WESTCARB Phase III Project Overview

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Outline

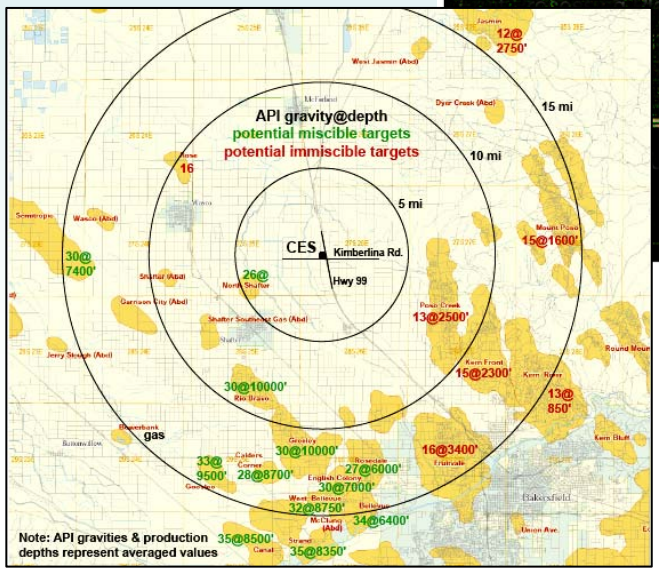
- Phase III objectives
- Project overview
- Geologic setting
- Preliminary reservoir modeling results
- Managing risk
- Initial risk assessment results
- Monitoring approach
- Regulatory and public outreach issues

Phase III WESTCARB Objectives

- Conduct a commercial-scale CCS test (1 million tons CO_2); nominal 10-year project
  - Access the best geologic target in California
- Co-locate project with advanced, commercial "sequestration friendly" oxy-combustion technology – Clean Energy Systems
  - Planned as first commercial-scale facility of its type in U.S.
- Demonstrate commercial-scale injection site characterization, operations, maintenance, and monitoring (Schlumberger)
- Conduct research to improve technologies for reservoir modeling/simulation and engineering, risk assessment, and measurement/monitoring (LBNL, LLNL, Stanford)
- ***Establish in the public mind—via direct proof—that emission-free fossil power is possible and geologic sequestration is safe***

Project Is Representative of Major California Sequestration/EOR Potential; Provides Underpinnings for Commercialization

Many nearby oilfields are EOR-suitable



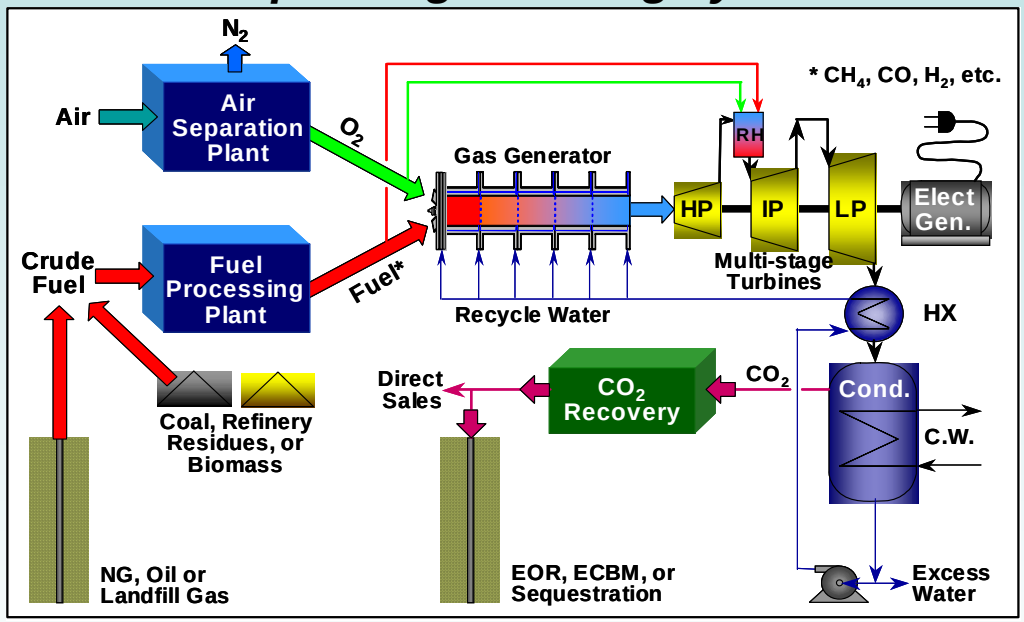
(J. Johnson, LLNL)

Source: California Geological Survey

Kimberlina Project Overview

- Lead industrial partners: Clean Energy Systems (CES), Schlumberger
- CES is planning ~50 MW power plant at Kimberlina, California (on CES property)
- Plant will provide ~250,000 tons of CO_2 per year for four years

CES power generating system



- Initial CO_2 injectivity; full exhaust stream injection to begin in 2011, one injection and one monitoring well
- Initial geologic modeling, reservoir simulation, and risk assessment completed
- Mineral rights and initial permitting issues seem workable; long-term liability for CO_2 unresolved

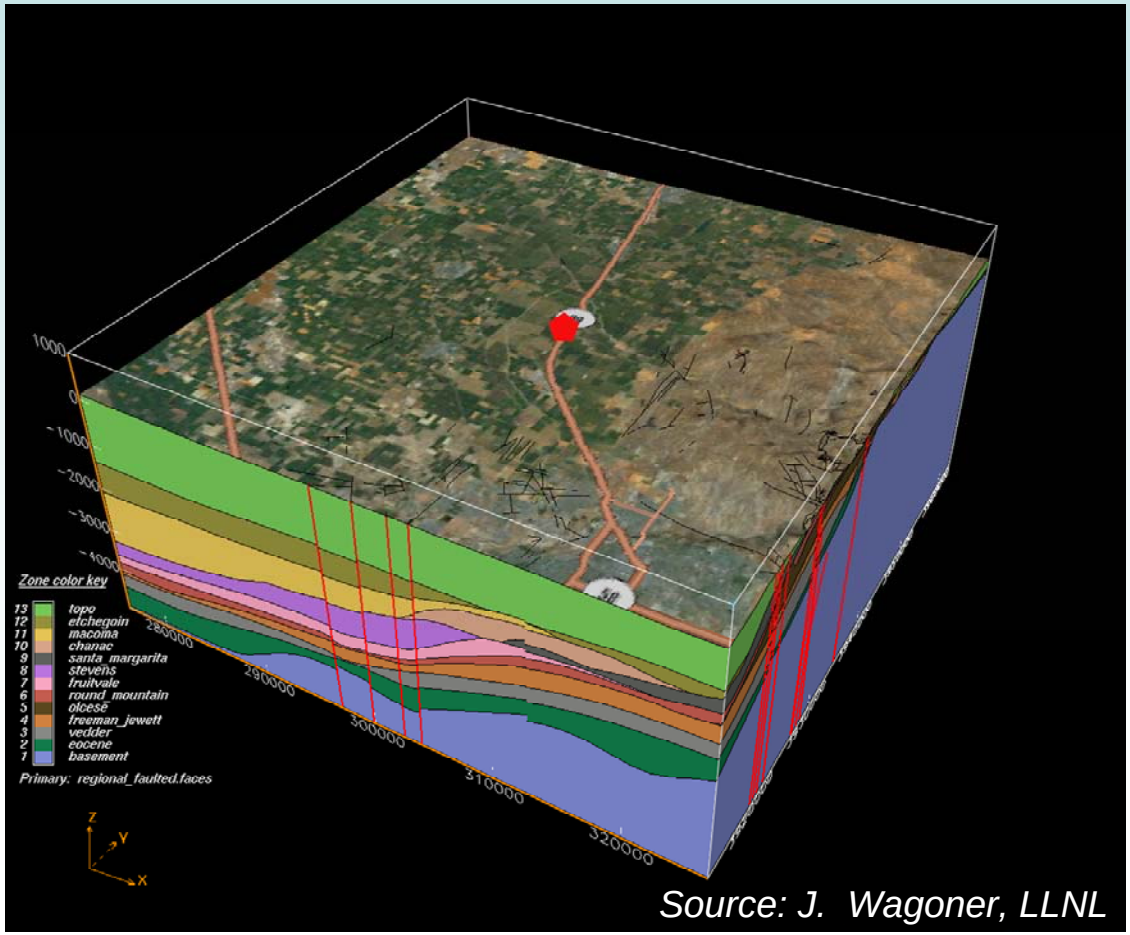
Who Is Clean Energy Systems?

- Technology developer for “rocket engine” oxy-combustion power systems; supported by DOE and CEC
- Owner of its demo plants

- Partners/investors from power and oil industries
- Currently scaling up and testing core component—gas generator
- Plants proposed for U.S. and Europe (Netherlands, Norway)

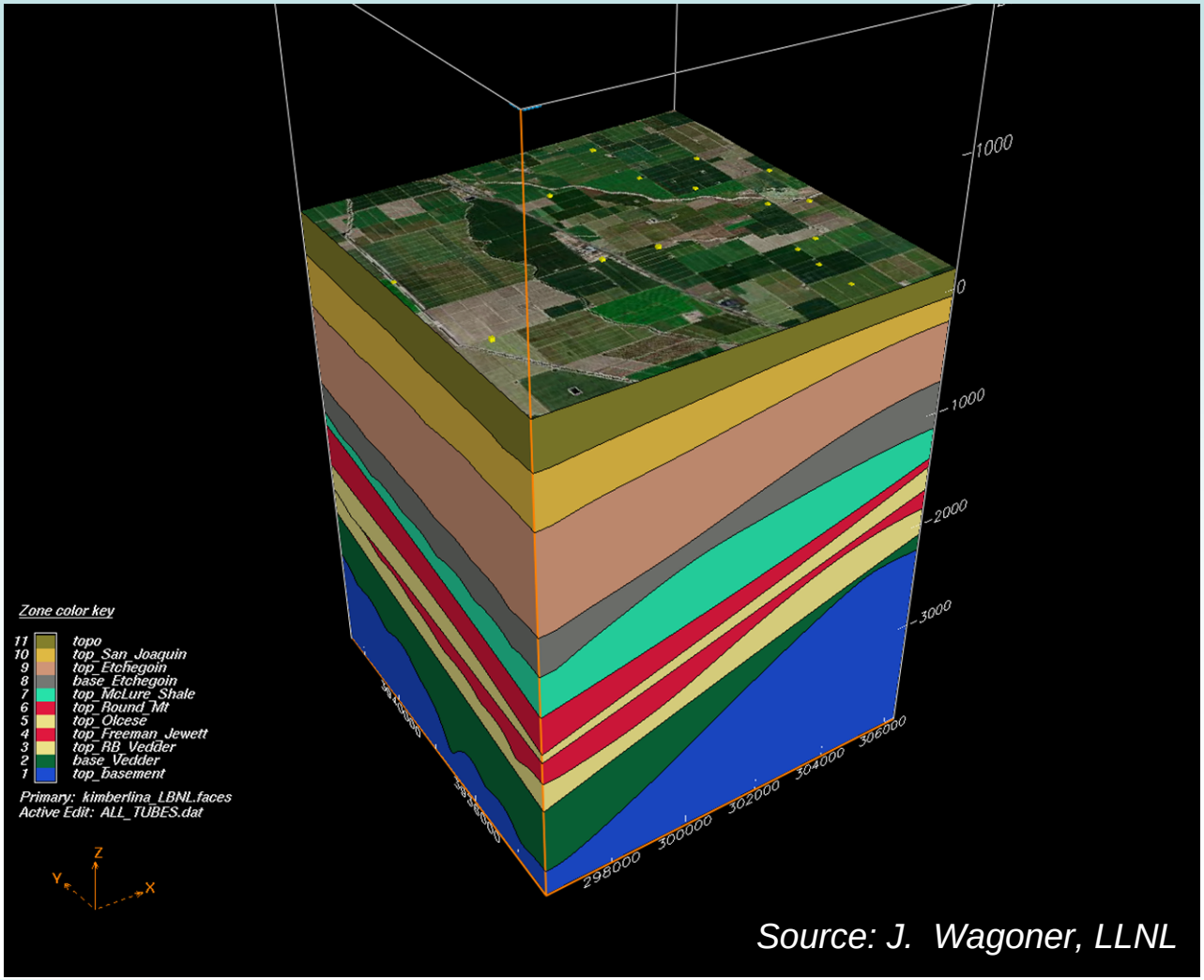
Regional Geologic Model Is Centered on CES Kimberlina Power Plant

25 km Northwest of Bakersfield, CA



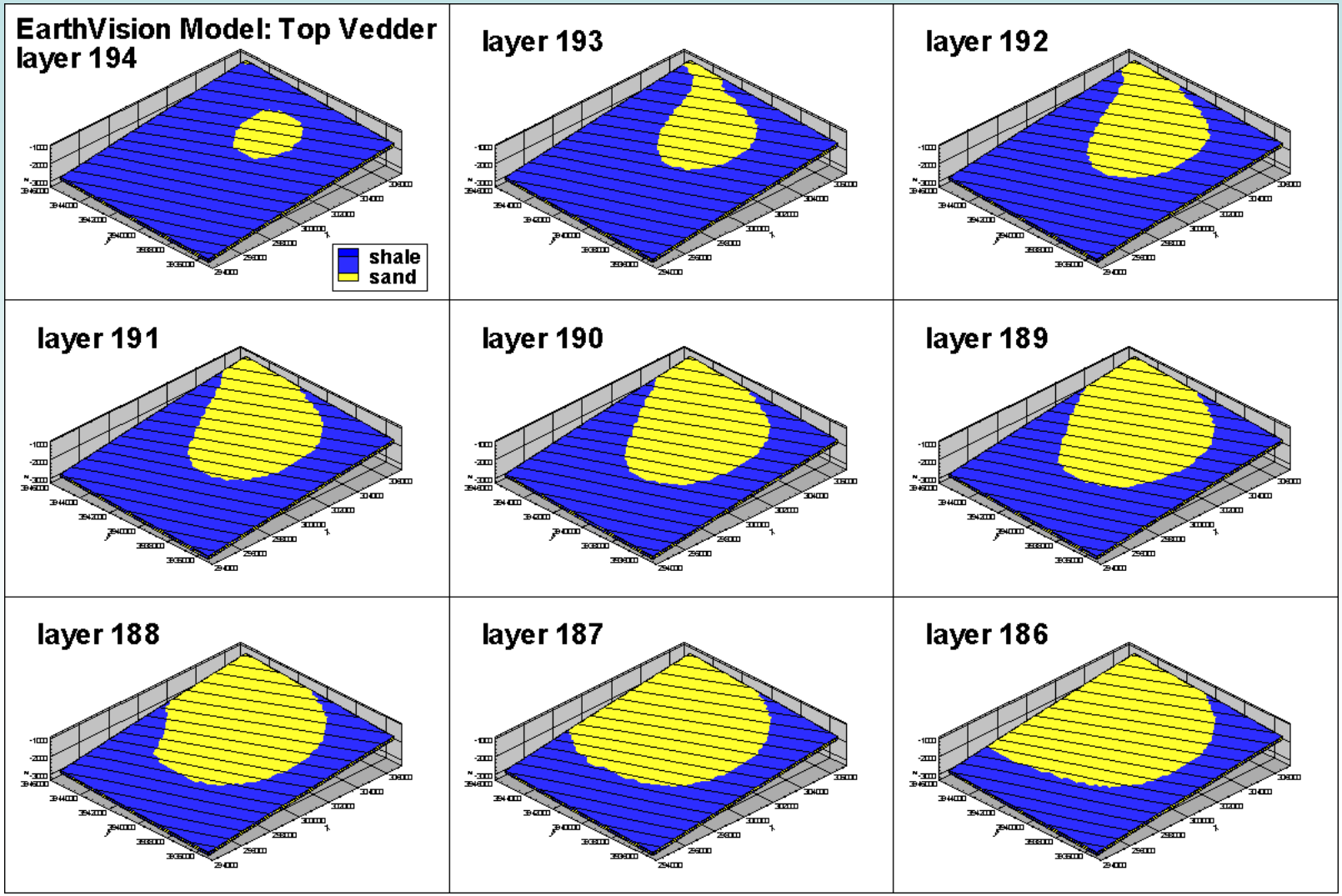
Source: J. Wagoner, LLNL

Initial Geologic Model for Kimberlina Site Based on Available Well Data



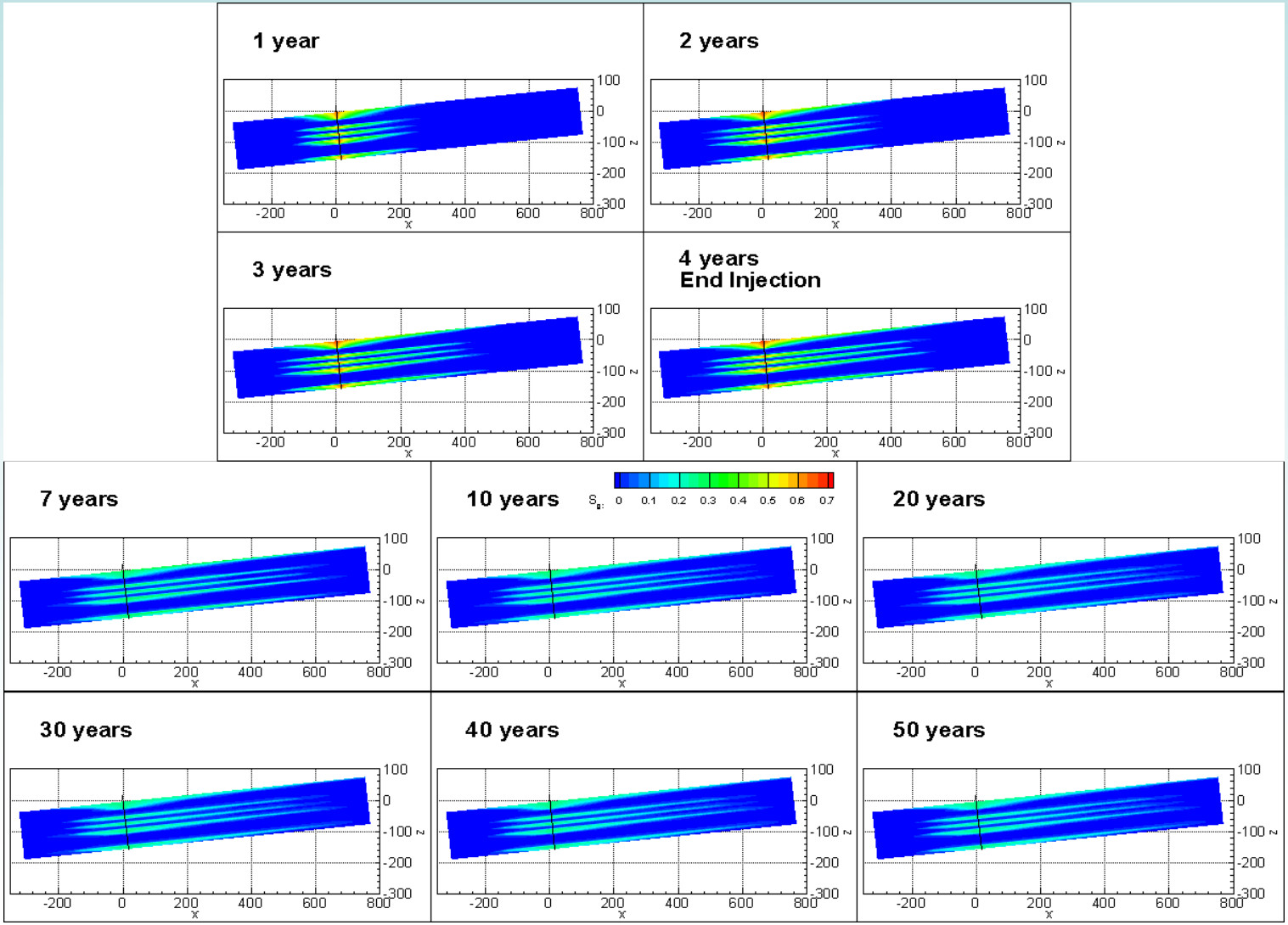
Source: J. Wagoner, LLNL

Reservoir Model Based on 600-Layer Sand-Shale Model for Olcese and Vedder



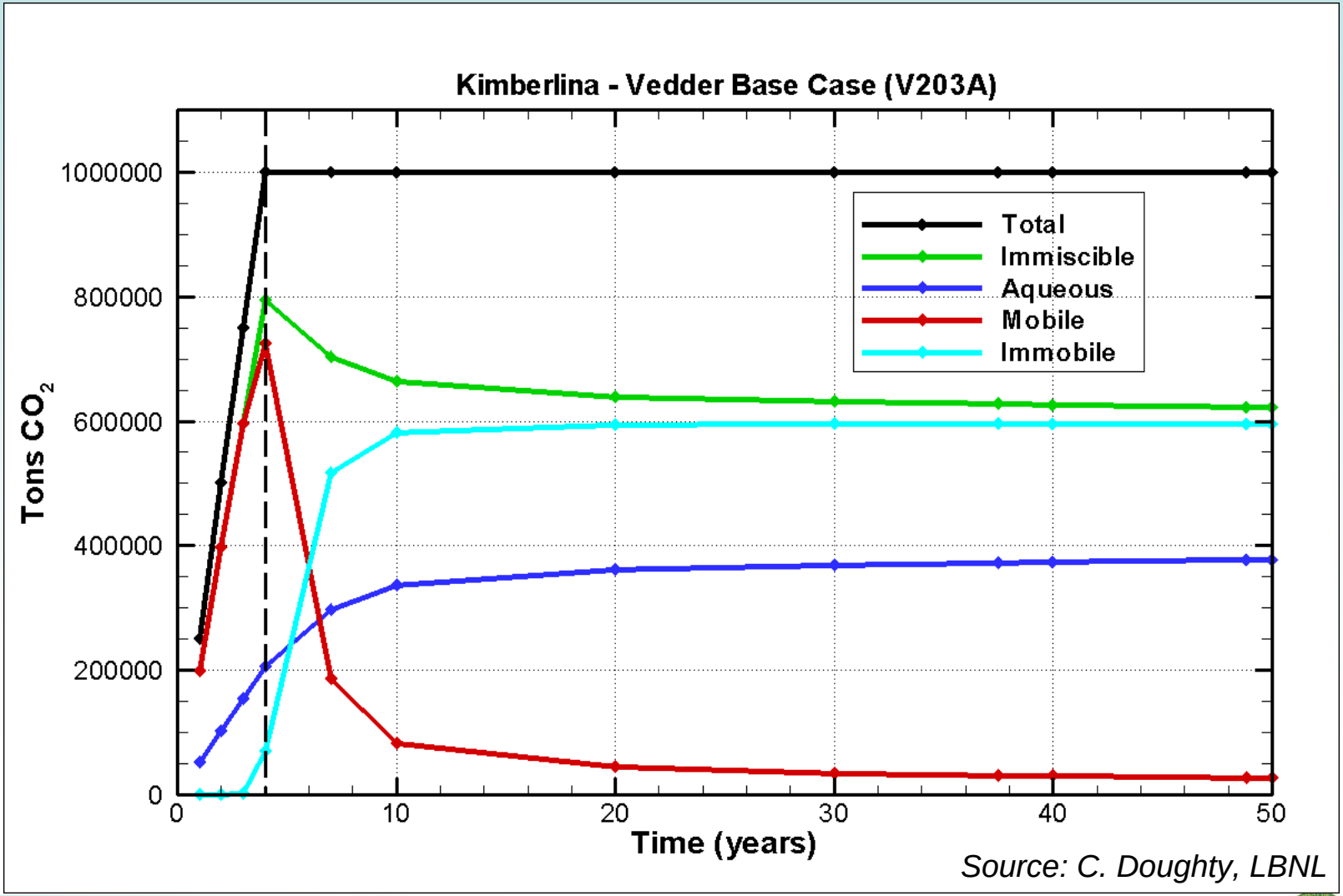
Source: J. Waggoner, LLNL

Simulations Show Plume Extent and Immobilization Over Time



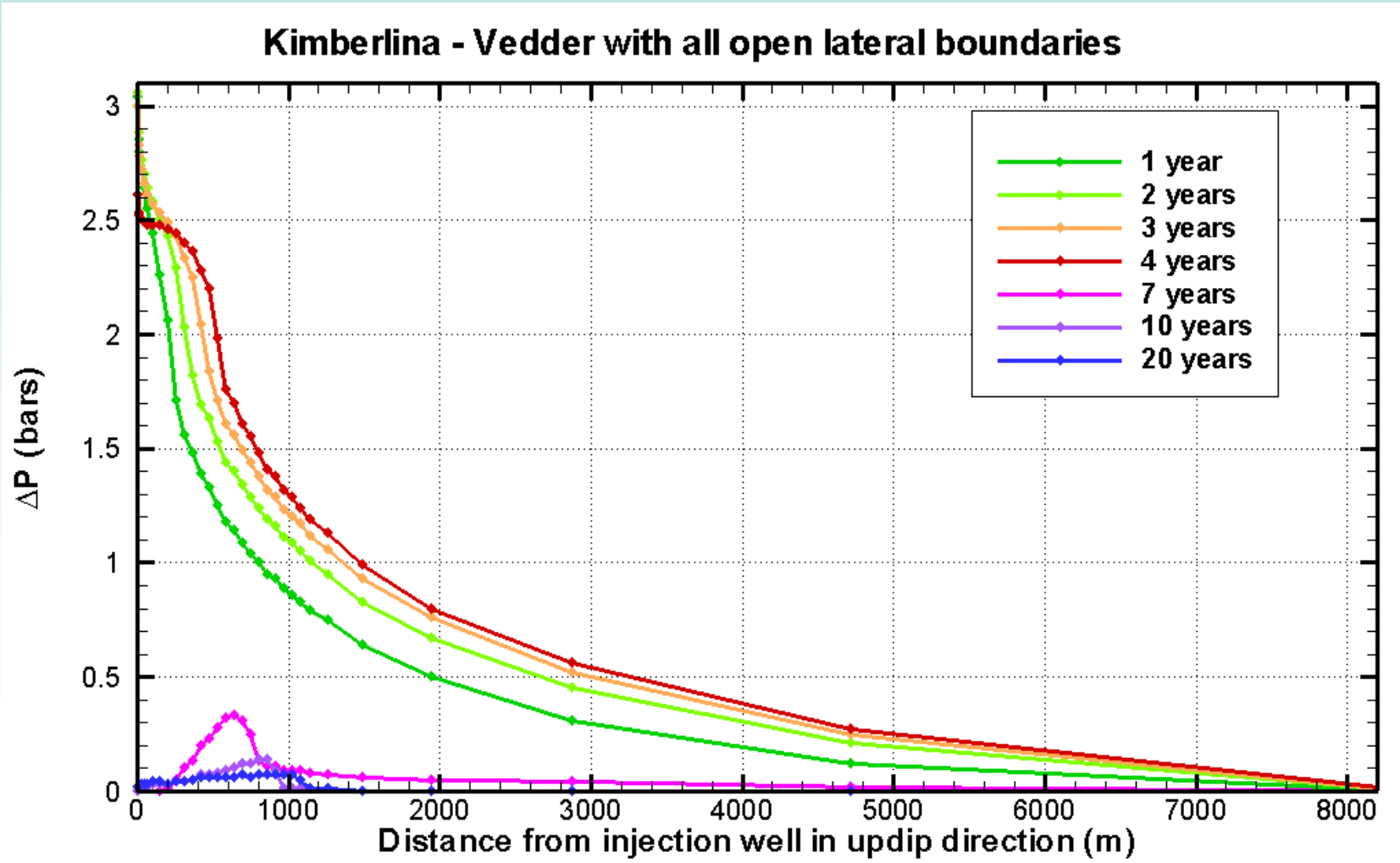
Source: C. Doughty, LBNL

Initial Simulation Shows Plume Approaches Immobility 5 Years After Conclusion of Injection



Source: C. Doughty, LBNL

Pressures Increases Over Large Area But Dissipates Quickly



Managing Risk

- Risk assessment program
  - CF assessment of leakage risk
  - Overall project risk assessment
- Project management plan
  - Contracts/legal agreements
- Comprehensive site safety plan
- Careful site characterization
  - Old wells
  - Subsurface geology
- Careful well construction and injection
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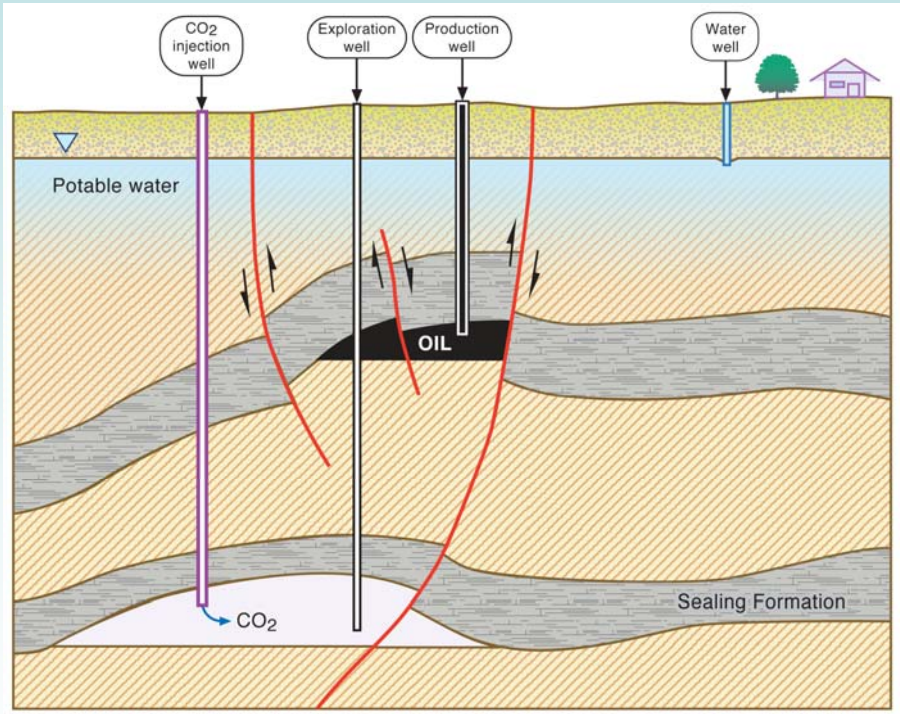
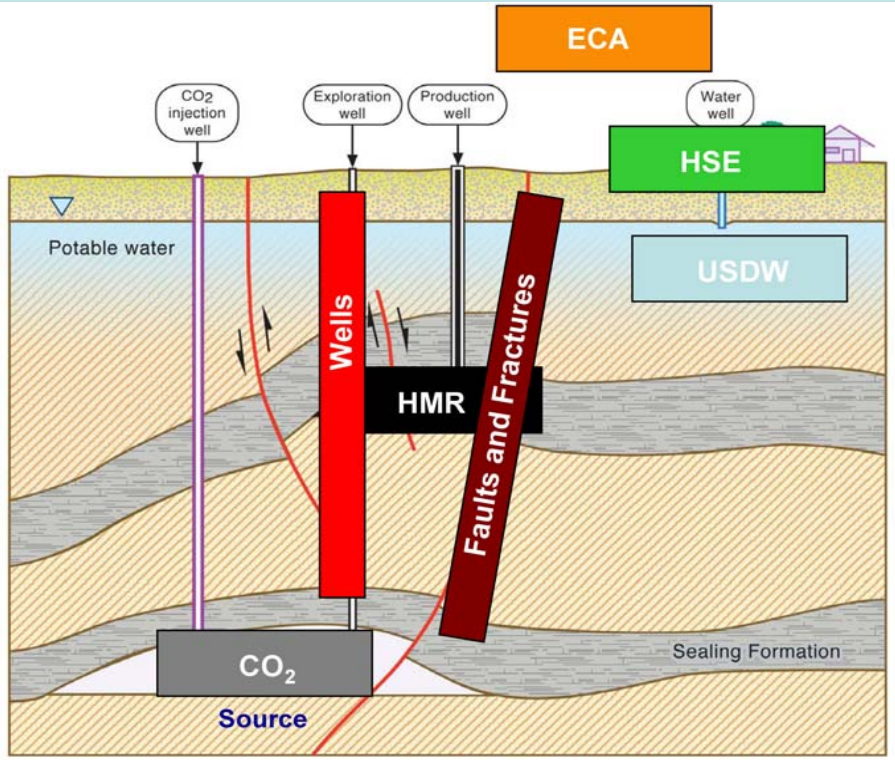
- Prediction of plume behavior
- Comprehensive monitoring program
  - Operational EH&S
  - Assurance monitoring
  - Storage security monitoring
- Mitigation plan
- Public outreach program
- Plan for site stewardship after Phase III

Risk Assessment Methods Developed in Carbon Capture Project 2 Being Applied



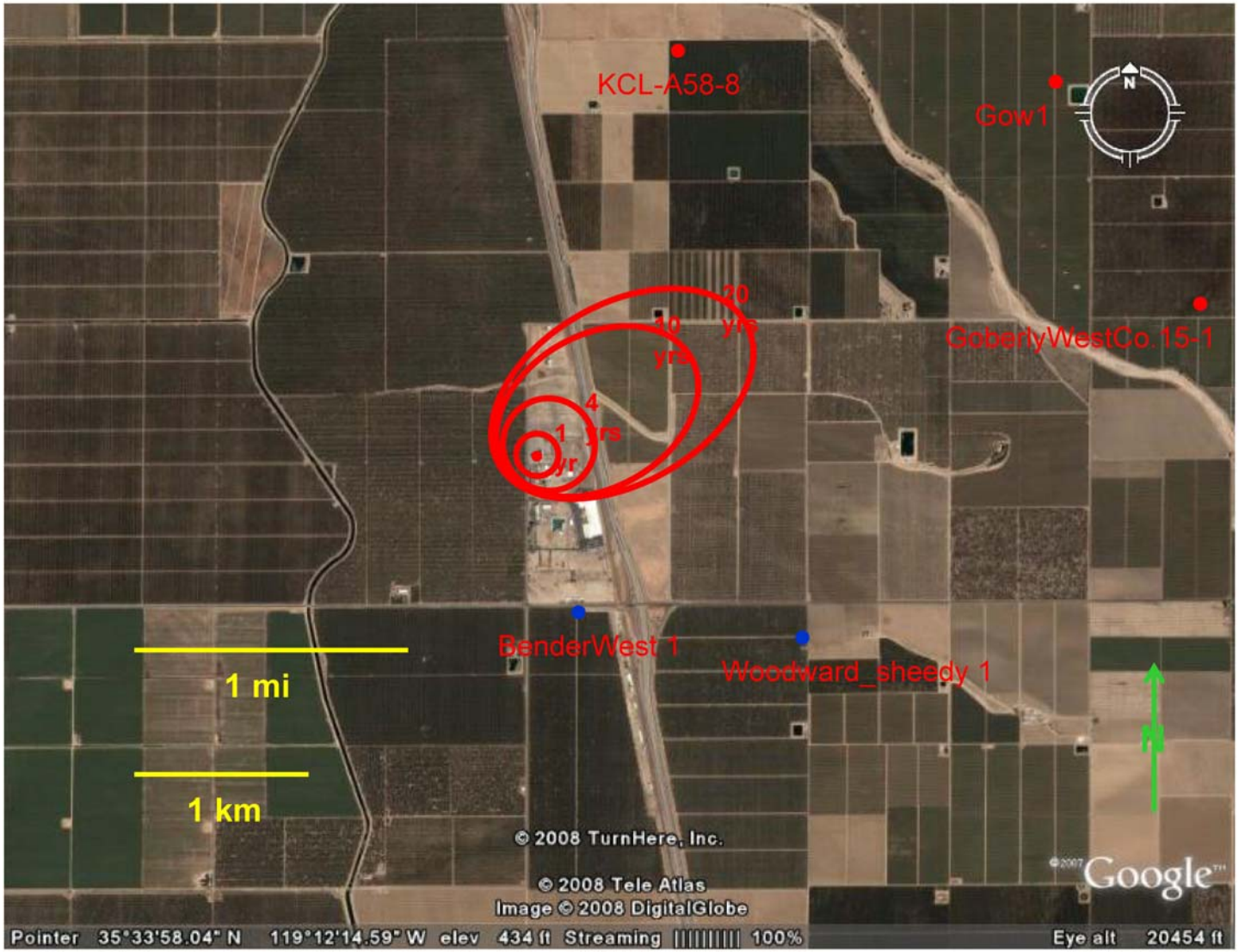
Four compartments vulnerable to impacts:
ECA = Emission credits and atmosphere
HSE = Health, safety, and environment
USDW = Underground sources of drinking water
HMR = Hydrocarbon and mineral resources



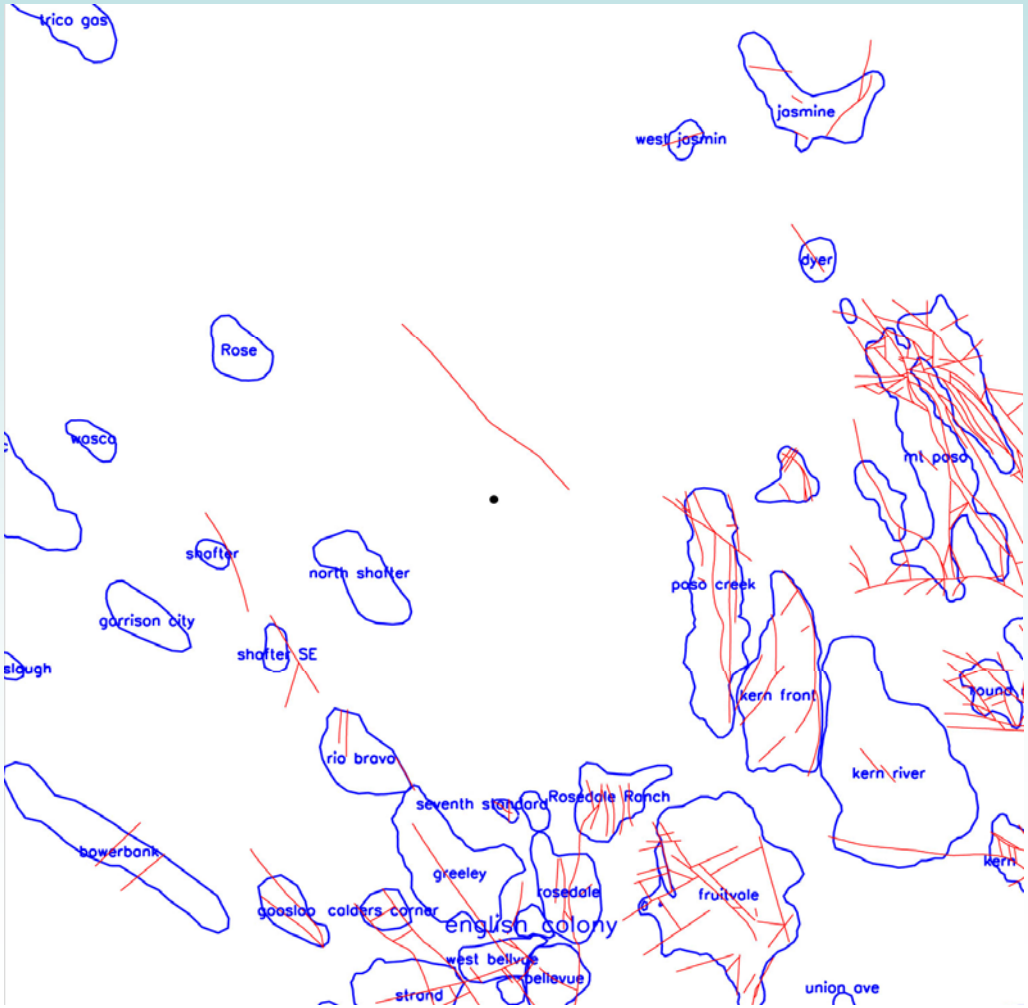
Two conduits with potential for leakage: Wells, Faults and Fractures
CO_2 Leakage Risk is probability that negative impacts will occur to HMR, USDW, HSE, or ECA due to CO_2 migration

Source: C. Oldenburg, LBNL

Plume Won't Intersect Known Wells



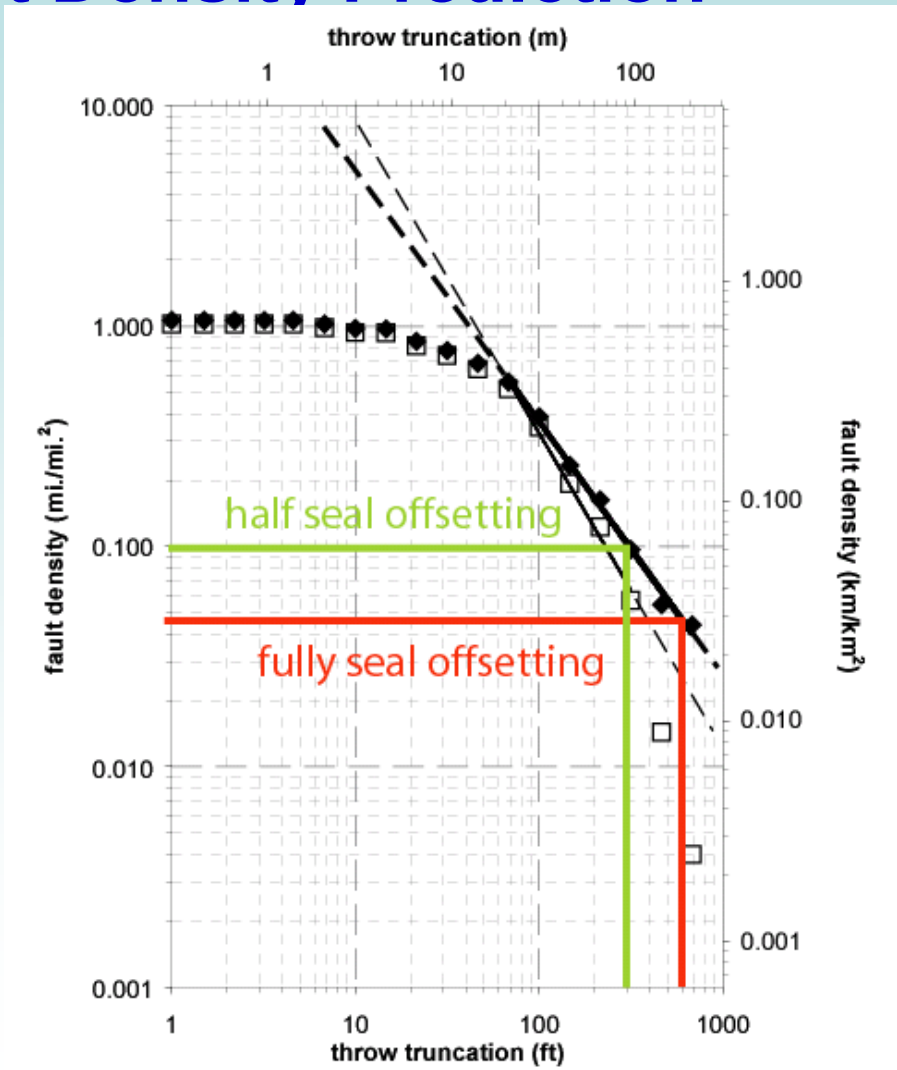
Faults Are Common in Oil/Gas Fields in Region



Most faults do not project to the land surface. Most known faults are located in oil and gas fields, where data are available. There are >140 faults in regional model; general trend is southeast to northwest. None intersect project site.

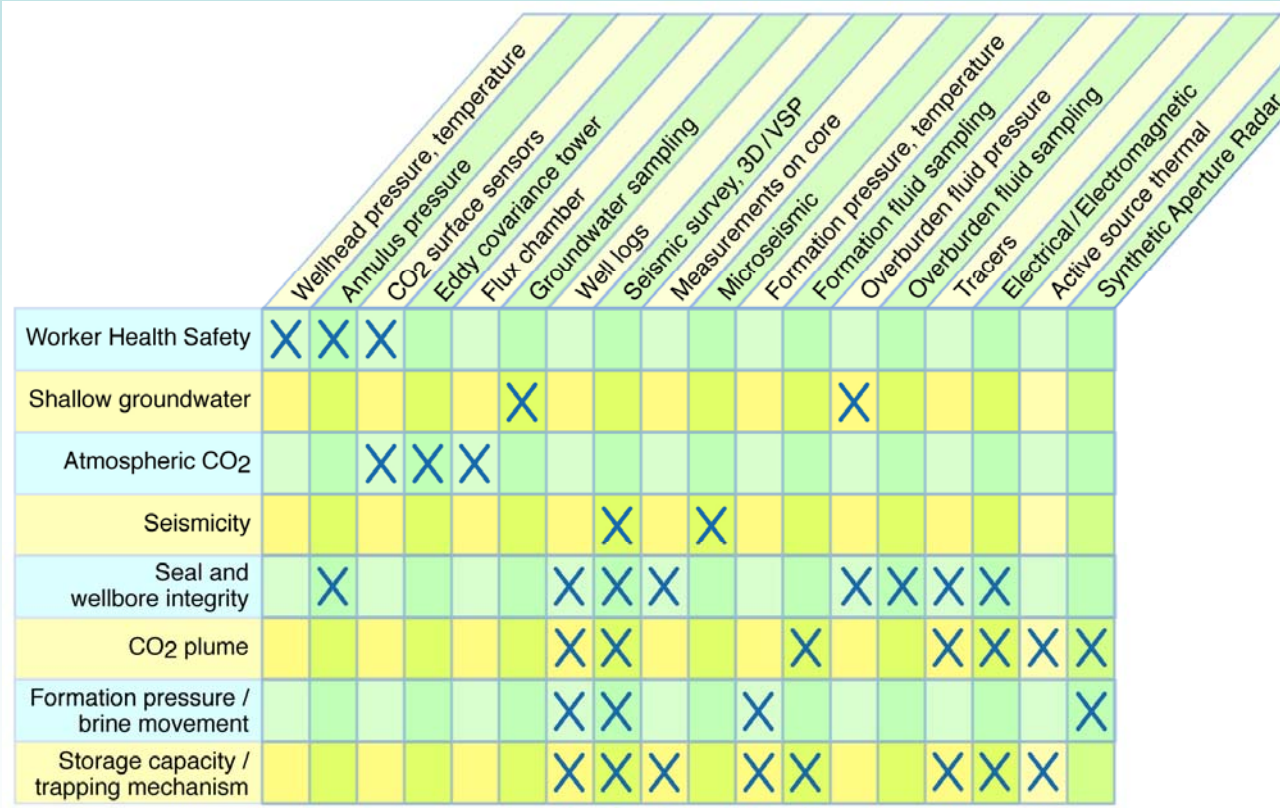
Initial Kimberlina Fault Density Prediction

- Length and orientation measured of 956 fault segments in surrounding fields
- Faults likely are sealing
- 3.3% chance of plume intersecting full seal offsetting fault
- Site characterization, monitoring to address faulting



Multiple Methods Provide Data Monitoring Needs

- Worker EH&S
- Assurance monitoring – shallow groundwater; atmospheric levels; seismicity
- Storage security – seal and wellbore integrity; plume movement; brine movement; capacity/trapping

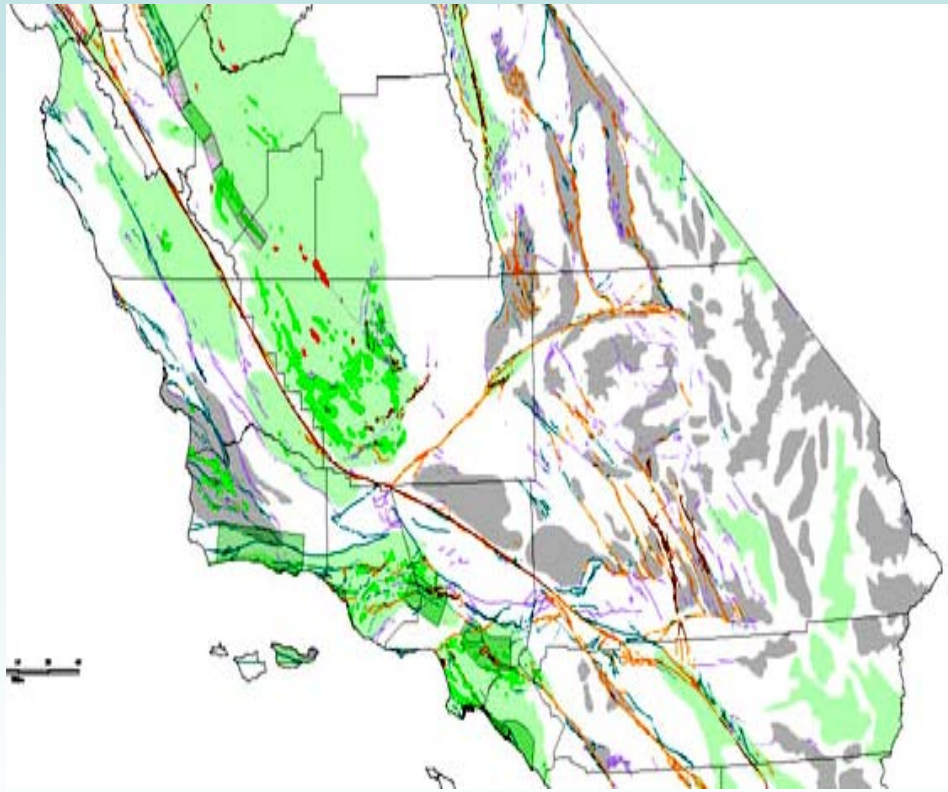


Monitoring of Groundwater Wells for Public Assurance

Large number of groundwater wells in region of Kimberlina site (green dot). Number of wells per square mile shown in red.

Potential for Seismicity Will Be Assessed

- Active fault mapping
- 3D seismic for structure
- Geomechanical analyses
  - In situ stress state assessment
  - Modeling of effect of pore pressure increase
- Passive seismic monitoring
  - Analysis of micro-seismicity

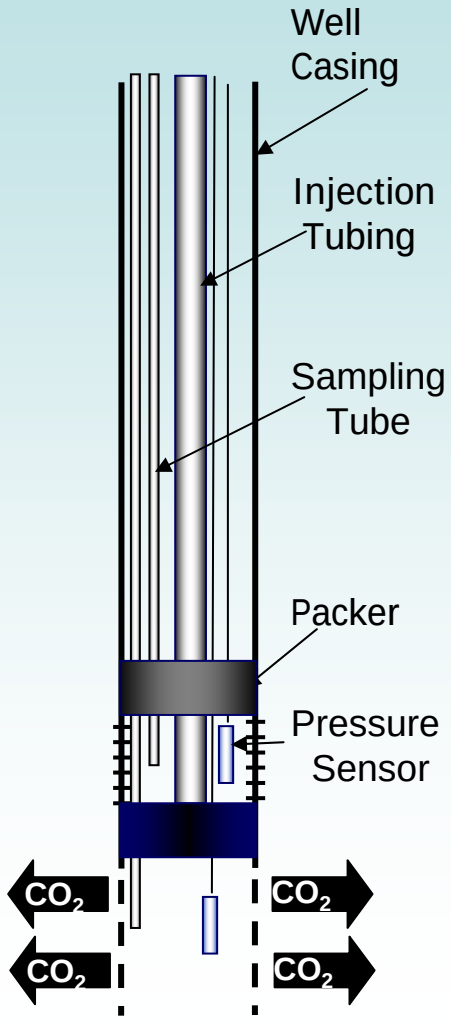


Map of quaternary faulting in Southern California

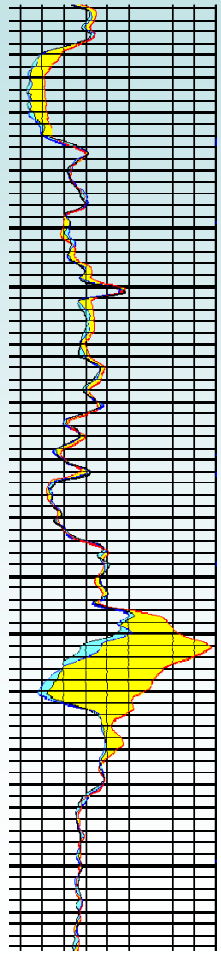
Source: California Geologic Society

Assessing Seal and Wellbore Integrity

- 3D seismic interpretation for seal continuity and vertical migration
- Seal properties confirmed in core
- Compare pressure and fluid chemistry above seal and in reservoir
- Geo-mechanical analysis to determine safe injection pressure
- Monitor pressure and water quality above seal
- Wire-line logs



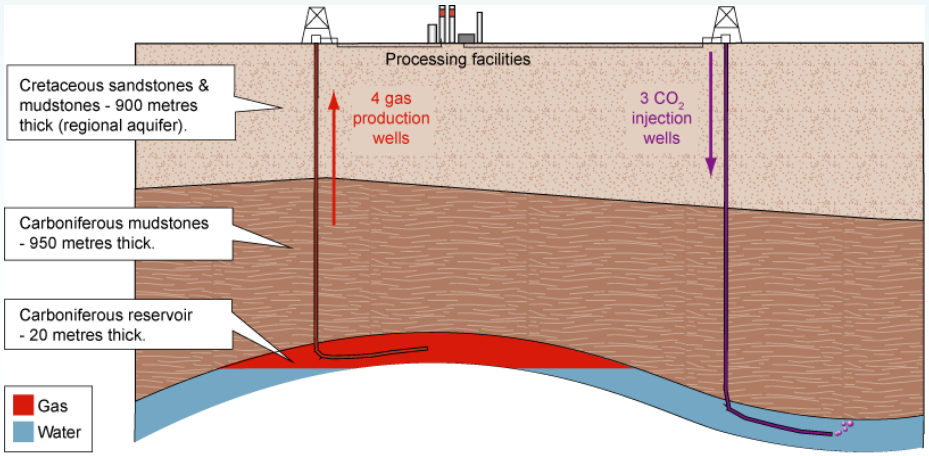
Pressure Monitoring

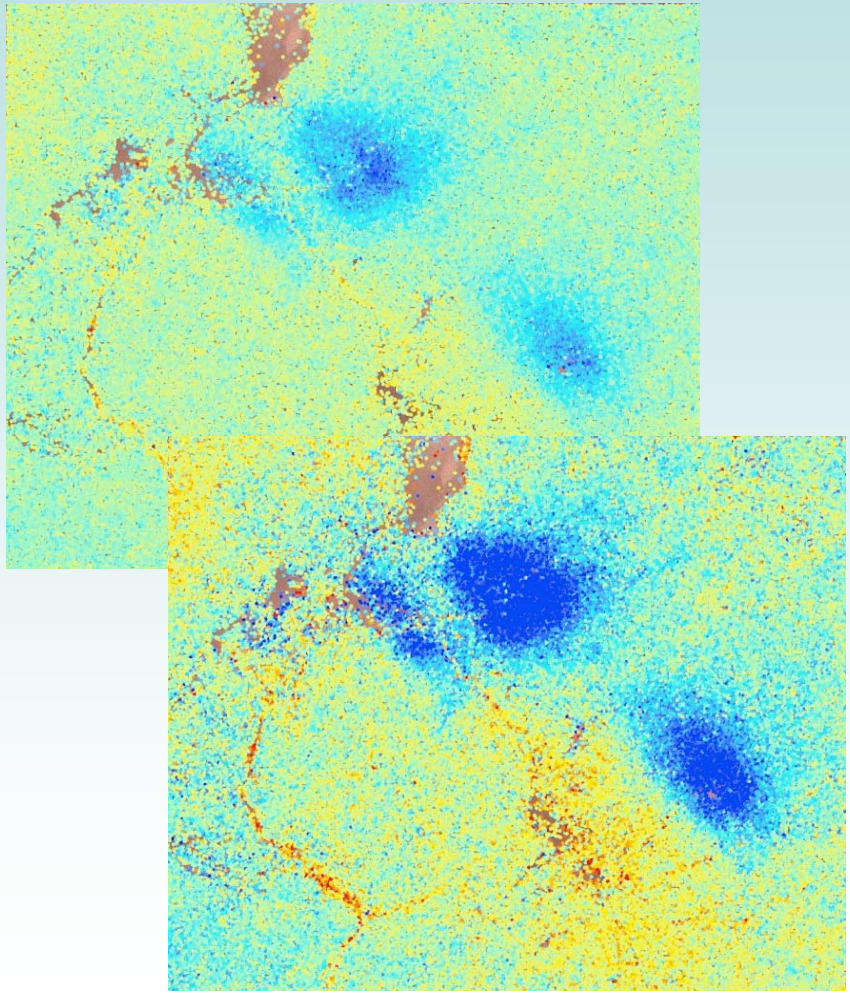


"RST" Log

Research-Stage MMV Methods Will Be Explored

- PSInSAR could provide inexpensive picture of pressure distribution
- Novel deployment and analysis of surface seismic for plume boundary monitoring
- Possible application of EM
- Thermal perturbation sensing





Time lapse PSInSAR data showing surface displacement due to CO_2 injection at In Salah

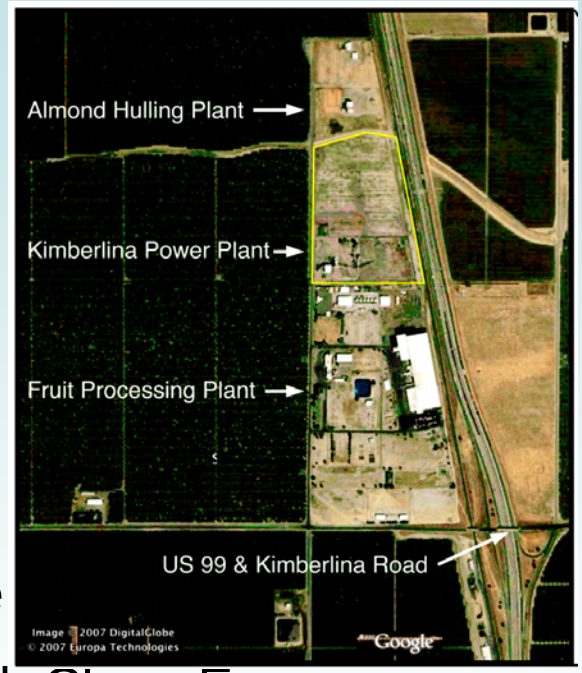
Source: D. Vasco, LBNL

Basic Requirements for Siting and Permitting Must First be Met

- CEQA and other permit work to build and operate ~ 50 MW power plant is underway
- California is an underground injection control (UIC) “mixed primacy” state, meaning federal and state regulators have a say
  - Working relationships with regulators established through Phase II pilots
- Drilling and other CEQA permits for injection of carbon dioxide is getting started
  - Development of materials for the UIC permit application is underway
  - University of Hawaii, through an interagency agreement, will develop an RFP and contract for the surface injection facilities CEQA permit
- Sub-surface ownership and other potential impact issues

WESTCARB Phase III Project Provides Significant Public Outreach Opportunity

- Clean Energy Systems' oxy-combustion technology among lowest emitting fossil power systems; full exhaust stream being injected during WESTCARB project
- CES technology has received positive local press
- Site may also host concentrating solar power demo, furthering clean energy image



- Plans for visitor center under discussion with Clean Energy Systems and its partners; excellent leverage opportunity for WESTCARB outreach
- Possible opportunity for educational outreach program in groundwater quality monitoring

Thank you for your attention!