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Bell Creek CO₂ EOR and CO₂ Storage Demonstration Project, Montana

**International Workshop on Knowledge Sharing in MVA/MMV in CCS
Demonstration Projects and Large- Scale CO₂ Injection Tests
Mobile, Alabama
May 16, 2012**

Charles D. Gorecki



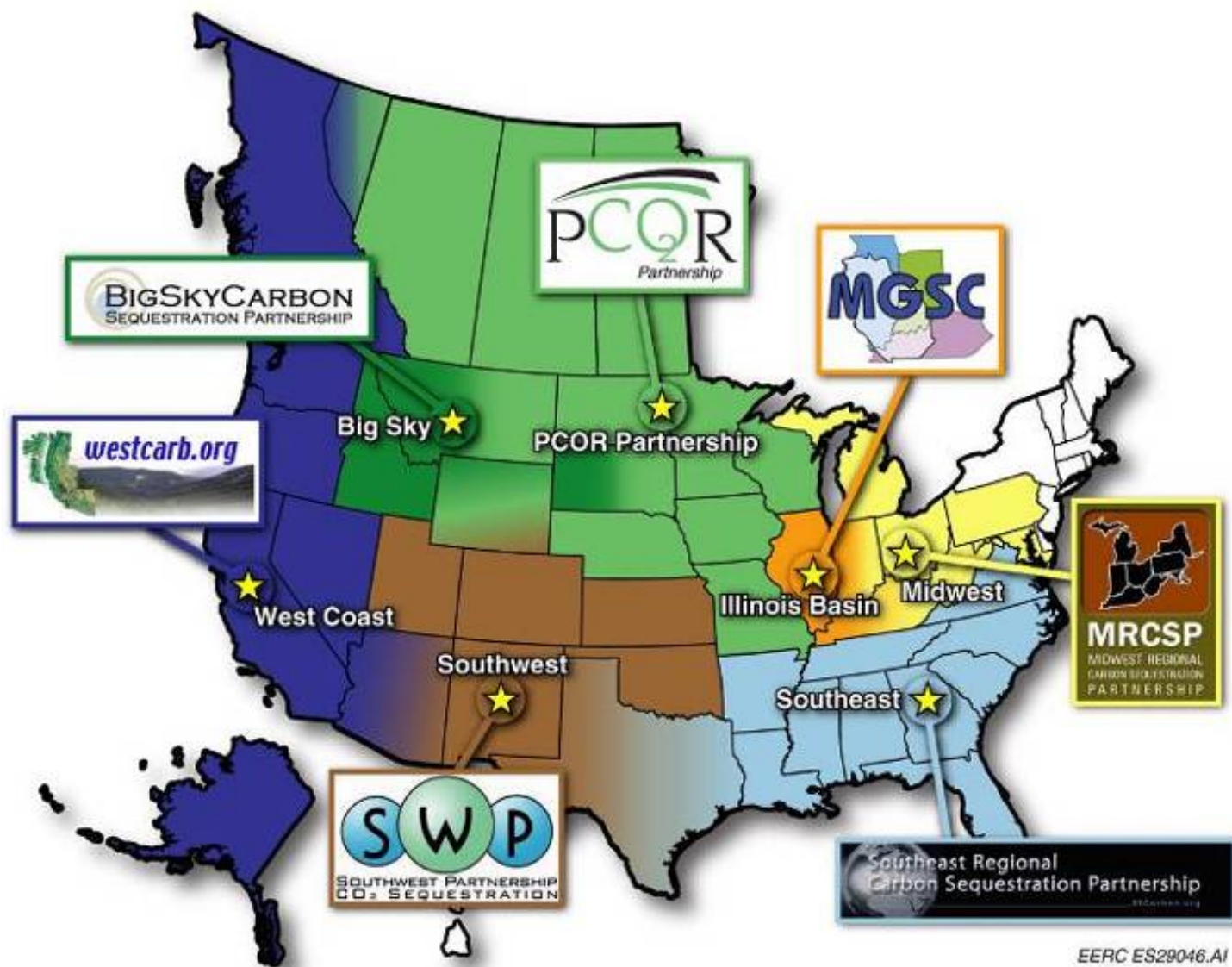
Acknowledgment

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U.S. Department of Energy Regional Carbon Sequestration Partnerships (RCSPs)

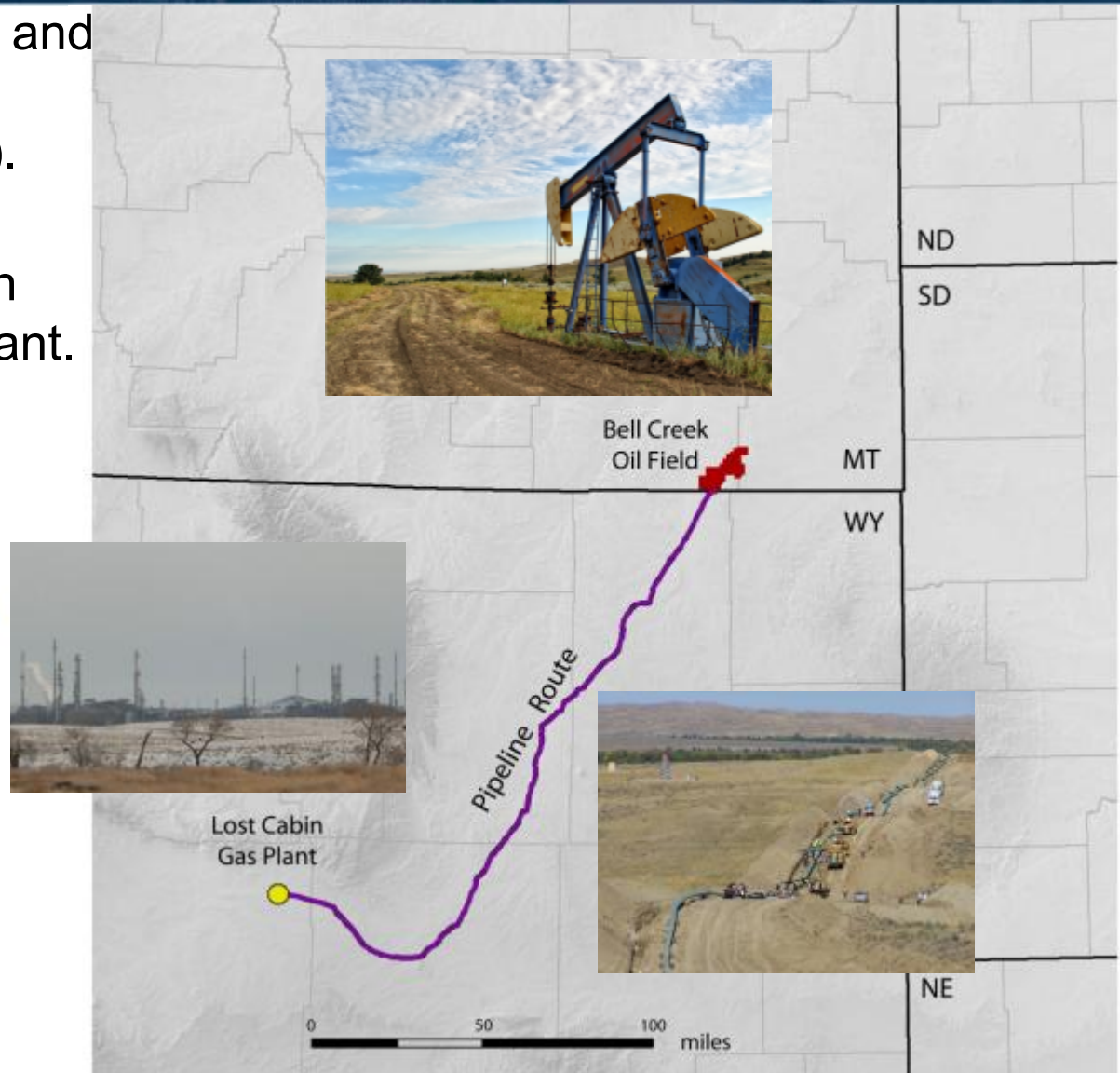


Plains CO₂ Reduction (PCOR) Partners



Bell Creek CO₂ Enhanced Oil Recovery (EOR) and Storage Project

- Bell Creek Field is owned and operated by Denbury Resources Inc. (Denbury).
- CO₂ sourced from ConocoPhillips Lost Cabin natural gas-processing plant.



Current Activities

- Denbury is preparing the field for CO₂ injection.
 - Wells are being recompleted, and facilities are under construction.
 - Approximately 50 MMscf/day of CO₂ will be delivered to Bell Creek.
 - Injection scheduled to begin first quarter of 2013.
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- An estimated 35 million incremental bbl of oil will be recovered using CO₂ EOR at Bell Creek.

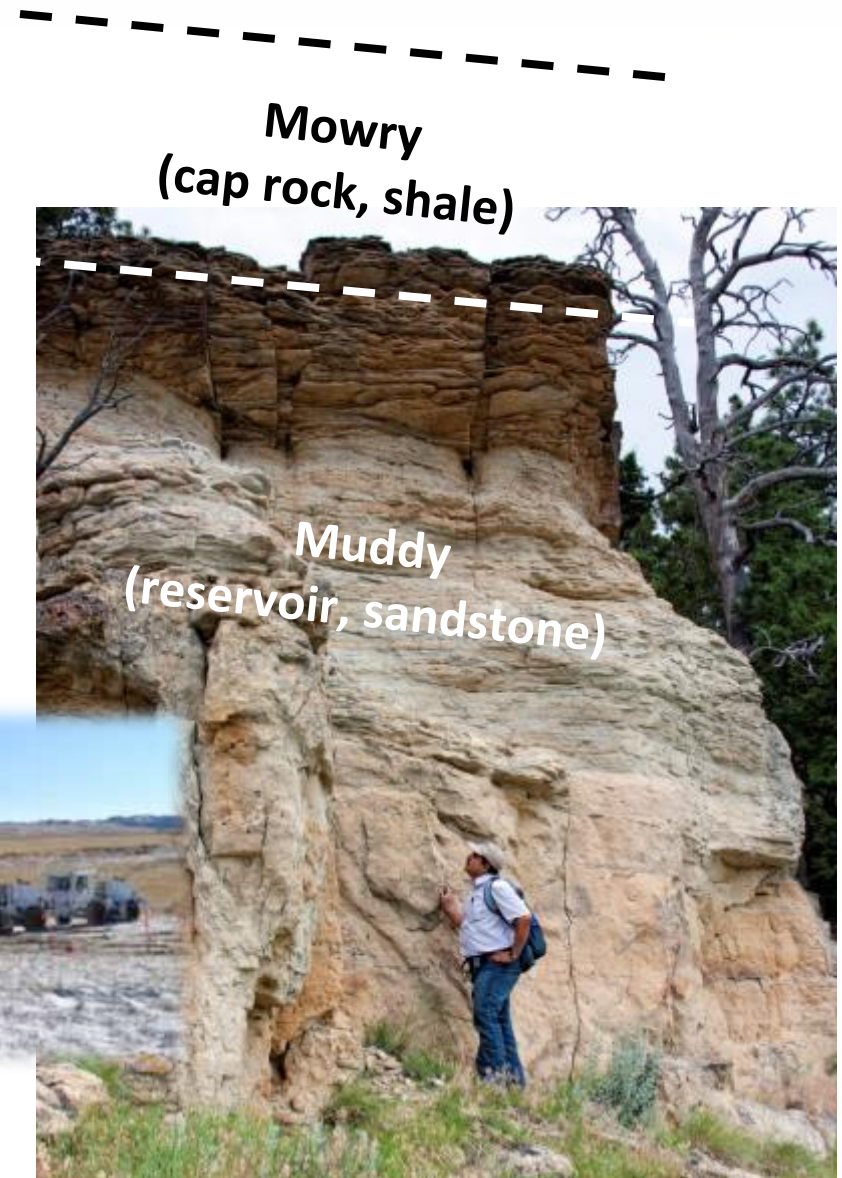
PCOR Partnership Activities at Bell Creek

- Developing an integrated approach to monitoring, verification, and accounting (MVA).
- Focused on site characterization, modeling and simulation, and risk assessment as a guide for developing an MVA strategy.



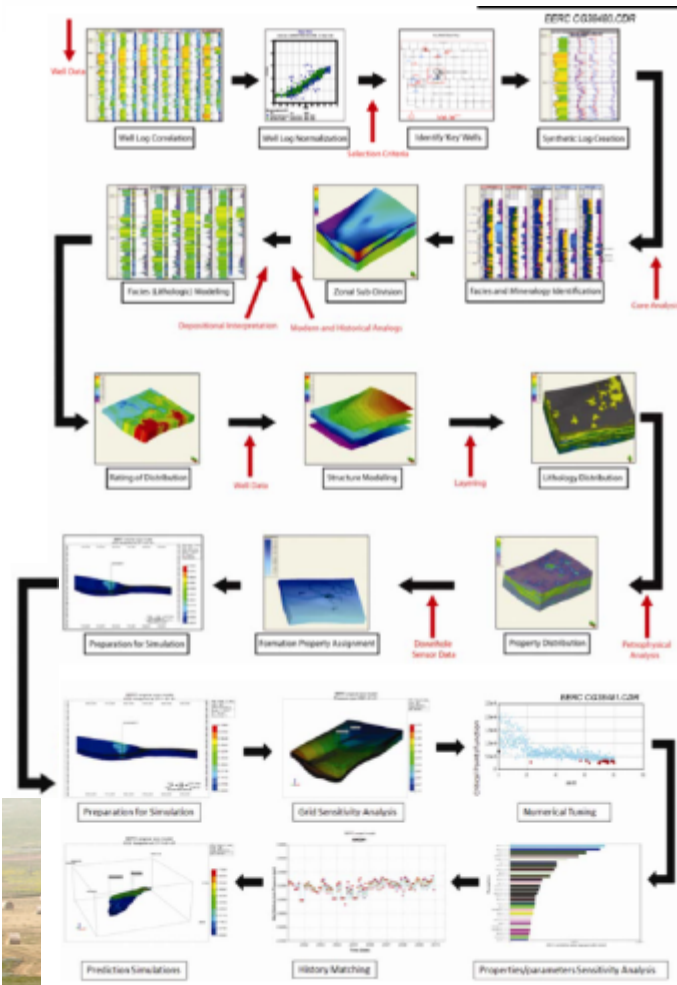
Site Characterization

- Outcrop field trip
- Visit core libraries (U.S. Geological Survey and Bureau of Economic Geology)
- Review historic data (well files)
- Lidar
- Drill a new dedicated data collection and monitoring well
 - Well logs
 - Core
- Collect baseline seismic data (2-D, 3-D, crosswell, and/or vertical seismic profile [VSP])



Modeling and Simulation

- Goals
 - Evaluate injection scenarios
 - Predict fluid migration pathways and area of influence at discrete time steps
 - EOR and CO₂ storage efficiencies
 - Predict reservoir response to injection
 - Aid in risk assessment



Risk Assessment

- Identify potential risks
 - Injectivity
 - Containment
 - Reservoir
 - Wellbores
 - Retention
 - Capacity
- Mitigate and monitor unacceptable risks
- Update based on monitoring and simulation

Frequency

Severity

	1	2	3	4	5
5	6	7	8	9	10
4	5	6	7	8	9
3	4	5	6	7	8
2	3	4	5	6	7
1	2	3	4	5	6

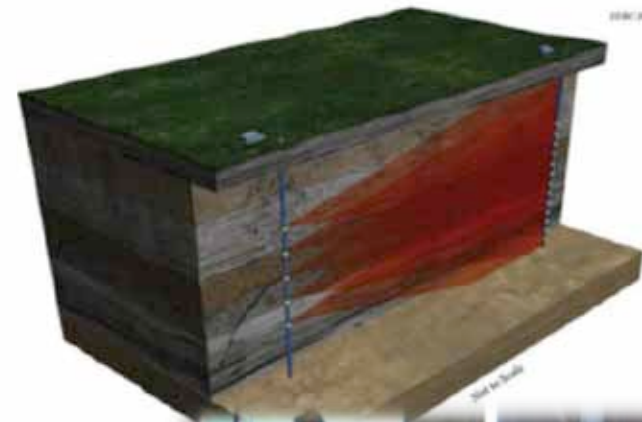
ERC-GAS-2017-ALP

Level	Risk Rank	Suggested Action
9-10	High	A.S.A.P: Immediate, short term risk treatment required
7-8	Moderate	Short-mid term risk treatment required, ALARP
5-6	Transition	Uncertainty reduction, ALARP(*), MVA(**), risk treatment whenever possible or affordable
2-4	Low	No immediate action required, continue to monitor. For Risk Rank = 2, look for possibility of cost reduction

(*) ALARP: As Low As Reasonably Possible

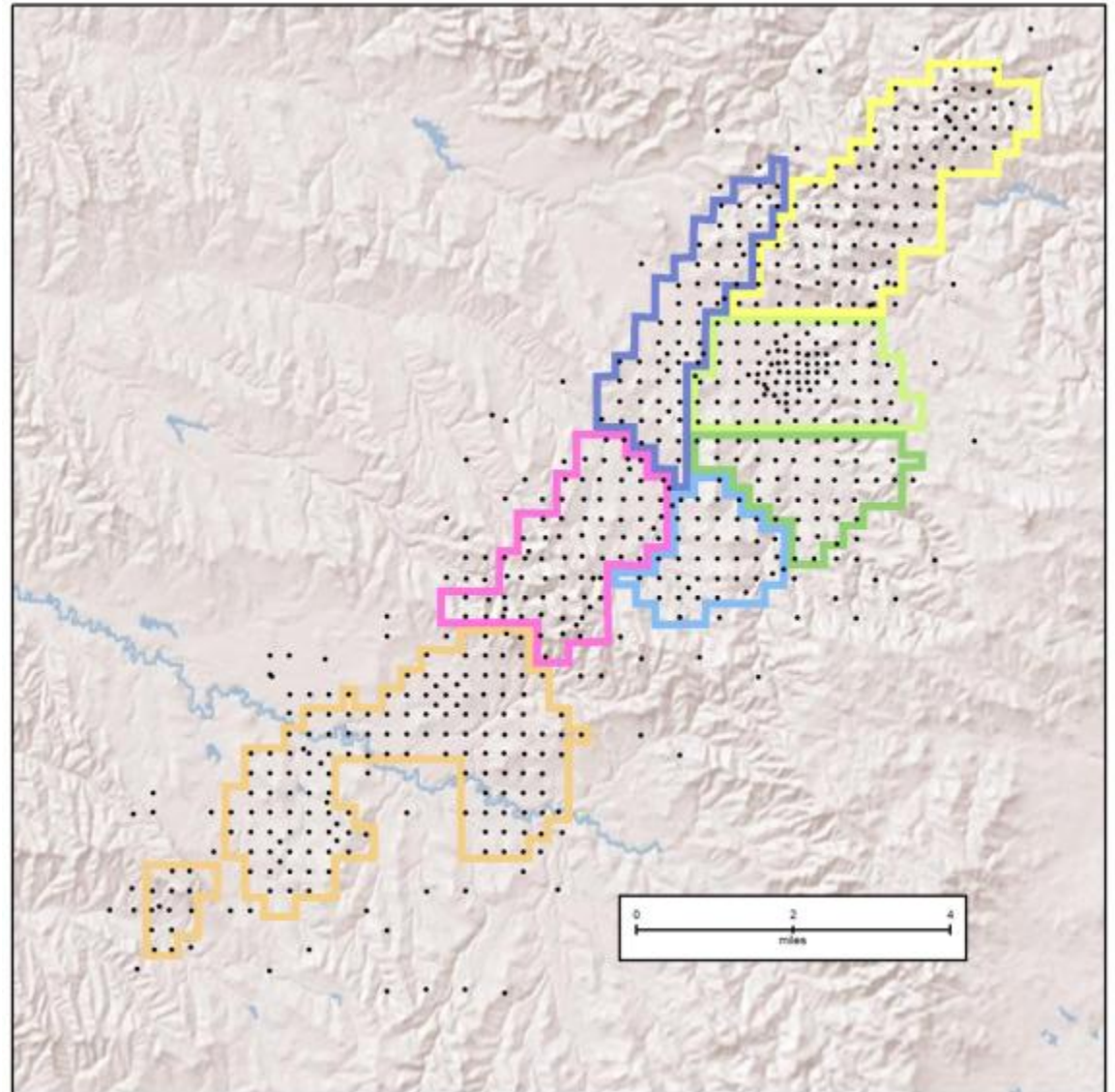
Bell Creek MVA Program Goals

- Demonstrate CO₂ storage can be safely and permanently achieved on a commercial scale in conjunction with an EOR project.
- MVA methods can be established to effectively monitor a commercial-scale EOR CO₂ storage project.
 - Baseline data acquisition
 - Establish preinjection conditions
 - Verify site security
 - Track movement of CO₂
 - Update risk assessment and simulation results
 - Identify fluid migration pathways
 - Evaluate containment
 - Establish relationship between the CO₂ EOR process and long-term storage of CO₂
 - Determine ultimate fate of CO₂



Bell Creek MVA Program

- CO₂ MVA program overlaid on a commercial EOR project
 - Guided by site characterization, modeling, simulation, and risk assessment
 - Compatibility with commercial project
 - Opportunity to supplement MVA program with commercial data
 - Focused on Phase 1 injection Area
- Two-pronged approach:
 - Surface and near surface
 - Reservoir



Surface and Near-Surface MVA Program

- Objectives
 - Verify site security
 - Identify and understand preinjection and postinjection anomalies
 - Update risk assessment based on monitor data
- Surface and near-surface monitoring program:
 - Soil gas
 - P&A (plug and abandon) wells
 - Active injection and production wells
 - Interspaced samples
 - Water
 - Residential wells
 - Stock wells
 - Surface waters

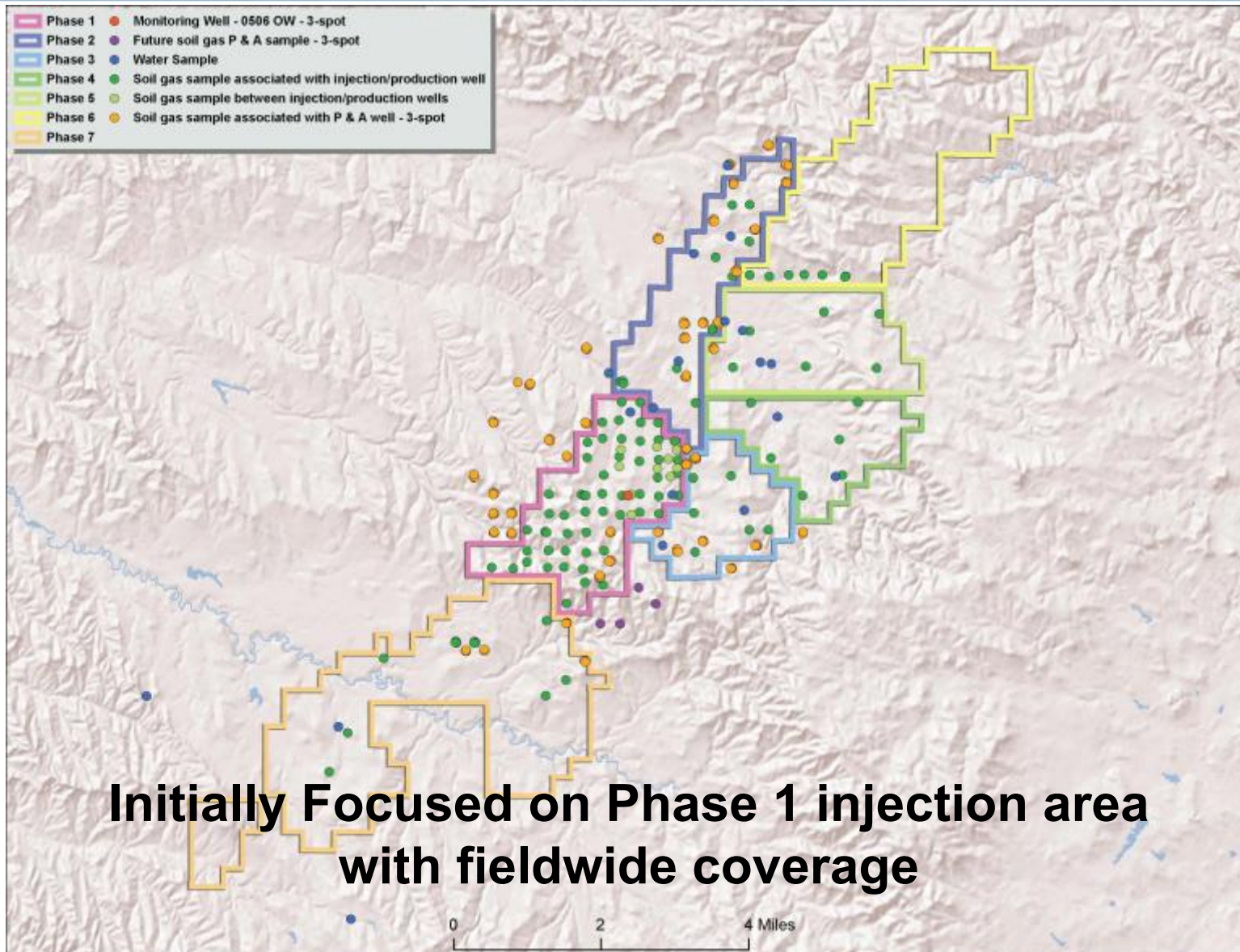


Surface and Near-Surface MVA Program (continued)

- Four quarterly preinjection surveys
 - Provide a 1-year baseline data set of seasonal CO₂ variations for comparison throughout the field.
 - Provide baseline data over a range of microenvironments present in field
 - Periodic postinjection surveys to monitor and understand variance from baseline data
- Identify and understand source of anomalies:
 - Natural biological processes
 - Seasonal variations
 - Agricultural practices
- Rigorous quality assurance/quality control (QA/QC) program to assure confidence of results



Soil Gas and Water



Soil Gas

- Soil gas
 - P&A wells (44 wells)
 - Three-spot pattern because of uncertainty in wellhead location
 - Active injection and production wells (93 wells)
 - Sample near wellhead
 - Interspaced samples (10 sample points)
 - Provide a control data set
 - Higher-frequency data collection
- Analysis provides concentrations of:
 - H_2S
 - CO_2
 - N_2
 - O_2
 - CH_4
 - CO
 - Volatile organic compounds (VOCs)



Water

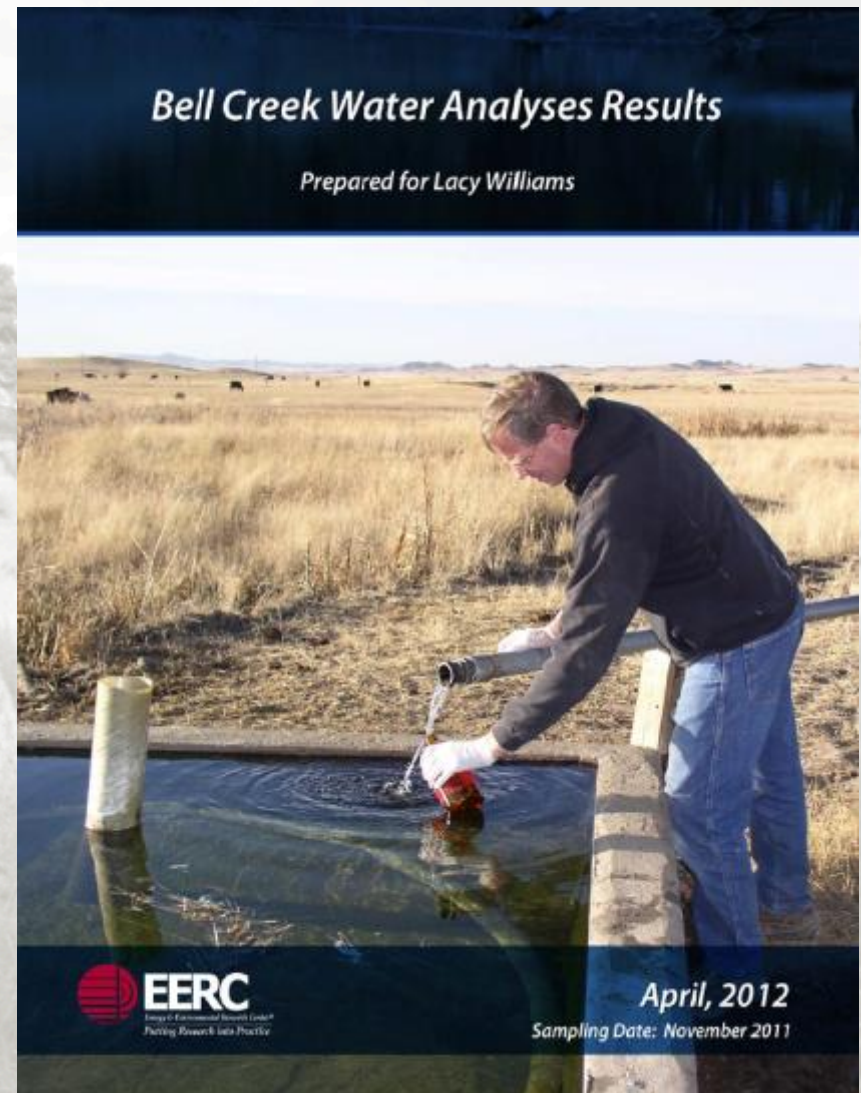
- Water
 - Residential wells (seven wells)
 - Stock wells (eight wells)
 - Surface waters (eight surface waters)
- Provide a means of tracking pre- and post-injection water quality throughout the field
- Provide a proactive means of monitoring for site security
- Analysis provides concentrations of:
 - Dissolved and total metals
 - Nonmetals
 - Dissolved gas
 - VOCs
 - Semi-VOCs
 - Hydrocarbons
 - Inorganics
 - Isotopes



Surface and Near-Surface MVA Program

- Analysis results
 - Fieldwide database
 - Updated quarterly
 - fieldwide statistic
 - Provide water analysis results to landowners in exchange for access

Landowner relations vital to MVA program!



LIDAR Data Set

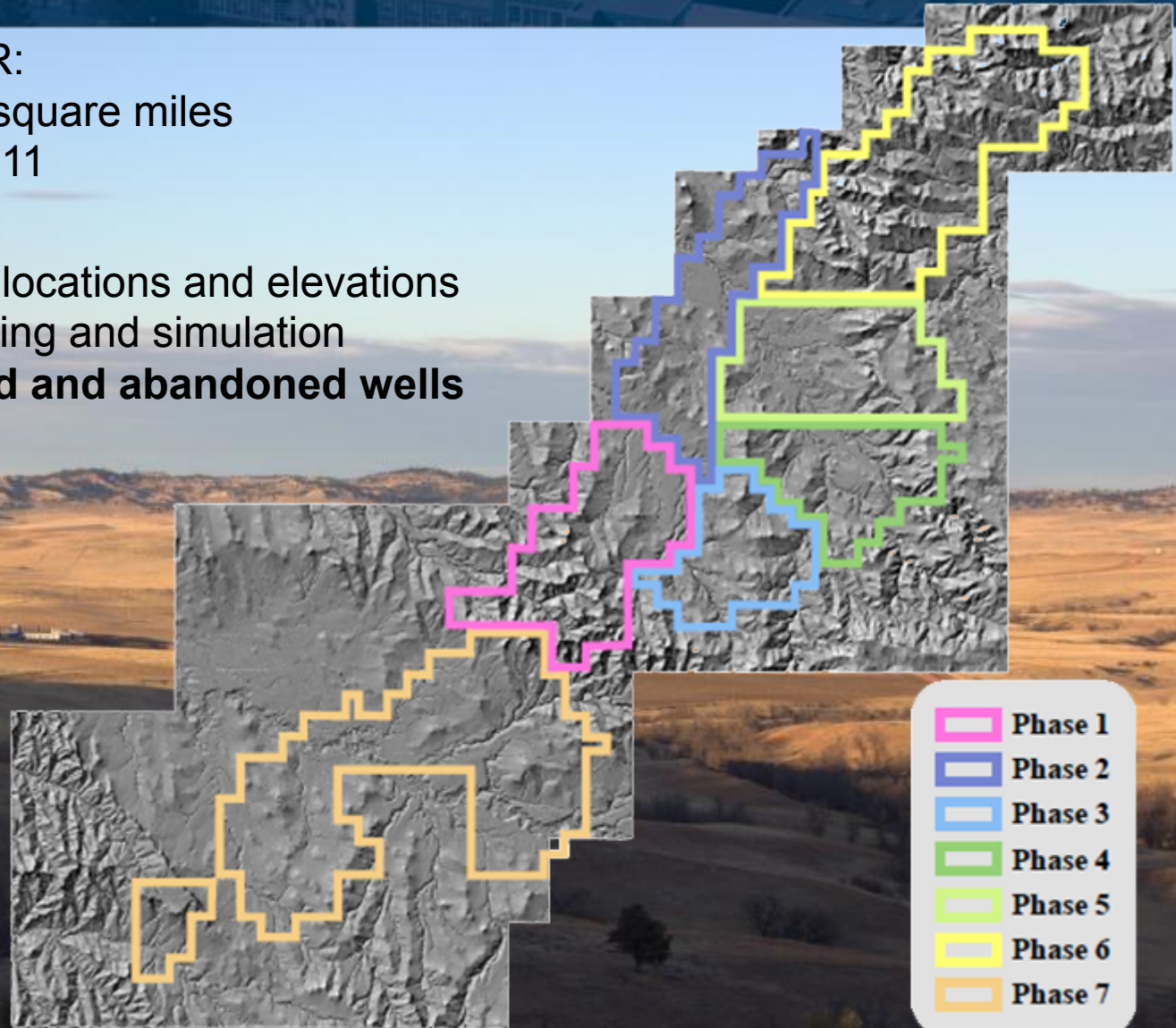
Area covered by LIDAR:

Approximately 75 square miles

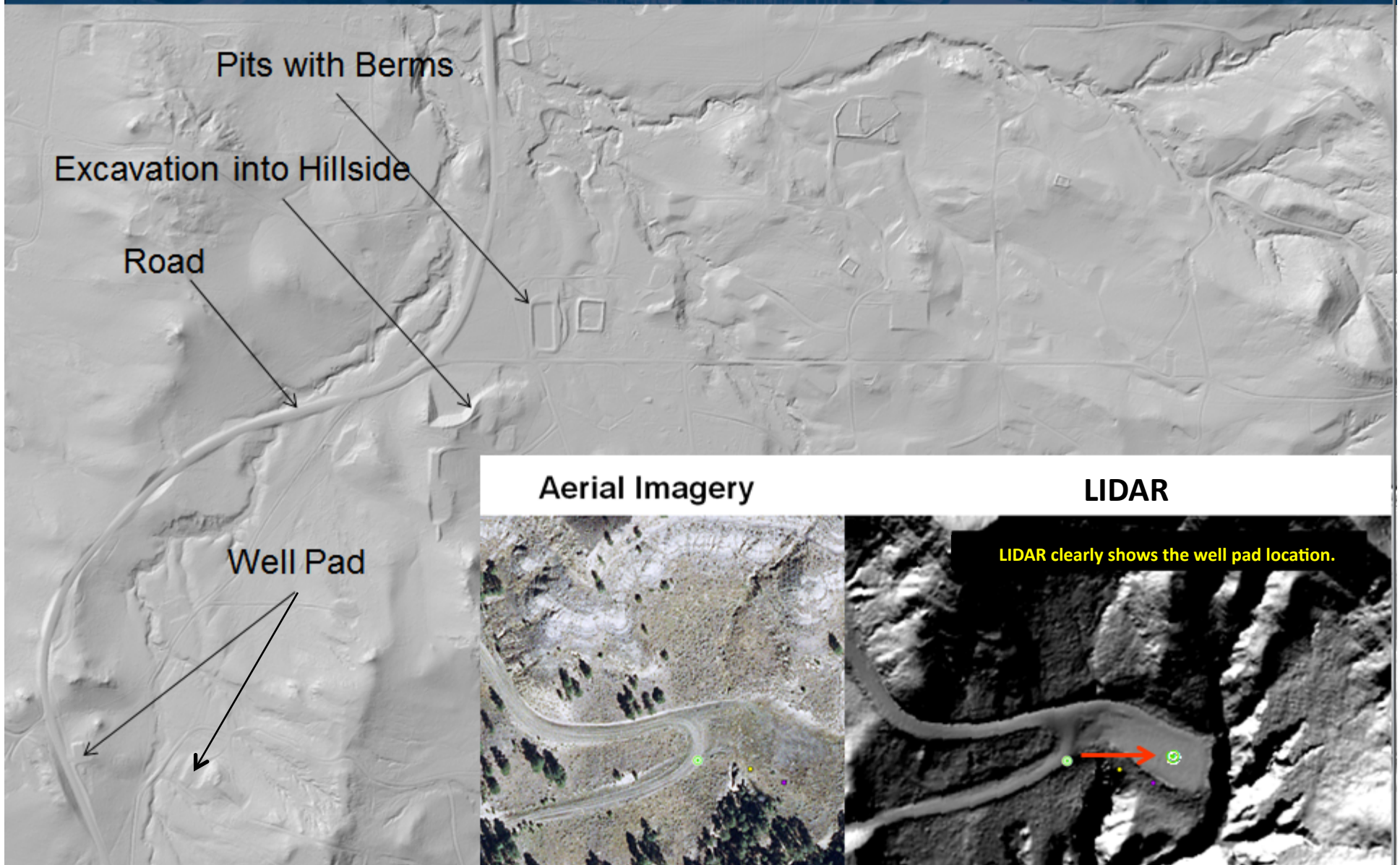
Date collected: 7/14/2011

Objective

- Precisely place well locations and elevations
 - Geologic modeling and simulation
 - **Locate plugged and abandoned wells**

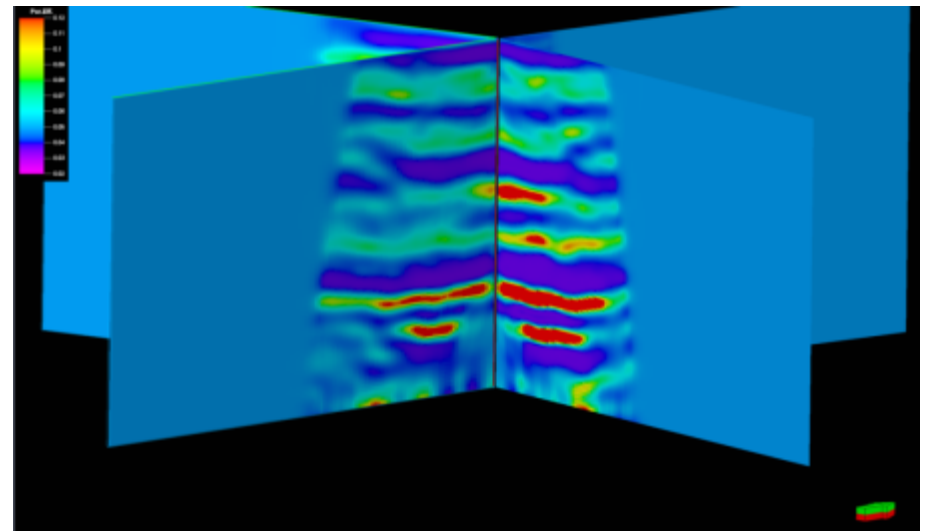


Impact of LIDAR Data Collected from Bell Creek Field



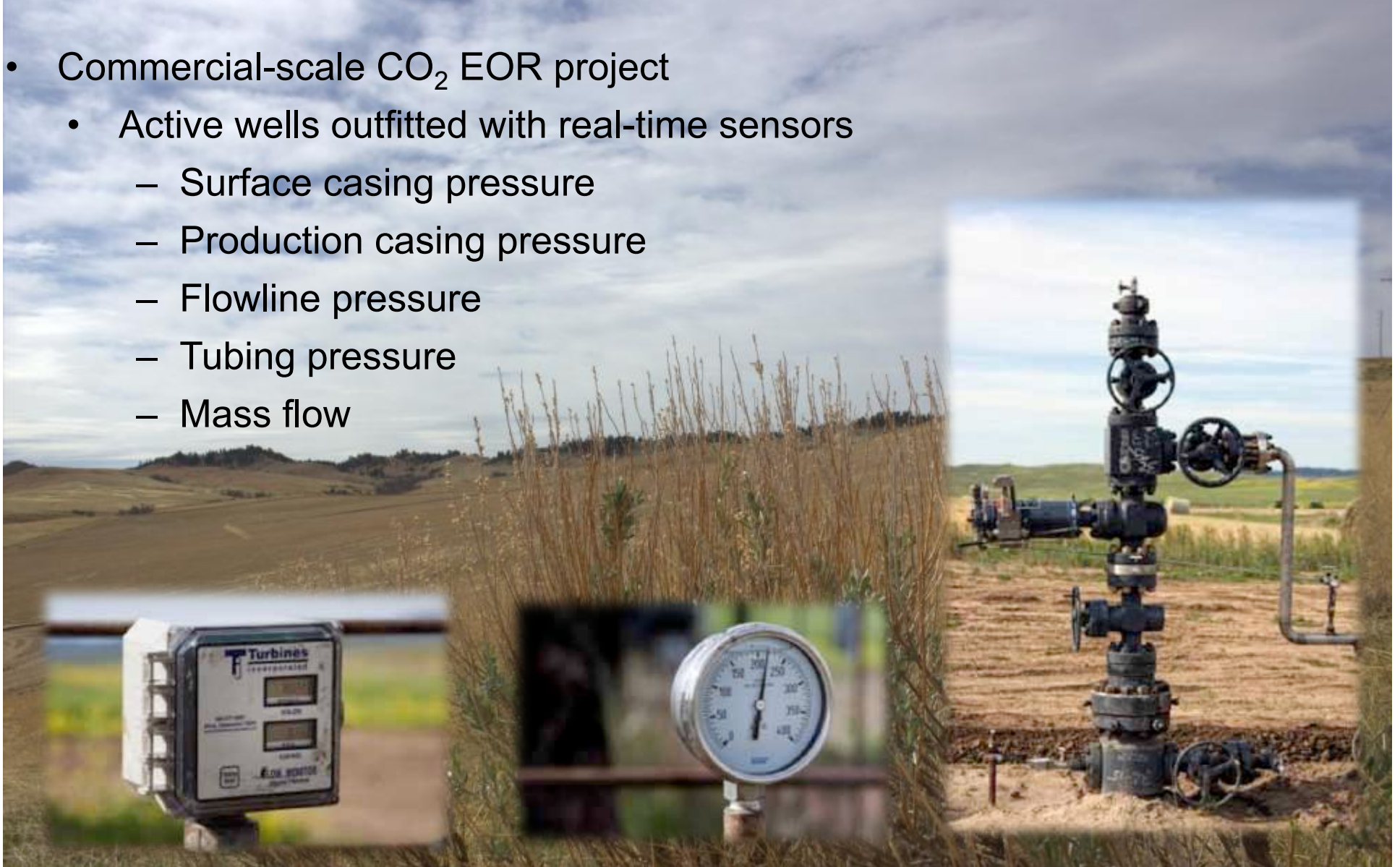
Reservoir MVA Program

- Objectives
 - Verify site security
 - Establish preinjection reservoir and subsurface conditions
 - Update risk assessment based on monitor data
 - Track movement of CO₂ and subsurface fluid migration
 - Establish relationship between the CO₂ EOR process and long-term storage of CO₂
- Reservoir-monitoring program:
 - Continuous
 - Wellhead pressures
 - Permanent downhole monitoring (PDM) equipment
 - Periodic
 - Seismic
 - Well logs
 - Pressure surveys
 - Tracer analysis?



Reservoir MVA Program (continued)

- Commercial-scale CO₂ EOR project
 - Active wells outfitted with real-time sensors
 - Surface casing pressure
 - Production casing pressure
 - Flowline pressure
 - Tubing pressure
 - Mass flow

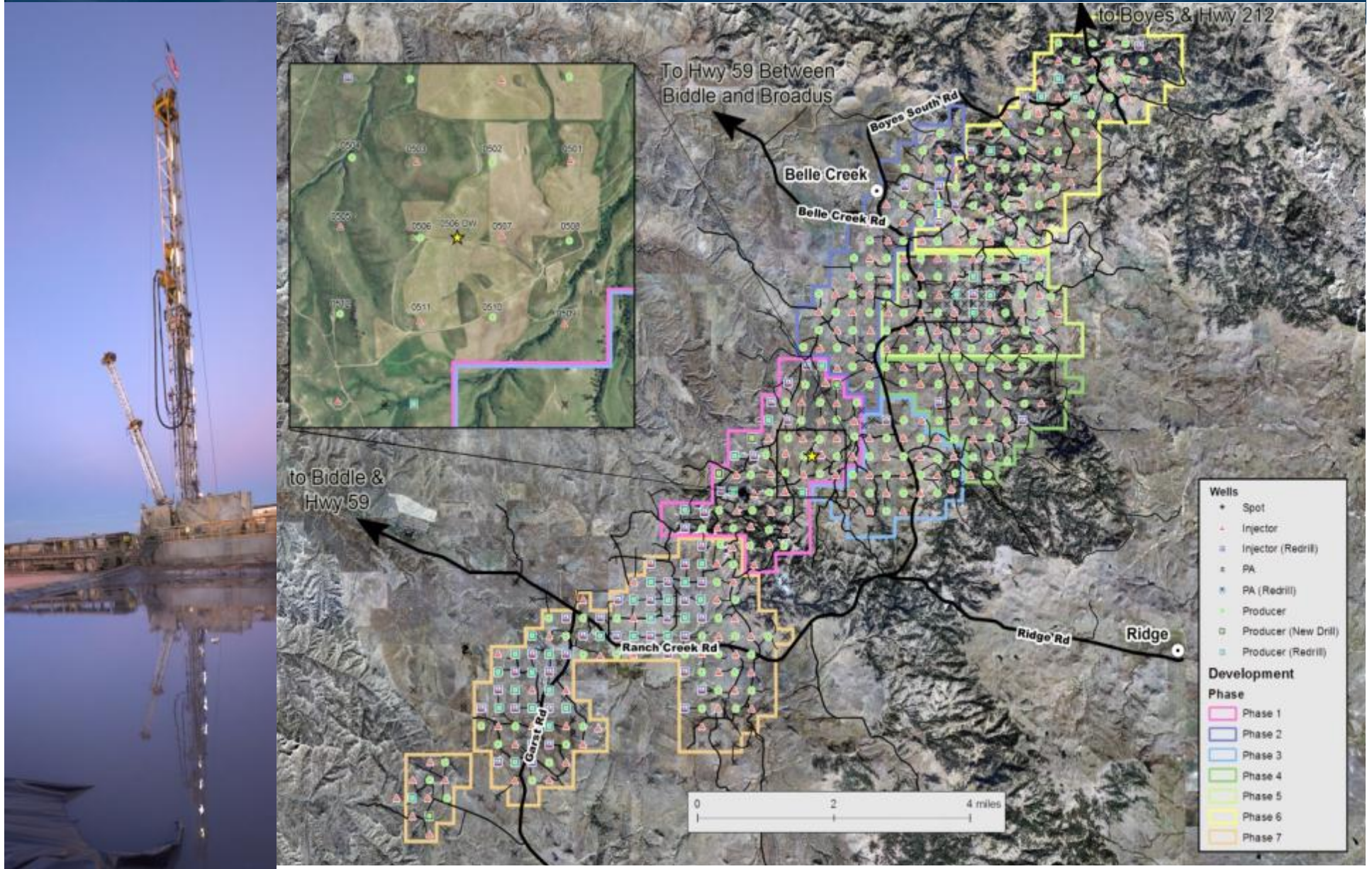


Reservoir MVA Program (continued)

- Ability to collect 4-D seismic data (time-lapse 2-D, 3-D, VSP, and crosswell seismic)
 - Check shot and seismic source testing completed November 2011
 - 3-D survey area planned for the fall of 2012
 - Baseline crosswell and/or VSP centered on monitoring well planned for the fall of 2012
- Provide time-lapse seismic plume tracking
 - Areal and lateral extent of subsurface CO₂ migration
 - Potential to extrapolate knowledge for fieldwide predictions

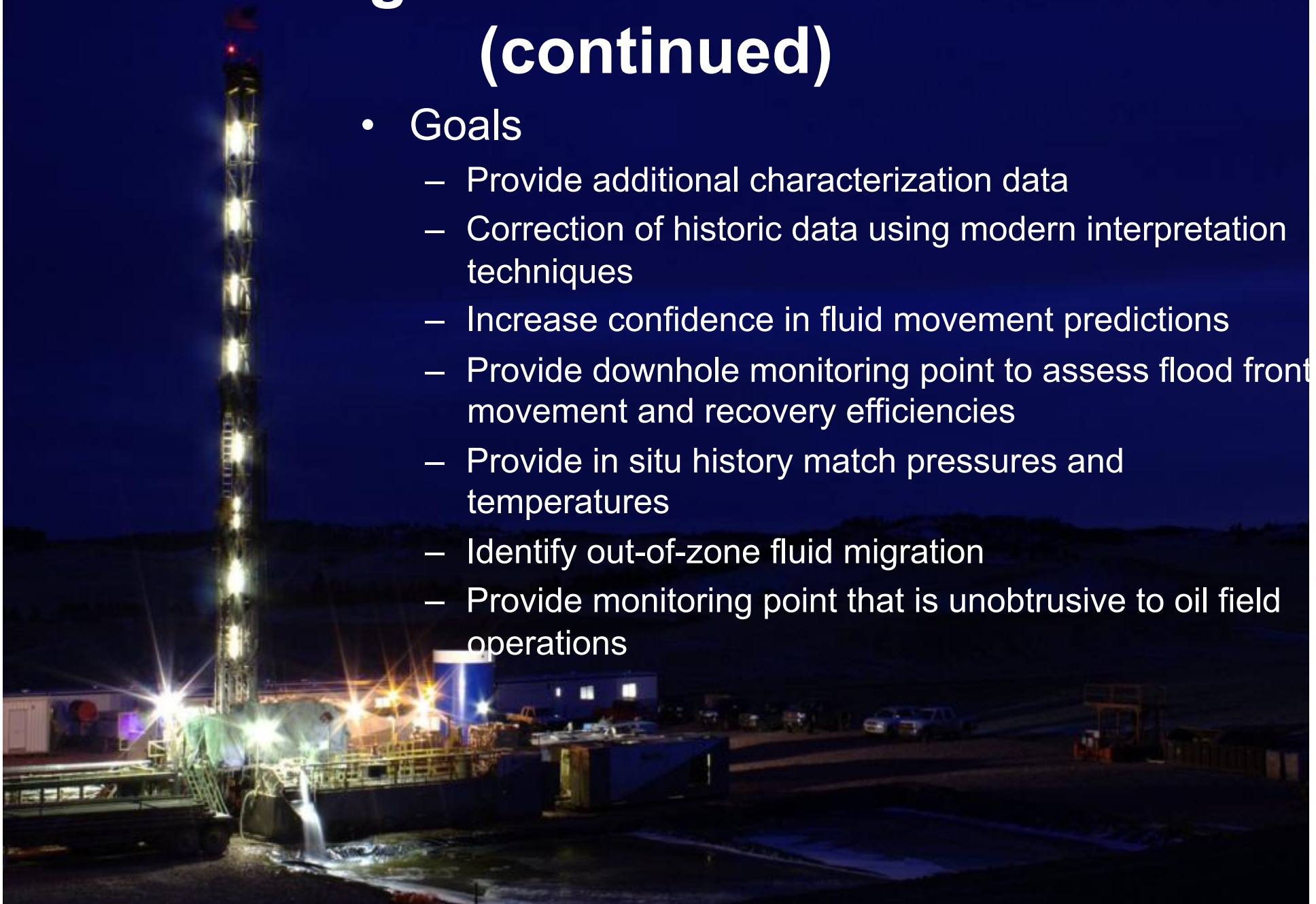


Monitoring and Characterization Well



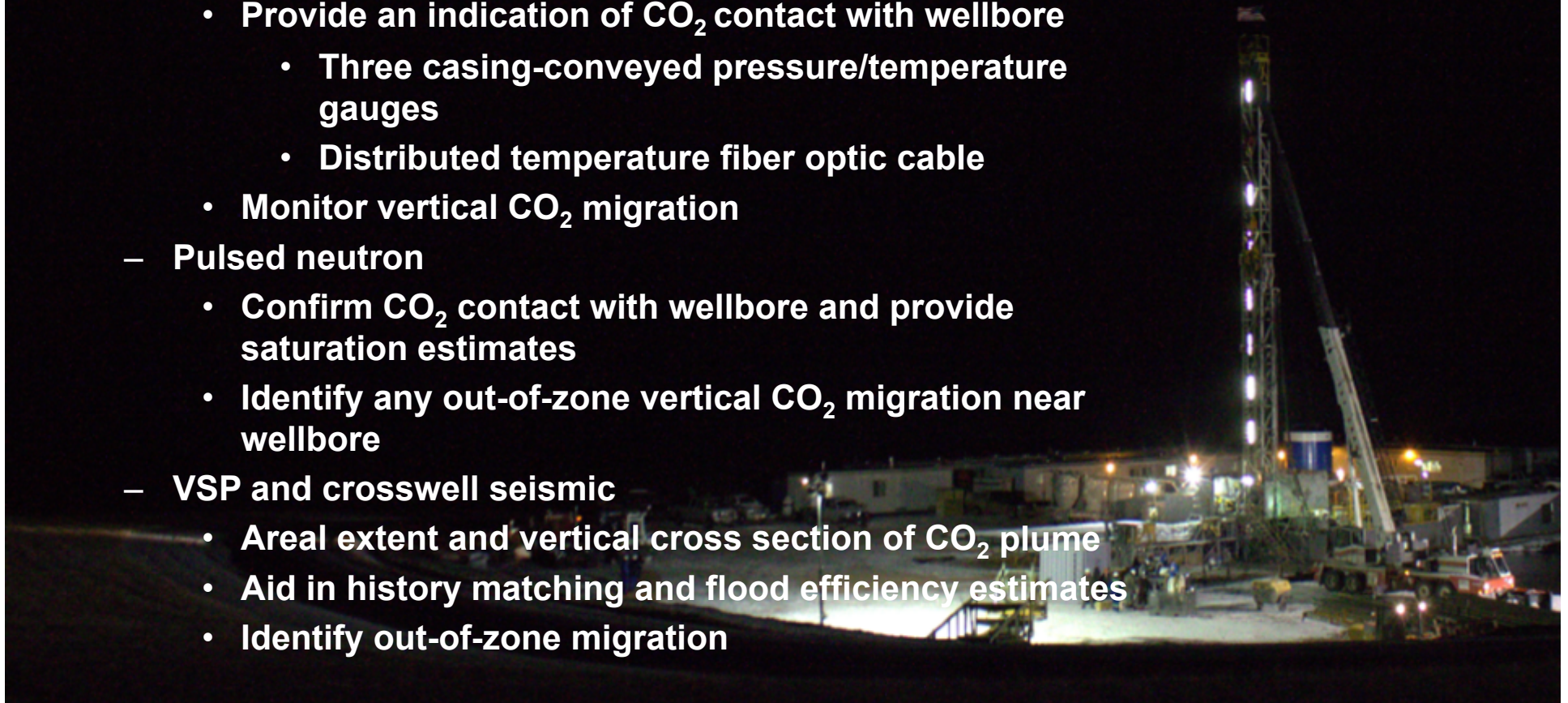
Monitoring and Characterization Well (continued)

- Goals
 - Provide additional characterization data
 - Correction of historic data using modern interpretation techniques
 - Increase confidence in fluid movement predictions
 - Provide downhole monitoring point to assess flood front movement and recovery efficiencies
 - Provide in situ history match pressures and temperatures
 - Identify out-of-zone fluid migration
 - Provide monitoring point that is unobtrusive to oil field operations



Monitoring and Characterization Well (continued)

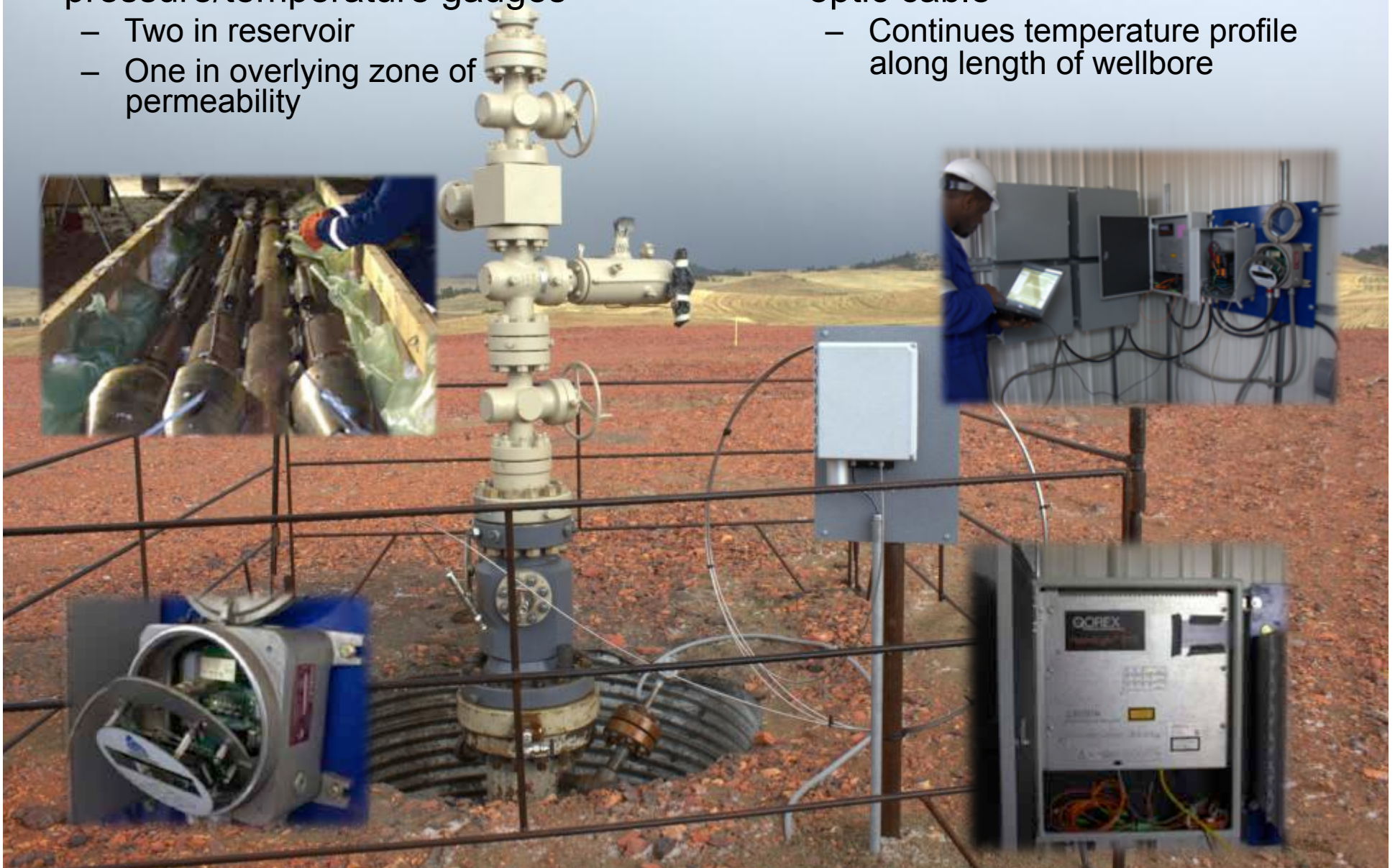
- **Staged monitoring program**
 - **Permanent real-time downhole pressure and distributed temperature**
 - Provide in situ history match data of reservoir conditions
 - Provide an indication of CO₂ contact with wellbore
 - Three casing-conveyed pressure/temperature gauges
 - Distributed temperature fiber optic cable
 - Monitor vertical CO₂ migration
 - **Pulsed neutron**
 - Confirm CO₂ contact with wellbore and provide saturation estimates
 - Identify any out-of-zone vertical CO₂ migration near wellbore
 - **VSP and crosswell seismic**
 - Areal extent and vertical cross section of CO₂ plume
 - Aid in history matching and flood efficiency estimates
 - Identify out-of-zone migration



Monitoring and Characterization Well Real-Time Data

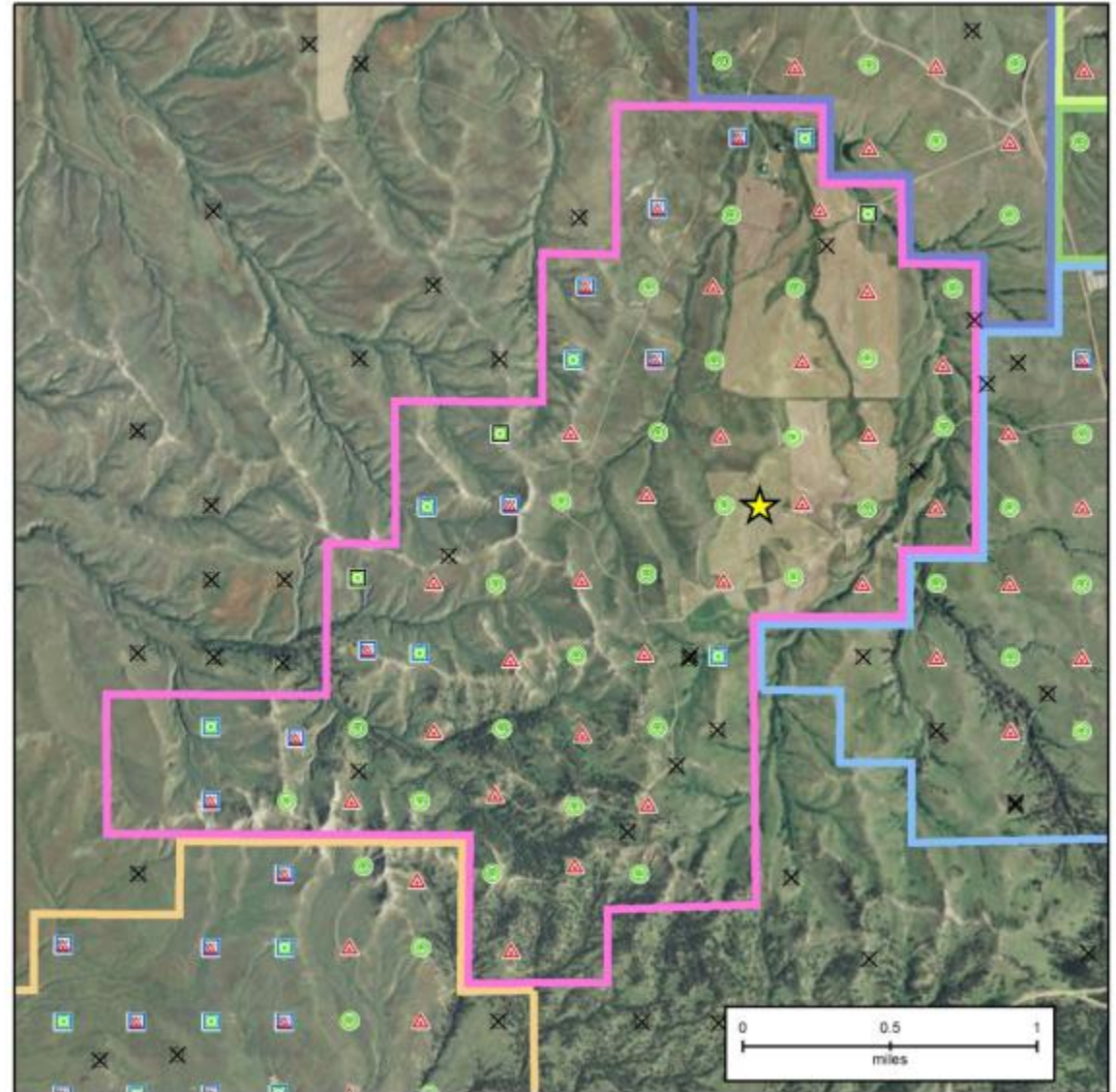
- Three casing-conveyed pressure/temperature gauges
 - Two in reservoir
 - One in overlying zone of permeability

- Distributed temperature fiber optic cable
 - Continues temperature profile along length of wellbore



Key MVA Challenges/Opportunities

- MVA program is overlaid on a commercial EOR project.
 - Limited access to active wells
 - Benefit of additional reservoir characterization and monitoring data part of the EOR project
 - Reservoir in constant flux
 - Water injection prior to CO₂ flood
 - Simultaneous production and injection



Summary

- The PCOR Partnership is working closely with Denbury to characterize the Bell Creek Field and set up for monitoring the CO₂ once injection begins.
- Injection of approximately 50 MMscf/day of CO₂ is scheduled to begin first quarter of 2013.
- An estimated 35 million incremental bbl of oil will be recovered using CO₂ EOR at Bell Creek.



Lessons Learned

- Keys to success
 - Integrated approach to MVA, risk assessment, characterization, modeling, and simulation
 - Public engagement and landowner relations
 - Adequate planning and contingency plans during drilling and monitoring operations
 - Communication
 - Providing clear objectives to service providers and stakeholders





Contact Information

Energy & Environmental Research Center

University of North Dakota

15 North 23rd Street, Stop 9018

Grand Forks, North Dakota 58202-9018

World Wide Web: **www.undeerc.org**

Telephone No. (701) 777-5355 (Charles Gorecki)

Telephone No. (701) 777-5472 (John Hamling)

Fax No. (701) 777-5181

Charles Gorecki, Senior Research Manager

PCOR Partnership Program Manager

cgorecki@undeerc.org

Thank You!

