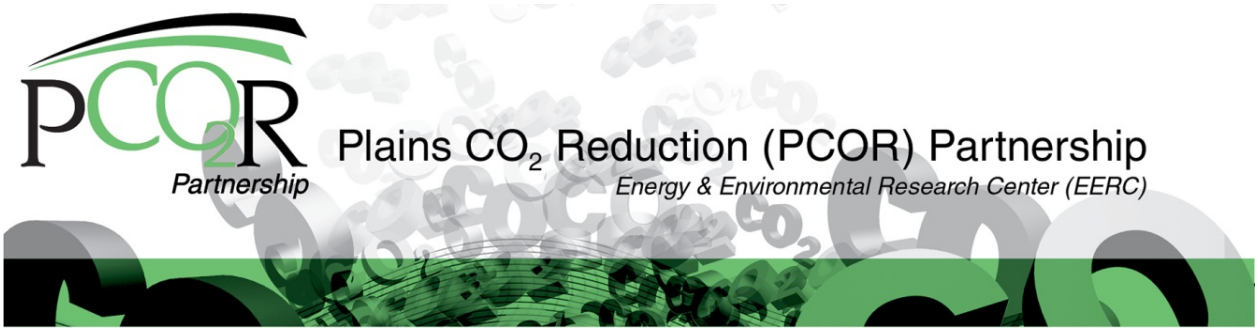


# BELL CREEK TEST SITE – INITIAL ANALYSIS OF PROCESSED InSAR DATA COMPLETED

**Plains $CO_2$ Reduction (PCOR) Partnership Phase III**
**Task 9 – Milestone M63**

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# BELL CREEK TEST SITE – INITIAL ANALYSIS OF PROCESSED InSAR DATA COMPLETED

## BACKGROUND

The Plains $CO_2$ Reduction Partnership (PCOR) Partnership, led by the Energy & Environmental Research Center (EERC), is working with Denbury Resources Inc. (Denbury) to study carbon dioxide ($CO_2$) storage associated with a commercial enhanced oil recovery (EOR) project at the Bell Creek oil field located in southeastern Montana, which is operated by Denbury Onshore LLC. Denbury is managing all injection, production, and recycle activities as part of its commercial $CO_2$ EOR operation. The EERC, through the PCOR Partnership, is studying the behavior of reservoir fluids and injected $CO_2$ to demonstrate safe and effective $CO_2$ storage associated with a commercial EOR project. The PCOR Partnership is developing practices and technologies that will allow future commercial-scale $CO_2$ storage projects to make informed decisions regarding site selection, injection programs, operations, and monitoring strategies that improve storage efficiency and effective storage capacity in clastic geologic formations.

Interferometric synthetic aperture radar (InSAR) satellite data provide a series of images that can be used to detect subtle movements of the ground surface, known as deformation. Ground elevation measurements from InSAR data have the potential to detect changing reservoir pressure conditions by observing the deformation at the overlying surface.

The objectives for InSAR analysis at the Bell Creek Field are to 1) determine naturally occurring deformation rates prior to the start of field pressurization, 2) determine if deformation has occurred as a result of the injection of $CO_2$ and/or pressure maintenance prior to $CO_2$ injection, 3) attempt to identify swept and unswept areas of the field, 4) provide an estimate of injection volumes or pressure differentials required to produce measurable surface deformation, 5) evaluate the potential to use ground deformation and ground motion obtained from InSAR to calibrate geologic models, 6) identify fault activation or reactivation if present, 7) evaluate the applicability of InSAR as an areal monitoring technique with regard to unique challenges imposed by the environment and EOR activities, and 8) compare with data from existing and planned time-lapse 3-D seismic monitoring surveys and passive seismic monitoring as validation and to investigate InSAR as a technique to delineate field compartmentalization and monitor subsurface pressure plumes over large areas.

The InSAR analysis is being completed in two stages. The first stage consisted of historical processing of lower resolution from an Advanced Land Observing Satellite (ALOS) data set prior to field pressurization. This phase determined that ground deformation can be sufficiently

detected and identified natural historical ground movement. Based on those data, it was decided to proceed with a second stage of data collection and analysis using higher-resolution COSMO-SkyMed (CSK) satellite data during and after field pressurization. Initial processing and analysis of the CSK InSAR data were provided by TRE Canada in June 2016.

## INITIAL ANALYSIS OF PROCESSED InSAR DATA COMPLETED

Initial processing and analysis of Stage 2 CSK InSAR data have been completed, satisfying Milestone 63 (M63). The area of interest (AOI) for the InSAR work is the Bell Creek oil field in southeastern Montana, covering an area of 143 sq mi. Land cover is mostly bare or lightly vegetated ground with oilfield infrastructure and sparse agricultural fields. The topography is hilly, with elevation ranging from 3274 to 4409 ft above sea level. The current monitoring analysis used high-resolution CSK imagery to compare with the ALOS baseline results and identify ground response to $CO_2$ injection. The data were analyzed using TRE's proprietary SqueeSAR algorithm. Sixteen CSK radar images were collected from September 11, 2015, to May 8, 2016.

Figure 1 shows the average ground deformation rates within each phase boundary during the historical (ALOS) and current (CSK) imaging periods. Deformation rates within each phase boundary range between −0.09 to +0.60 in./yr during the injection period, compared to −0.06 to 0.05 in./yr in the baseline period. The most notable change between the two periods was observed in Phase 4, where uplift started in January 2016 and cumulative deformation reached +0.37 in. in May 2016. This uplift is in agreement with the start of $CO_2$ injection (08 December 2015) in Phase 4. Mild uplift of +0.18 in. was also detected in Phase 2, beginning in early 2016. The data indicate a positive correlation between ground deformation within a 300-foot radius of the wells and cumulative injected fluid (gas and water) volume.

Based on the results of this work, it was decided to continue collecting CSK data through June 2017. Analysis of the data will be completed by TRE in August 2017. Pertinent results will be reported in best practices manual D51 "Monitoring for $CO_2$ Storage and $CO_2$ EOR," which will be submitted to DOE by the end of October 2017.

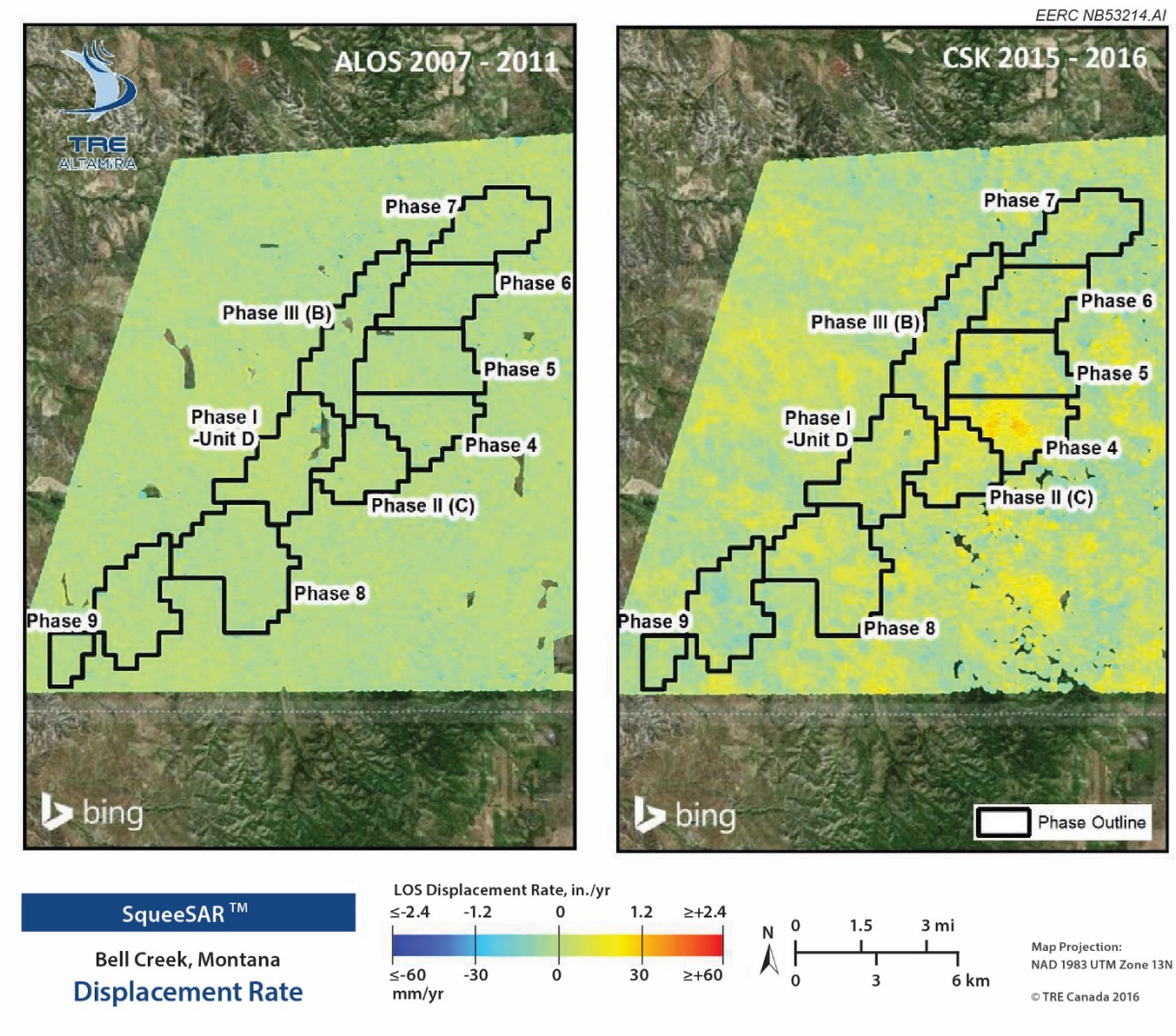


Figure 1. Historical deformation within the injection phase boundaries from 2007 to 2011 compared to deformation from September 2015 to May 2016.