure (Heebink and others, 2014).

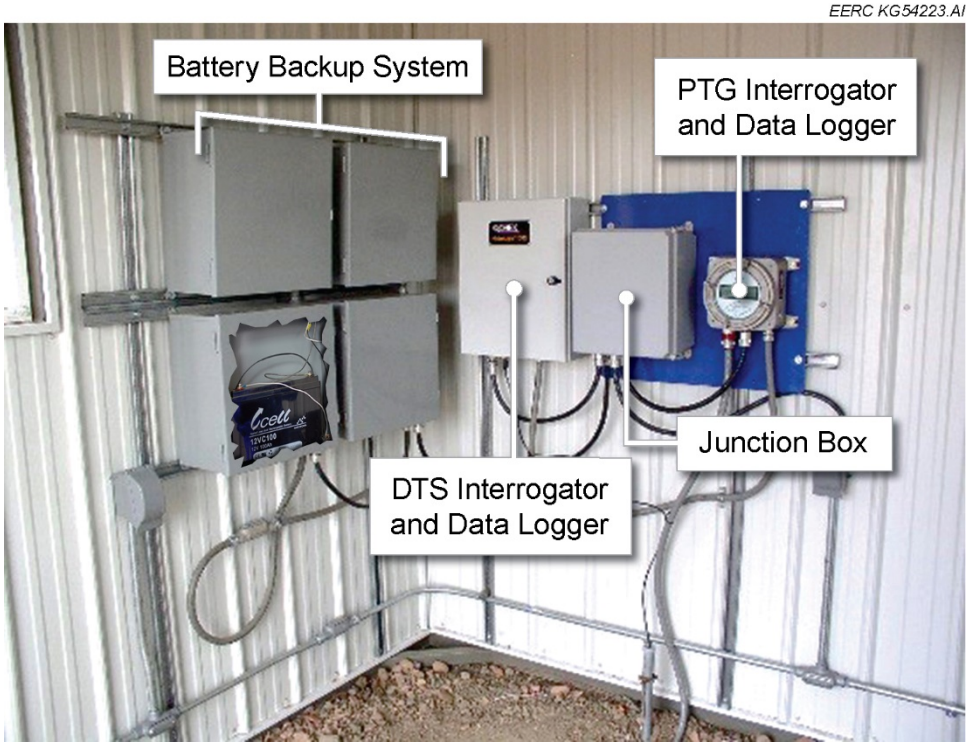

Figure 4. 05-06 OW data collection systems within the environmental enclosure. Image modified to show battery system.

04-03 OW

In April 2013, the 04-03 OW observation well was drilled to a depth of 2604 ft (Heebink and others, 2014) (Figure 5). The well was instrumented with a permanent 50-level geophone array spanning a 2400-ft interval (from 60-ft measured depth to 2460 ft) with 15-meter spacing between the geophones. The geophone array was installed to provide continuous passive seismic monitoring and as a receiver array for periodic time-lapse 3-D VSP acquisitions. After geophone installation, the wellbore was filled with cement to effectively plug and abandon the hole; however, the geophones remain active for use with the Bell Creek monitoring program.

Surface systems include an environmental enclosure, power and operating systems for the geophone, data collection and processing software and systems and a satellite dish that provides Internet communication with installed control and data acquisition systems (Figures 6 and 7). The system was operational between May 2013 and May 2016. The surface systems have reached their operational life and have been inoperable since May 2016. During the most recent attempt in July 2017, telemetry were only able to be established with 50% of the geophones, and the data acquisition and processing systems were completely inoperable. A technical assessment indicates that the surface system needs to be completely replaced prior to thorough diagnostics and testing of the geophones to determine their operational readiness.

As a practical, prudent, and cost-effective measure, the EERC is planning to decommission the site by removing the environmental enclosure from the site and scrapping the enclosed systems. The telemetry cable for the downhole geophones will be cut off and protected to preserve any potential future use of the geophones, and operations will be transferred to Denbury.

Groundwater Monitoring Wells (MW0504 and MW3312)

In January and February 2013, two monitoring wells (MW0504 and MW3312) were drilled to characterize and monitor the Fox Hills Formation, the lowermost underground source of drinking water (USDW), within the Bell Creek oil field (Heebink and others, 2014). MW0504 (Figure 8) was drilled to a depth of 820 ft into the Pierre shale and screened from 677 to 757 ft, an interval corresponding to the middle of the Fox Hills Formation. MW3312 (Figure 9) was drilled to a depth of 605 ft into the Pierre shale and screened from 545 to 605 ft, an interval corresponding to the middle of the Fox Hills Formation.

Both monitoring wells are colocated on the well pads of active oil-producing wells with the same well numbers. The wells were fitted with electric submersible pumps to allow for sampling as part of the Bell Creek monitoring program designed to characterize natural variability in water chemistry of the Fox Hills Formation and to demonstrate that CO_2 injection is not adversely impacting the Fox Hills Formation.

As a practical, prudent, and cost-effective measure, ownership and operation of both groundwater monitoring wells were transferred to the landowner as of July 18, 2016. As part of the transfer agreement, the EERC maintained the ability to access the wells for sampling throughout the remainder of the project.

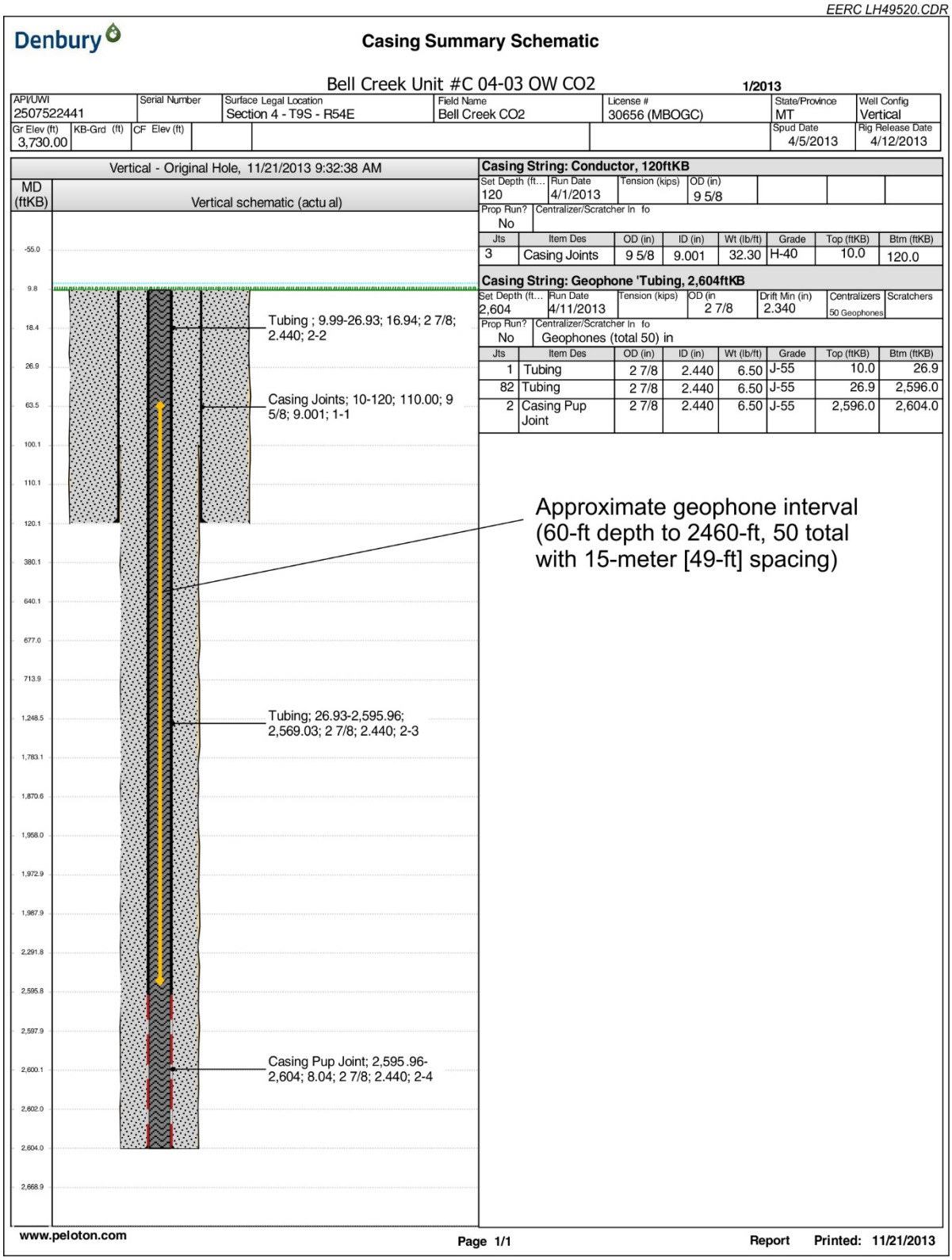

Figure 5. Well completions "Casing Summary Schematic" for 04-03 OW (Heebink and others, 2014).

Figure 6. 04-03 OW environmental enclosure and satellite communication system (Heebink and others, 2014).

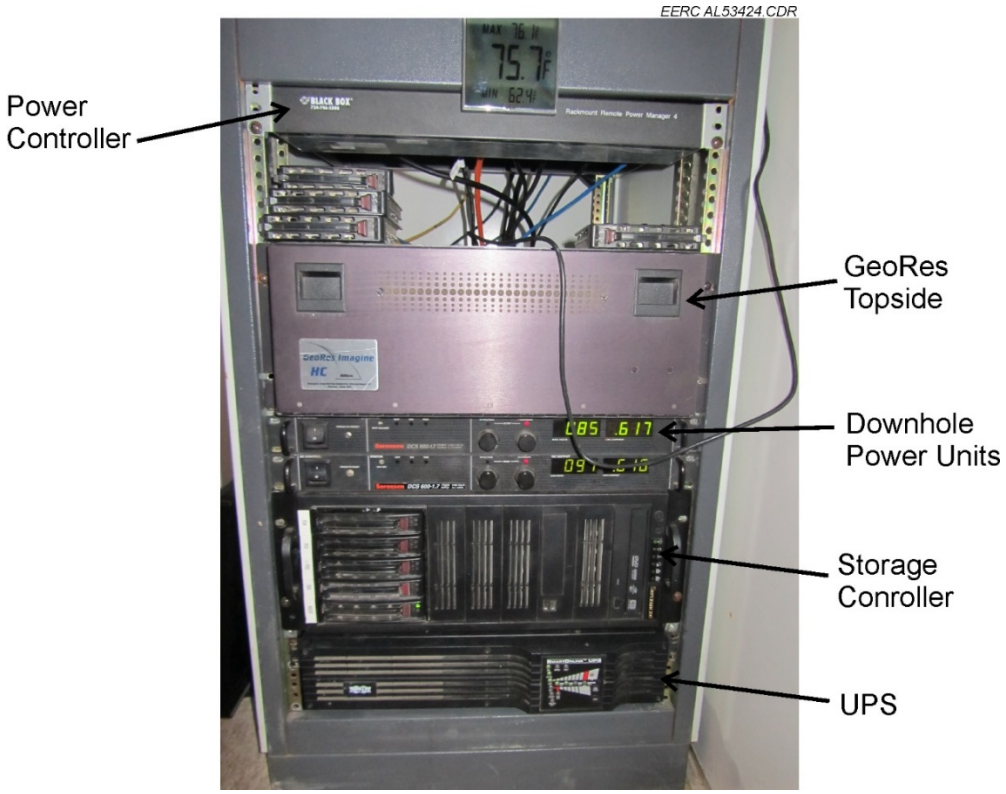

Figure 7. 04-03 OW data collection systems.

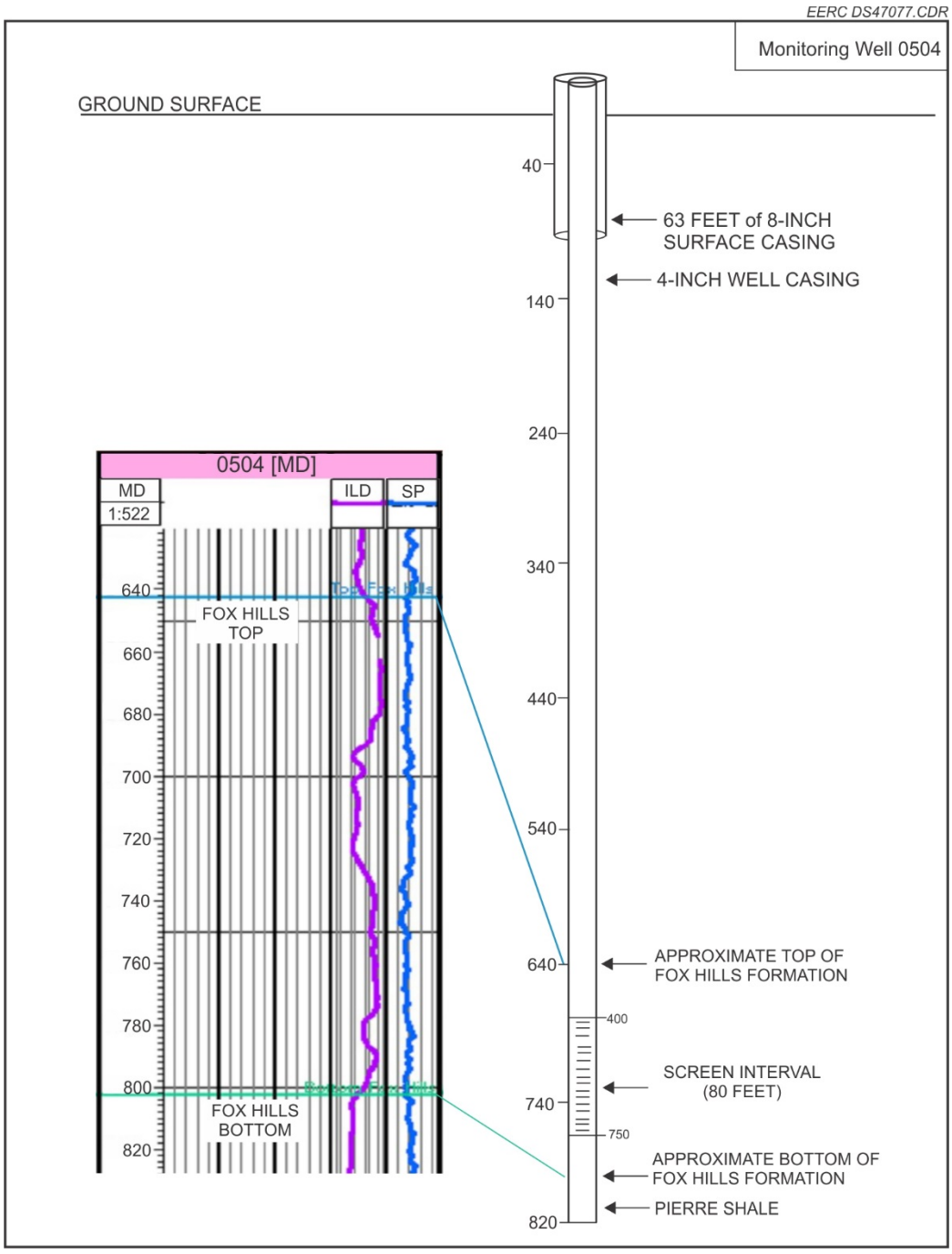

Figure 8. Completion details for MW0504.

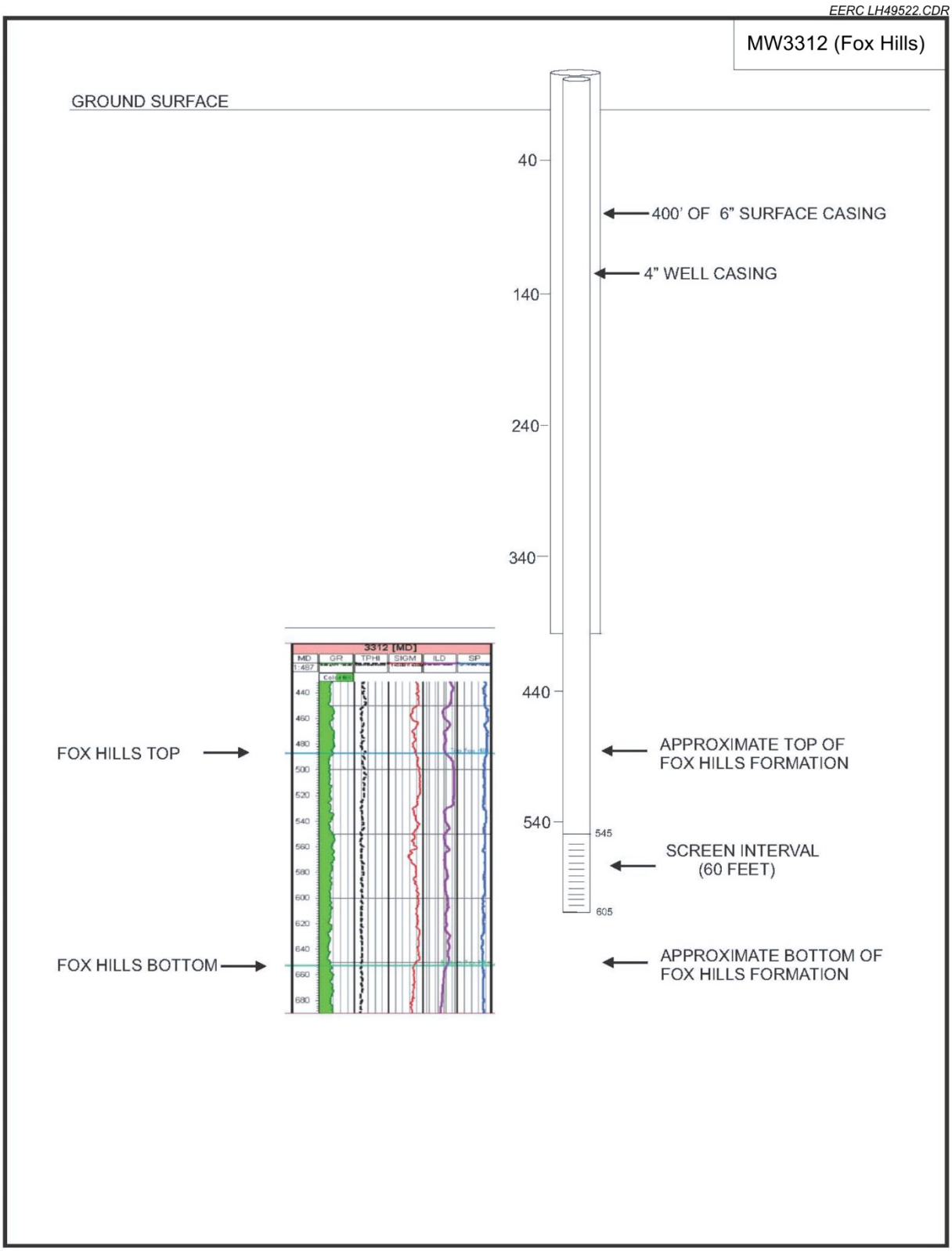

Figure 9. Completion details for MW3312.

Soil Gas Profile Stations

Ten fixed semipermanent SGPSs were installed in and around the Phase I development area of the Bell Creek oil field (Figure 10) (Kalenze and others, 2013). Installation occurred in October 2012. The SGPSs were installed to provide an understanding of the natural variability of soil gas chemistry at varying depths. Each SGPS consists of a shallow polyvinyl chloride (PVC) casing with nested ¼-inch stainless steel tubing individually screened at depths of 3.5, 9, and 14 feet below ground level. Each of the screened areas was packed with sand and sealed above and below with a layer of bentonite (Figures 11 and 12). This design allowed for consistent and efficient collection and analysis of soil gas samples at each depth interval year-round, providing that climate conditions allow site access. Between October 2012 and October 2016, the SGPSs have been sampled, and gas compositions have been analyzed and archived during 26 sampling events as part of a near-surface monitoring program.

As a practical, prudent, and cost-effective measure, the EERC is planning to transfer operation of the SGPSs to the site operator. In exchange, EERC will negotiate continued access to the SGPS for the duration of the project. If the site operator does not agree to take over operation of the systems, the ten SGPSs will be removed when conditions permit (i.e., spring or summer of 2018). Removal of each SGPS will be done by using a hand jack, but if stations cannot be removed, the tubes will be cut off at least 1 foot below the surface, and the site will be restored to native ground conditions and compliant with governing regulations.

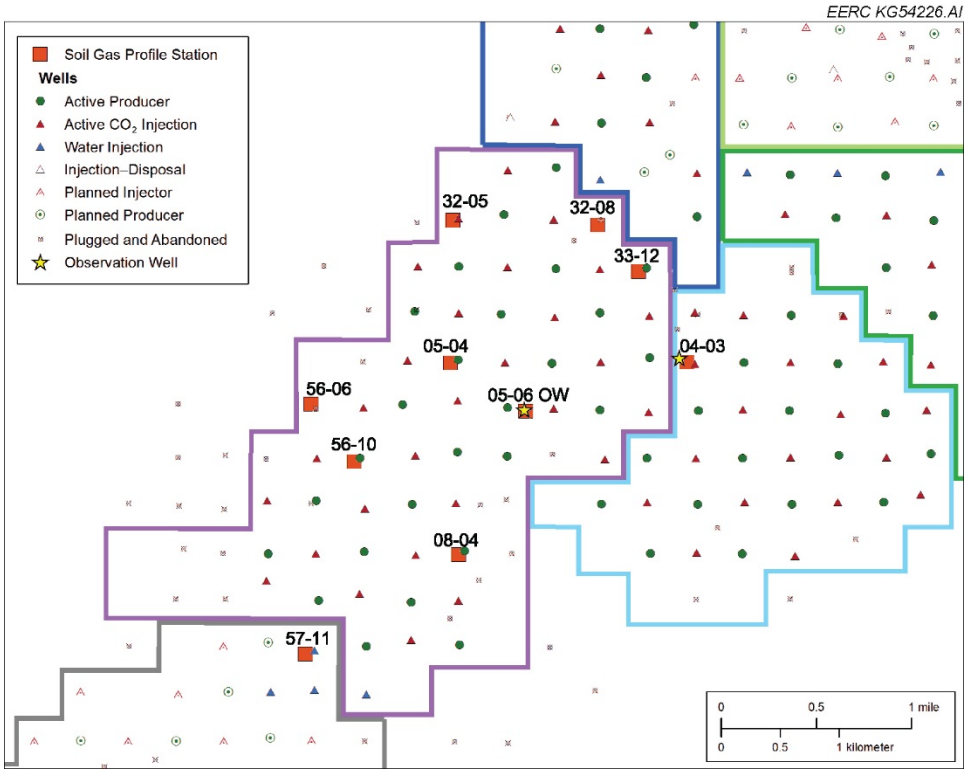

Figure 10. Location of SGPSs.

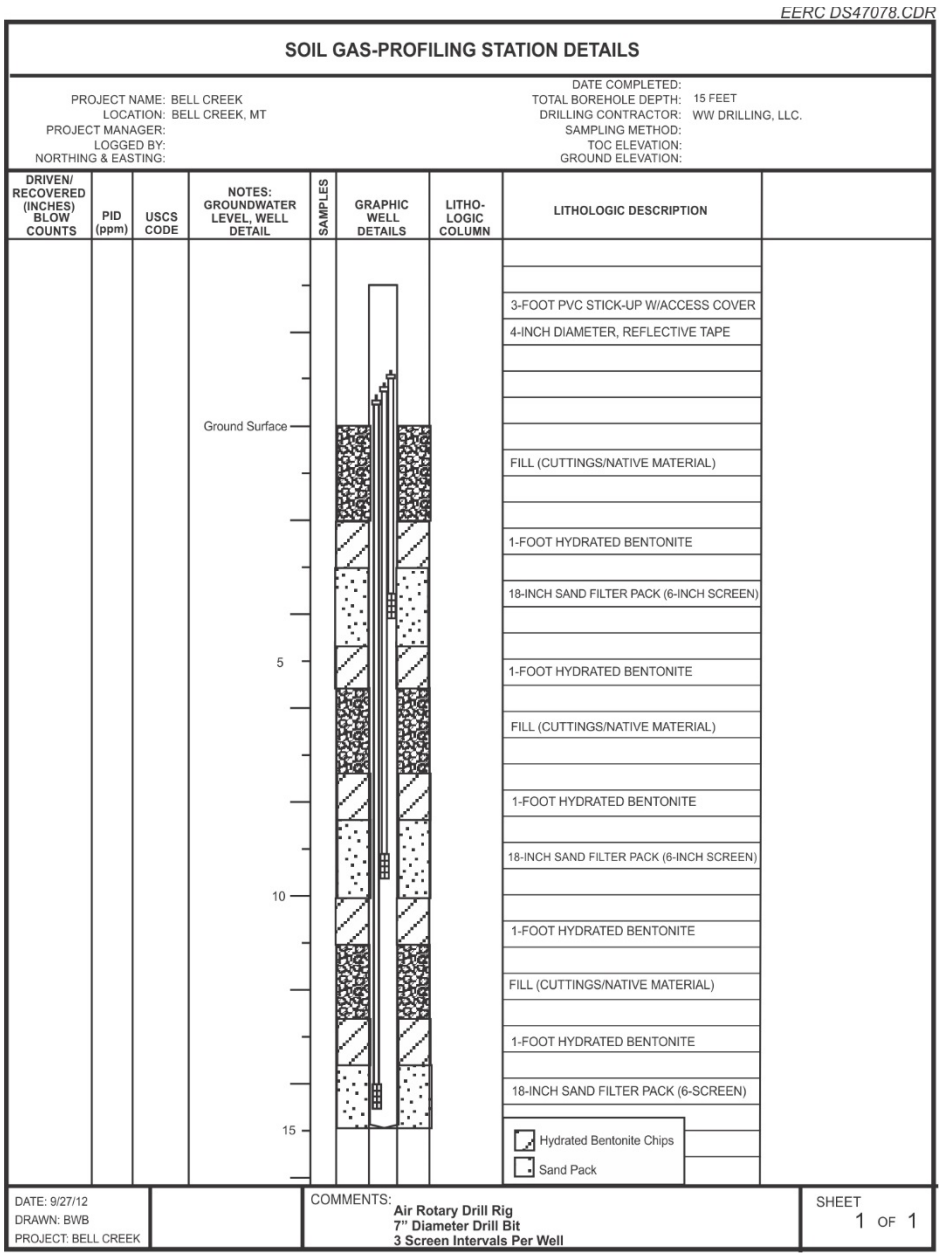

Figure 11. Schematic of the SGPS design.

Figure 12. SGPS at the surface.

EERC Field Office

The EERC staff established a semipermanent field office in 2012 to serve EERC personnel conducting field activities. The field office consists of two EERC-owned and environmentally controlled mobile trailers (Figure 13) that allow for lab analysis, data processing, or staff meetings. Field office support services, including satellite Internet and portable facilities (i.e., sanitation), have been canceled and removed from the field site. The two trailers will remain on-site until all project-related field activities, potential site visits, and planned decommissioning activities have been completed. After which, maintenance will be performed on the trailers, and they will be transported back to the EERC.

SUMMARY

The Bell Creek project has involved extensive field monitoring activities since 2011. As part of this monitoring program, monitoring systems and/or access points were established at two observation wells, two groundwater monitoring wells, and ten SGPSs. Support systems included a mobile field office, satellite communication, and sanitary facilities to support field efforts.

Figure 13. EERC Bell Creek oilfield office.

The EERC is working with the host site operator (Denbury) and pertinent landowners to either repurpose, transfer ownership and operations, or abandon locations and installed systems in-place where practical, prudent, and cost-effective to do so or to remove and remediate when necessary. Closure activities related to Bell Creek research efforts began in July 2016 (FY16). Field office support services, including satellite Internet and portable facilities (i.e., sanitation), were canceled and removed from the field site. A passive seismic array deployed in the dedicated 04-03 OW monitoring well was powered down and idled in anticipation of decommissioning. Two groundwater monitoring wells completed into the lowermost USDW were idled and abandoned in place, effectively transferring operations to the associated landowner while maintaining access rights for future fluid sampling. A casing-conveyed PTG system and a DTS installed at the 05-06 OW well were put into a minimum maintenance acquisition mode in anticipation of relinquishing operations to the site operator. Ten SGPSs were idled in anticipation of either transferring operations to the site operator or removal and remediation. A decommissioning plan/schedule for EERC mobile operations support trailers located in the field was developed. Progress of ongoing site closure activities will be reported to the DOE Project Manager in future quarterly reports, with all activities anticipated to be completed by the end of Task 10 (currently scheduled for December 31, 2018).

REFERENCES

Heebink, L.V., Smith, S.A., Hamling, J.A., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2014, Bell creek test site—drilling and completion activities report: Plains CO_2 Reduction (PCOR) Partnership Phase II, Task 5 – Deliverable D44, June.

Kalenze, N.S., Hamling, J.A., Klapperich, R.J., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2013, Bell Creek test site—monitoring experimental design package: Plains CO_2 Reduction (PCOR) Partnership Phase III, Task 5 – Deliverable D43, May.