Southwest Regional Partnership on Carbon Sequestration (SWP)

DE-FC26-05NT42591

Phase III Demonstration: Farnsworth Unit

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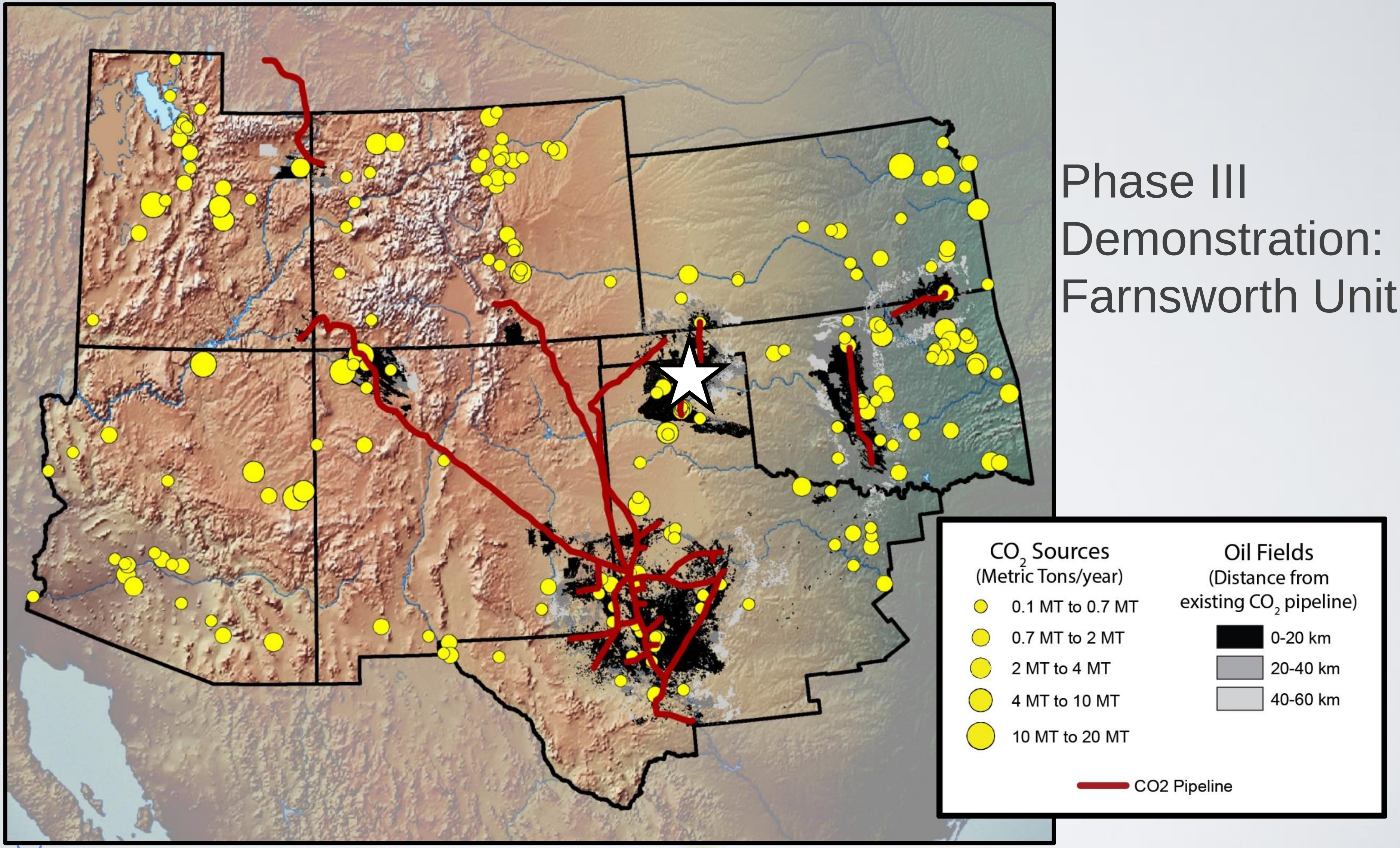
Mastering the Subsurface through Technology Innovation & Collaboration:
Carbon Storage & Oil and Natural Gas Technologies Review Meeting
August 16-18, 2016

Outline

- **Introduction to the SWP**
- **Introduction to Farnsworth Unit**
- Major tasks:
    - Geologic Characterization
    - Simulation
    - Risk
    - MVA
- Conclusions and ongoing work

The Southwest Partnership



Phase III Demonstration: Farnsworth Unit

Project Goals

- SWP’s Phase III: large-scale EOR-CCUS demonstration
- General Goals:
  - One million tons CO_2 storage
  - Optimization of storage engineering
  - Optimization of monitoring design
  - Optimization of risk assessment
- Blueprint for CCUS in southwestern U.S.

Project Site: Farnsworth Unit

- Farnsworth field discovered in 1955.
- About 100 wells completed by the year 1960.
  - Field was unitized in 1963 by operator Unocal
  - Water injection for secondary recovery started in 1964.

Property	**Value**
Initial water saturation	31.4%
Initial reservoir pressure	2218 PSIA
Bubblepoint Pressure	20-150 PSIA
Original Oil in Place (OOIP)	120 MMSTB (60 MMSTB west-side)
Drive Mechanism	Solution Gas
Primary Recovery	11.2 MMSTB (9.3%)
Secondary Recovery	25.6 MMSTB (21.3%)

Project Site: Farnsworth Unit

Anthropogenic CO_2 Supply:

500-600,000 Metric tons CO_2/year for four fields

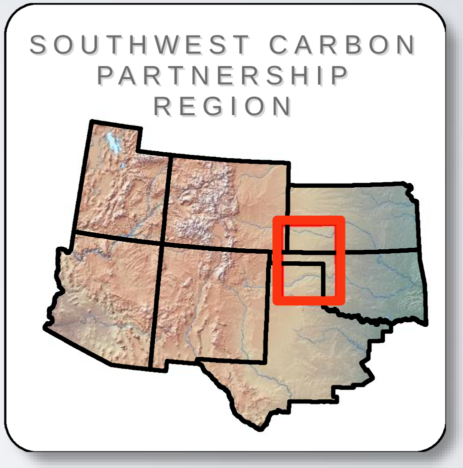
Legend

- 🟩 Utiilization & Storage
- ⬟ Carbon Capture
- ▬ Transportation
- ▬ Oil Fields

Other CO_2 Sources

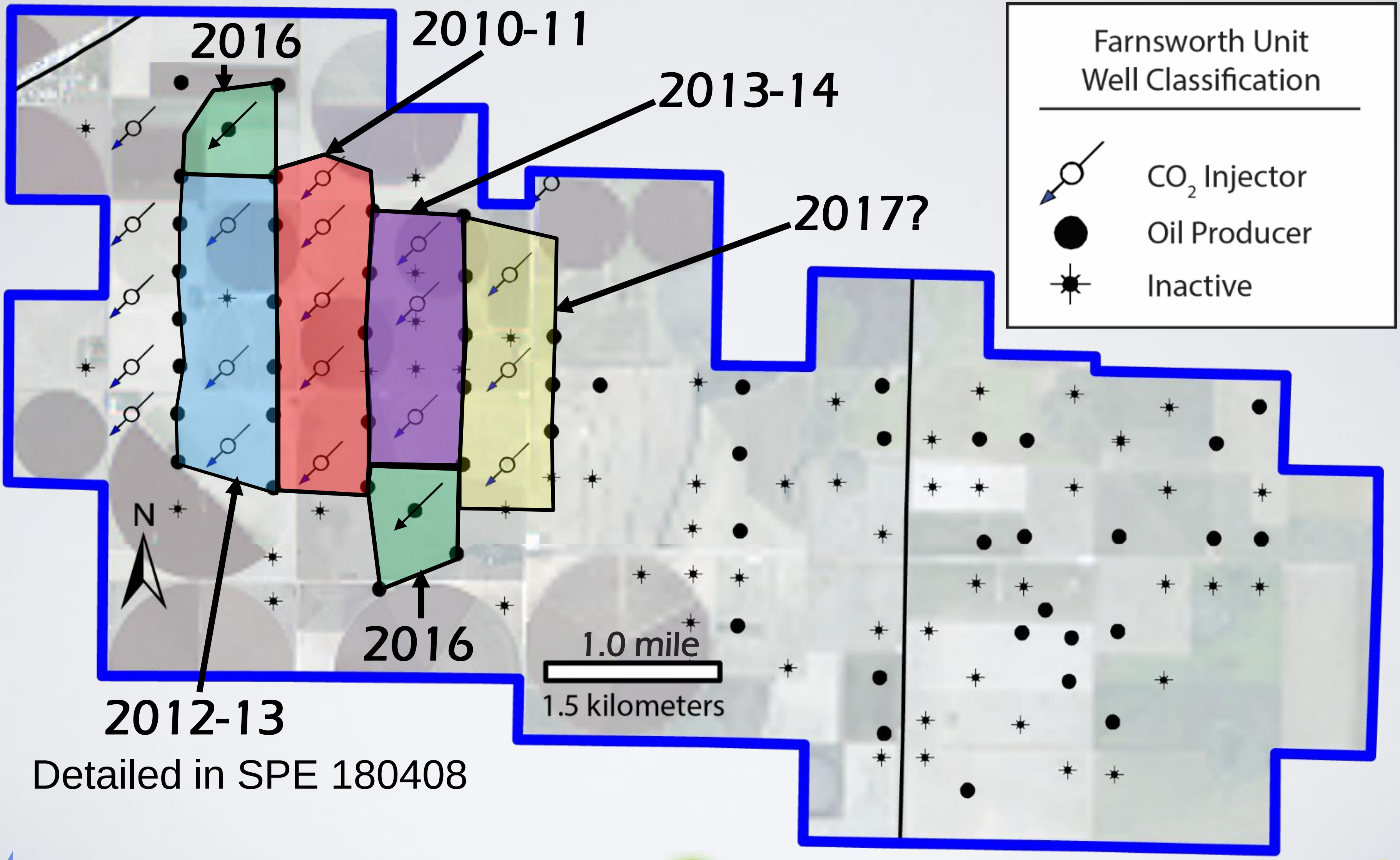
- ● 0.1 to 0.7 MT/yr
- ● 0.7 to 1.8 MT/yr
- ● 1.8 to 4 MT/yr
- ● 4 to 10 MT/yr
- ● 10 to 20 MT/yr

http://www.conestogaenergy.com/arkalon-ethanol



www.agrium.com

Active and Currently Planned CO_2 Patterns



Farnsworth Unit Well Classification

- CO_2 Injector
- ● Oil Producer
- Inactive

Detailed in SPE 180408

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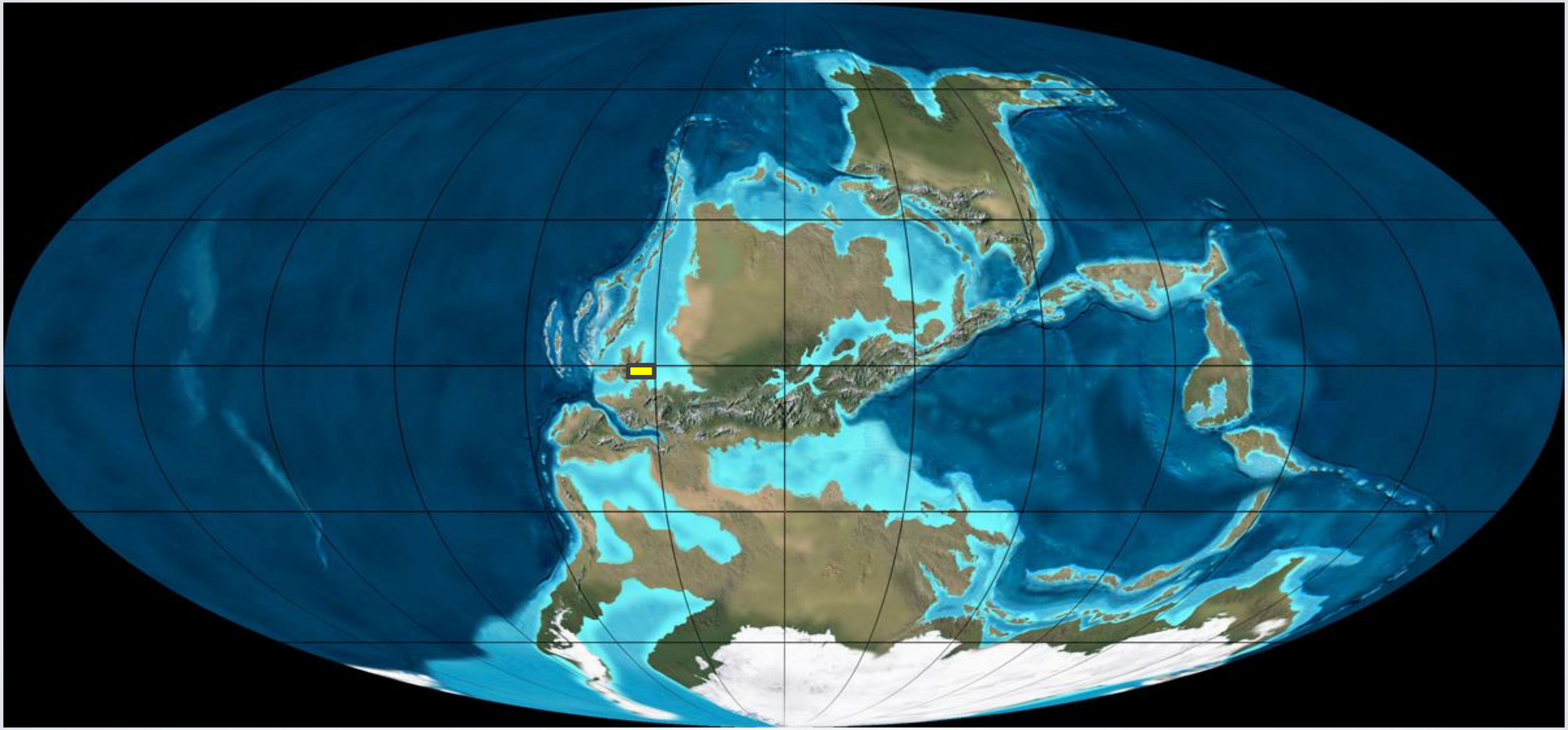
Characterization

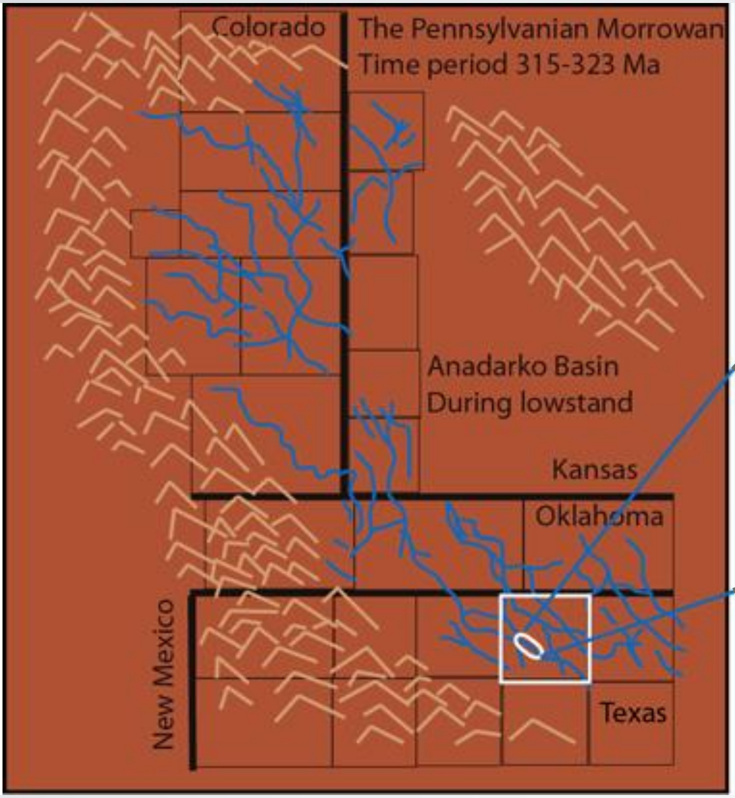
- Goals are to better understand geology of the storage system
- Deliver fine scale facies based models including hydraulic flow units to improve flow simulation and risk assessments



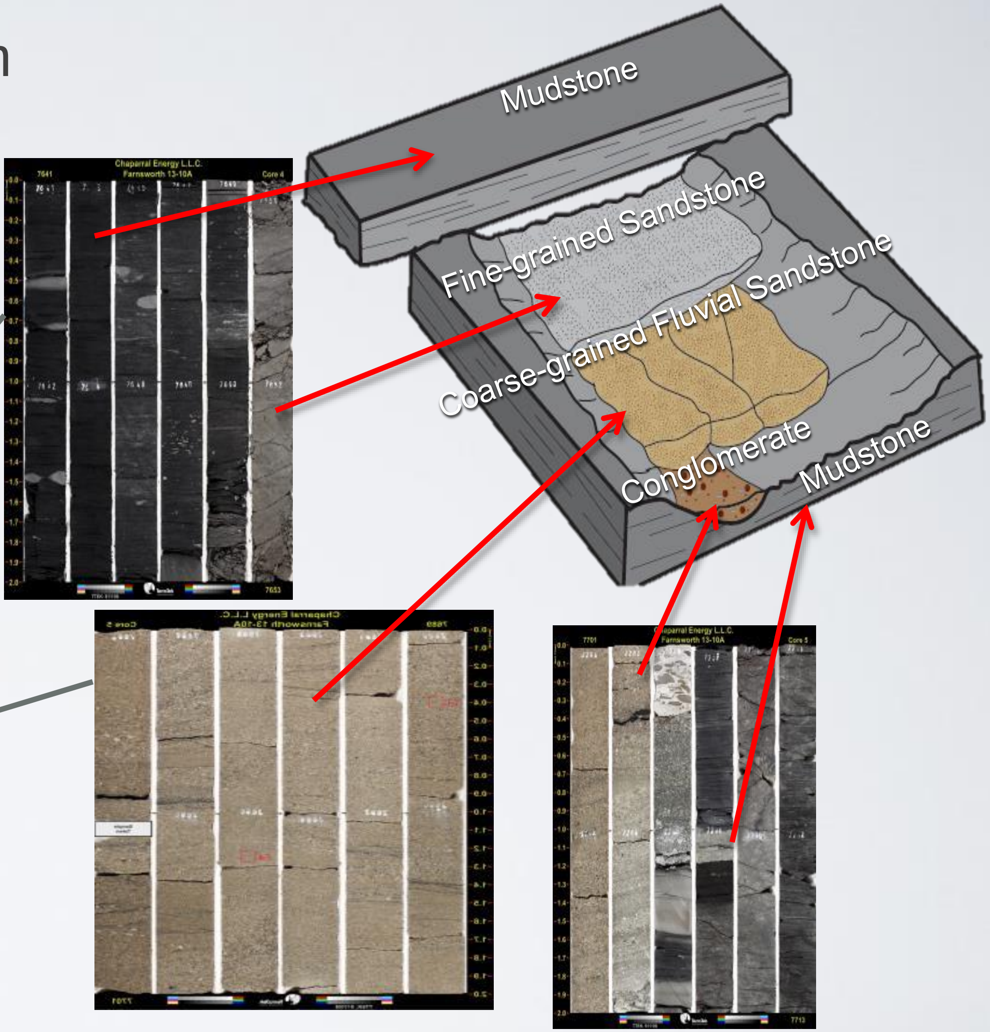
Ron Blakey - http://jan.ucc.nau.edu/rcb7/300moll.jpg

Characterization: Geologic Model

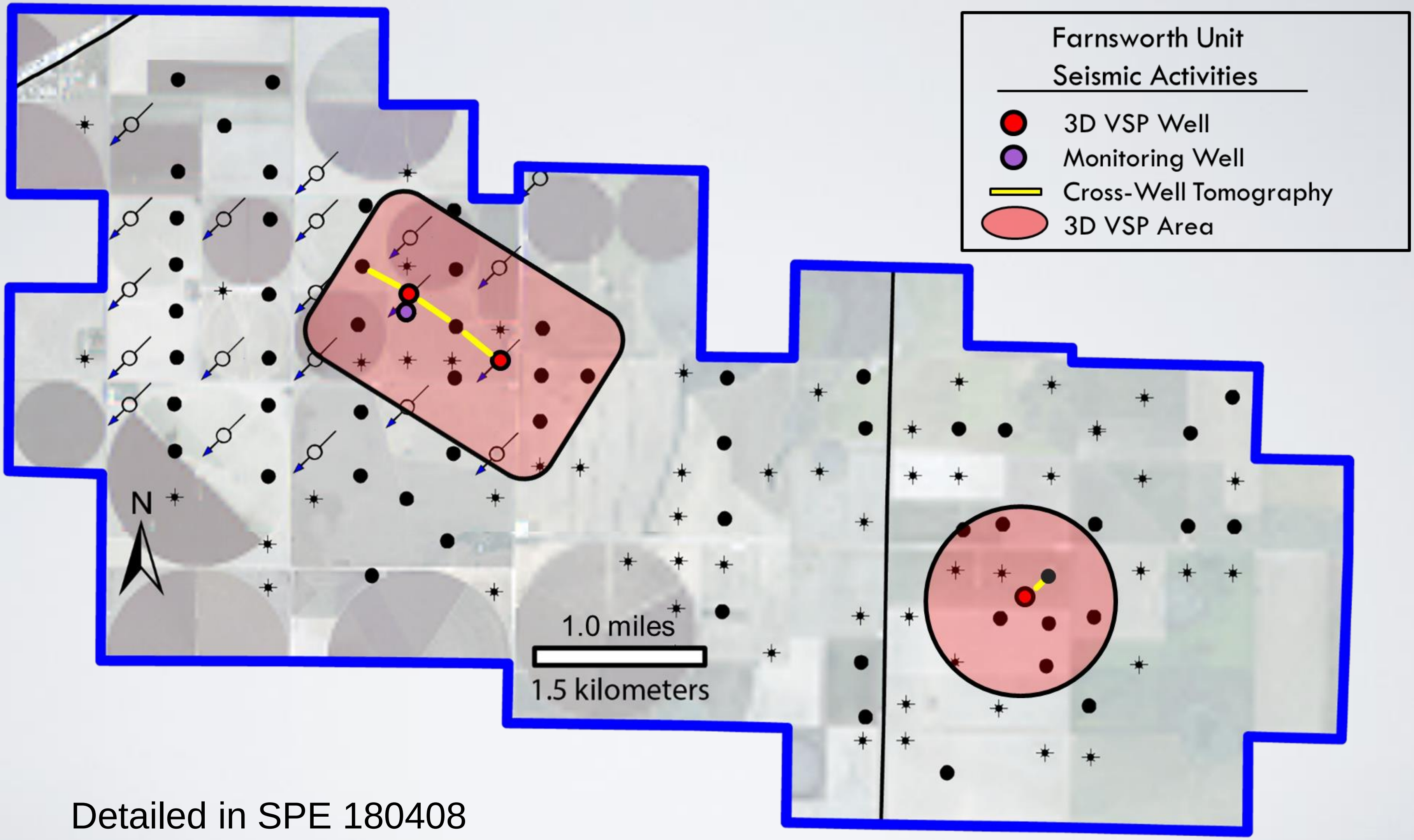
Incised Valley Depositional System



Rose-Coss 2015, after Puckette et al., 2008

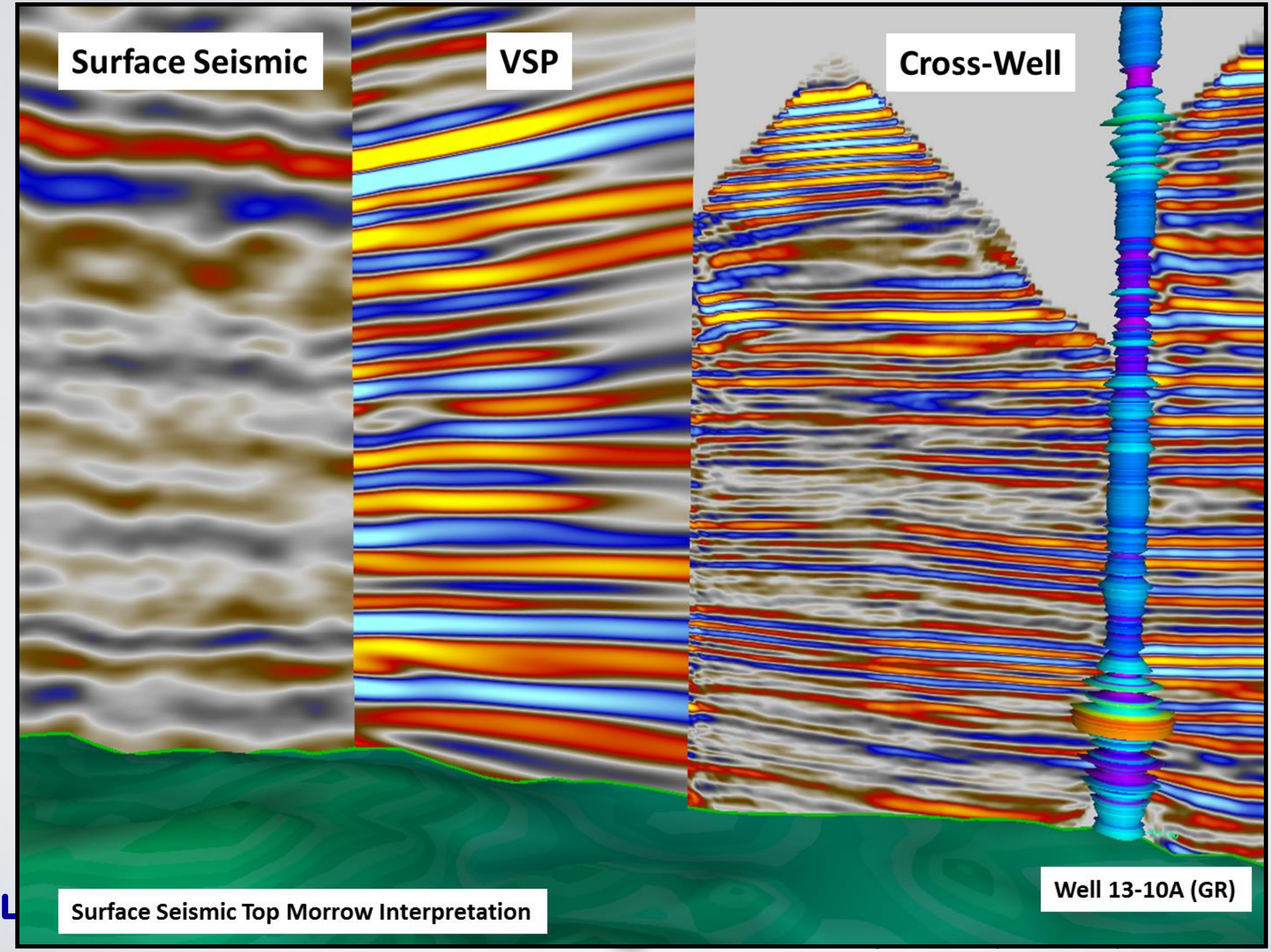


Characterization: Role of Seismic Data

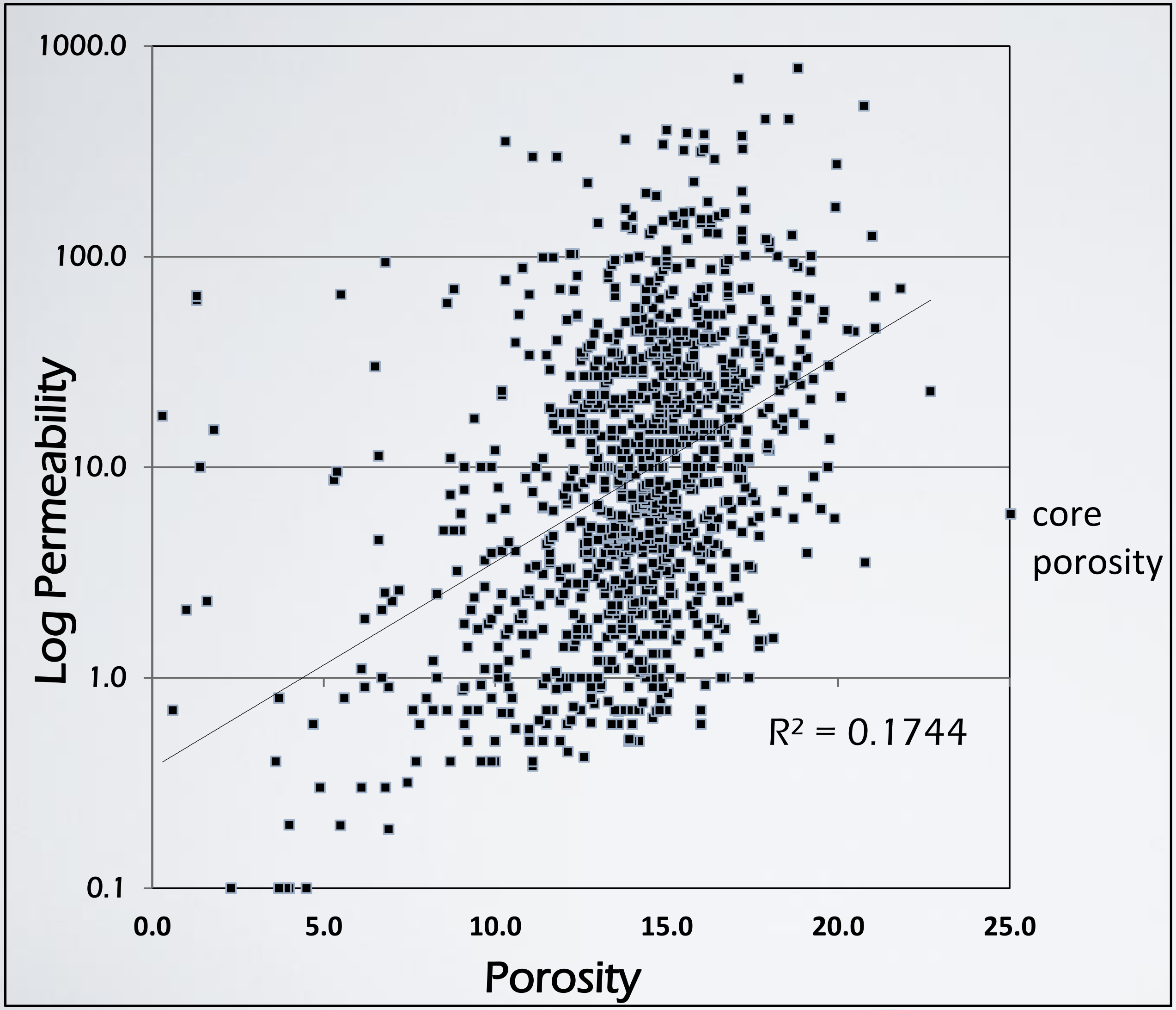


Detailed in SPE 180408

Characterization: Seismic Interpretation



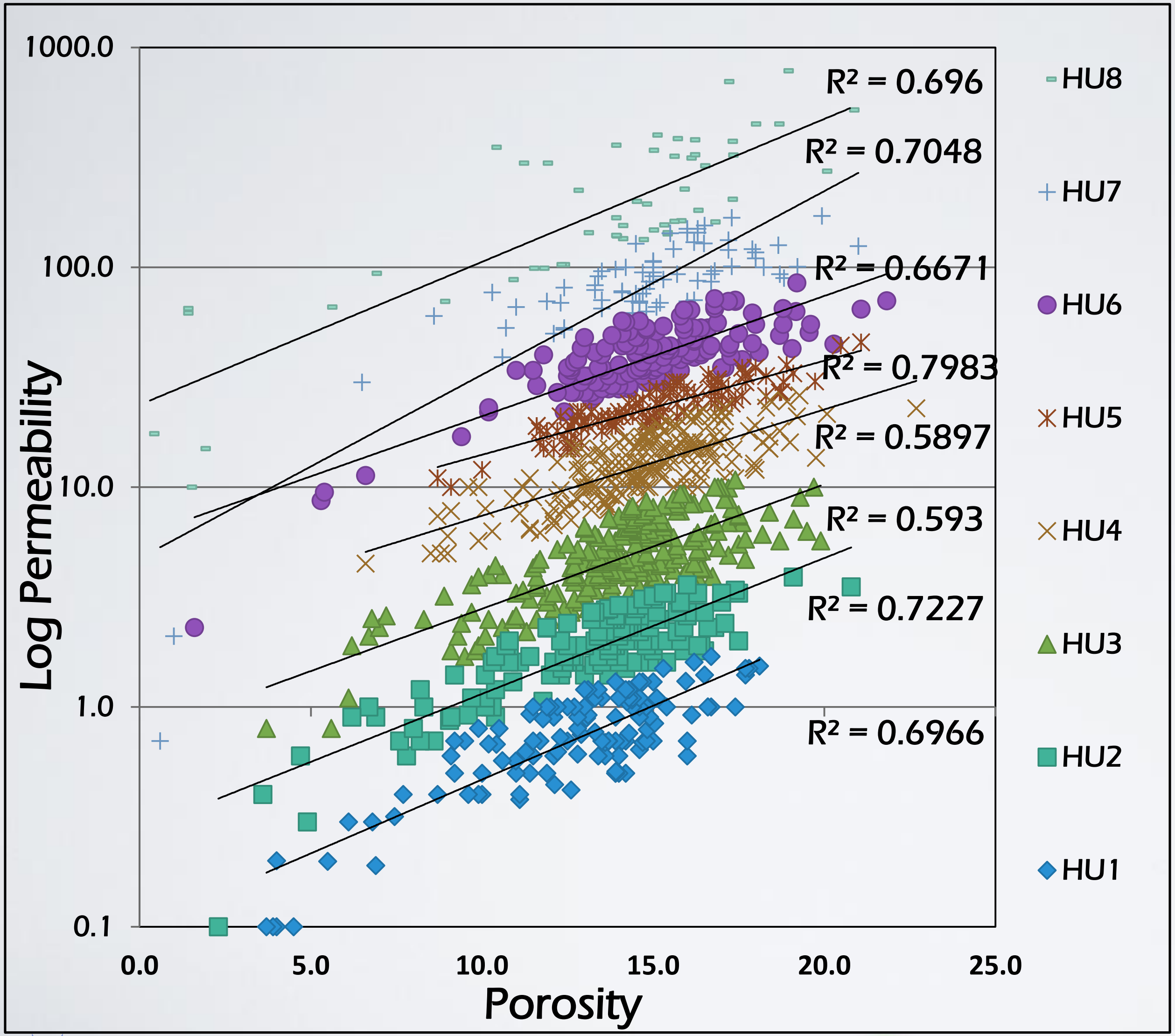
Characterization: Petrophysical Studies



Core porosity vs log of permeability was computed for 51 cored wells

- Over 750 feet of core were collected in three SWP drilled characterization wells
- Extensive logs from near surface through the reservoir were collected
- The data was inconclusive in relating porosity to permeability

Characterization: Hydraulic Flow Units



The Winland equation relates porosity to permeability using variables that impact hydraulic flow (Kolodzie, 1980):

- log R35 = 0.732 + 0.588 log Kair – 0.864 log ϕ core
- Hydraulic units were grouped into porosity/permeability categories based on similar pore throat sizes

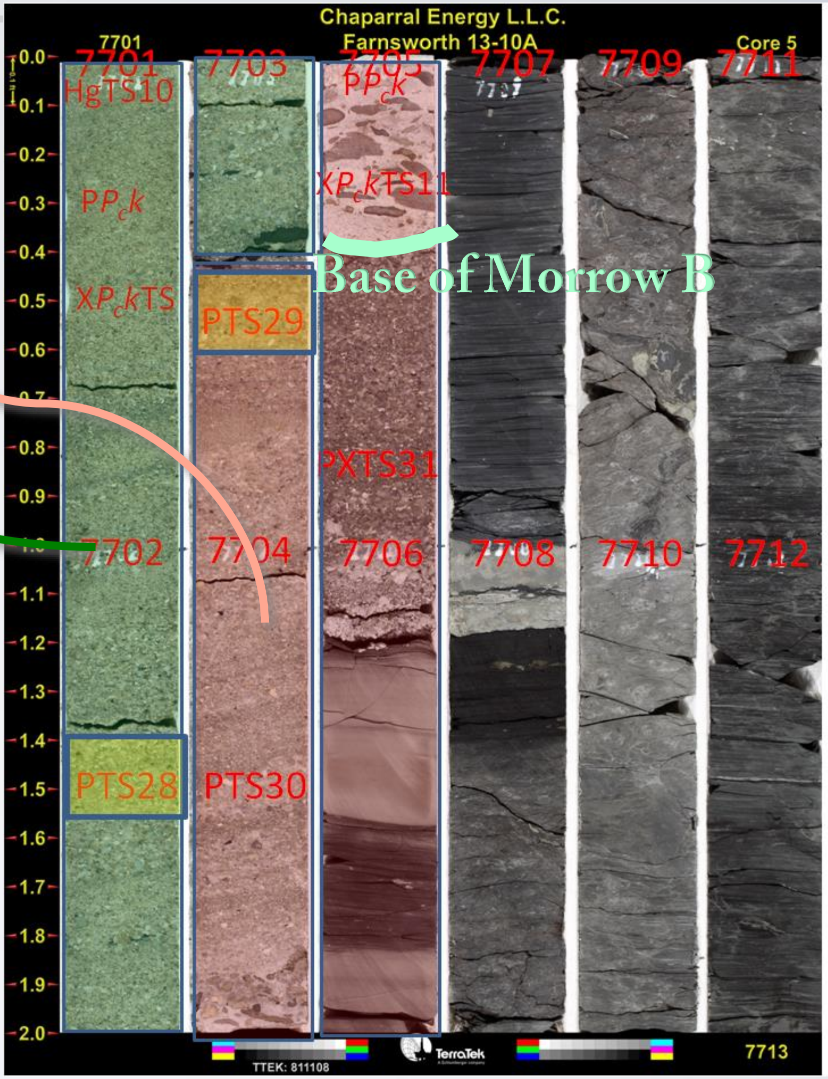
Detailed in SPE 180375

Characterization: Core Correlation

HFU 1 associated with the lowest porosity and permeability values.

HFU 8 in green interval highlighted indicates the highest porosity and permeability values.

Yellow boxes indicate sample locations chosen to be used in core flood experiments intended to capture variability in relative permeability within the core and Hydraulic flow units (HFU).

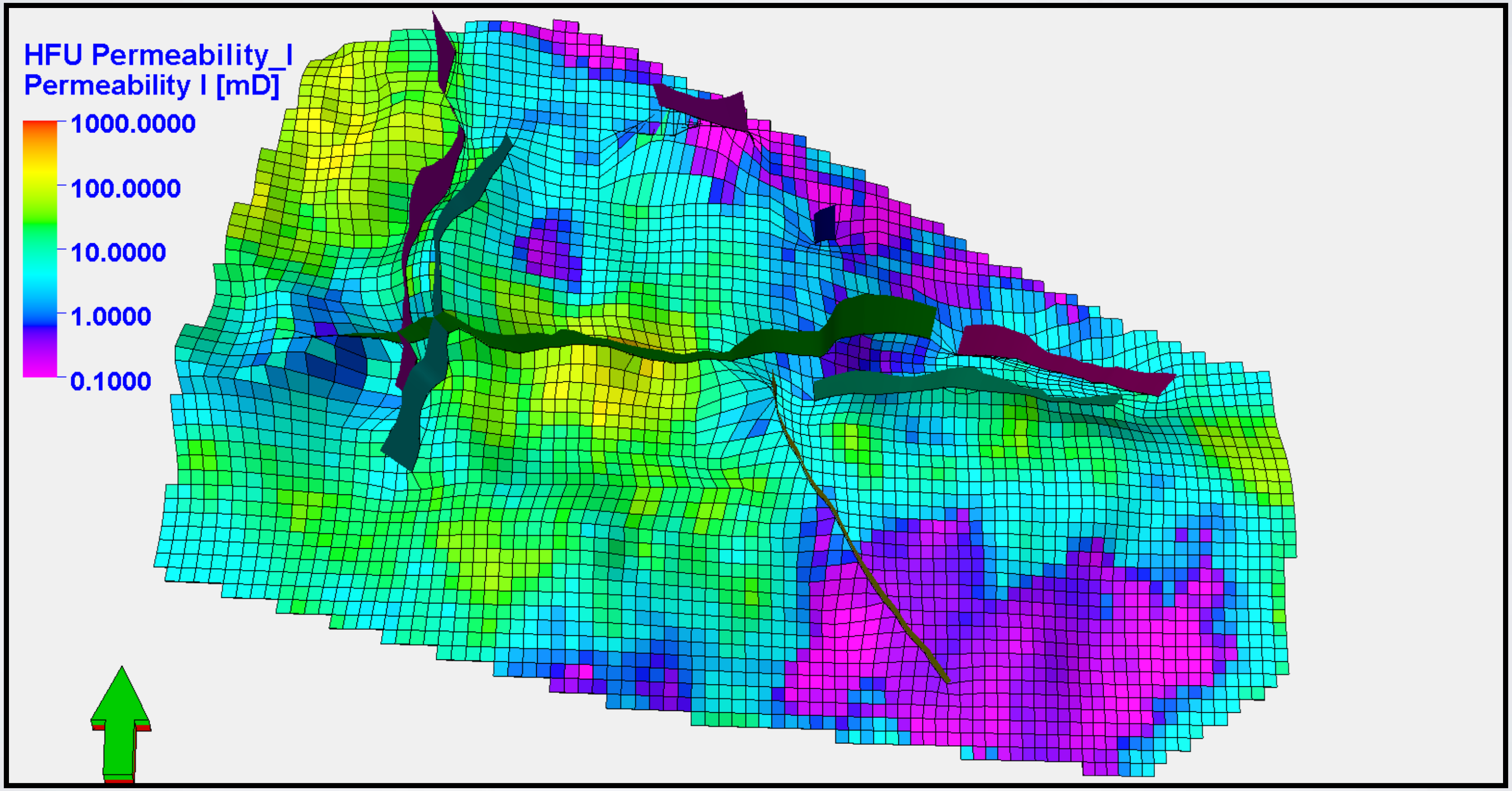


🟥 HFU 1-3
🟨 HFU 3-4
🟦 HFU 4-5
⬜ HFU 6-7
🟩 HFU 7-8

Ts, T – Thin Section
P – Routine Plug analysis
P_c - Capillary pressure

Characterization: Geologic Models

- SWP evaluates and updates fine-scale geologic models at least annually for use in simulation modeling and risk assesment
  - Goal is to integrate, and honor, seismic and well data
- Includes fault planes picked from seismic



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- Introduction to the SWP
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- **Major tasks:**
    - Geologic Characterization
    - **Simulation**
    - Risk
    - MVA
- Conclusions and ongoing work

Simulation: Design, Forecasts, Risk

- Simulation of production/storage history matching of primary, secondary, and tertiary recovery provides some calibration
- Calibrated simulation used for predictions of future and CO_2 storage in the reservoir;
- Uncertainty estimates are critical for forecast context and risk assessment; relative permeability is paramount
- Forecasting potential impacts (risk FEPs) via coupled thermal, geochemical and geomechanical processes;
- Fully-coupled, full-scale simulations used to calibrate reduced order models for uncertainty quantification, risk assessment and optimization for ongoing forecasts.

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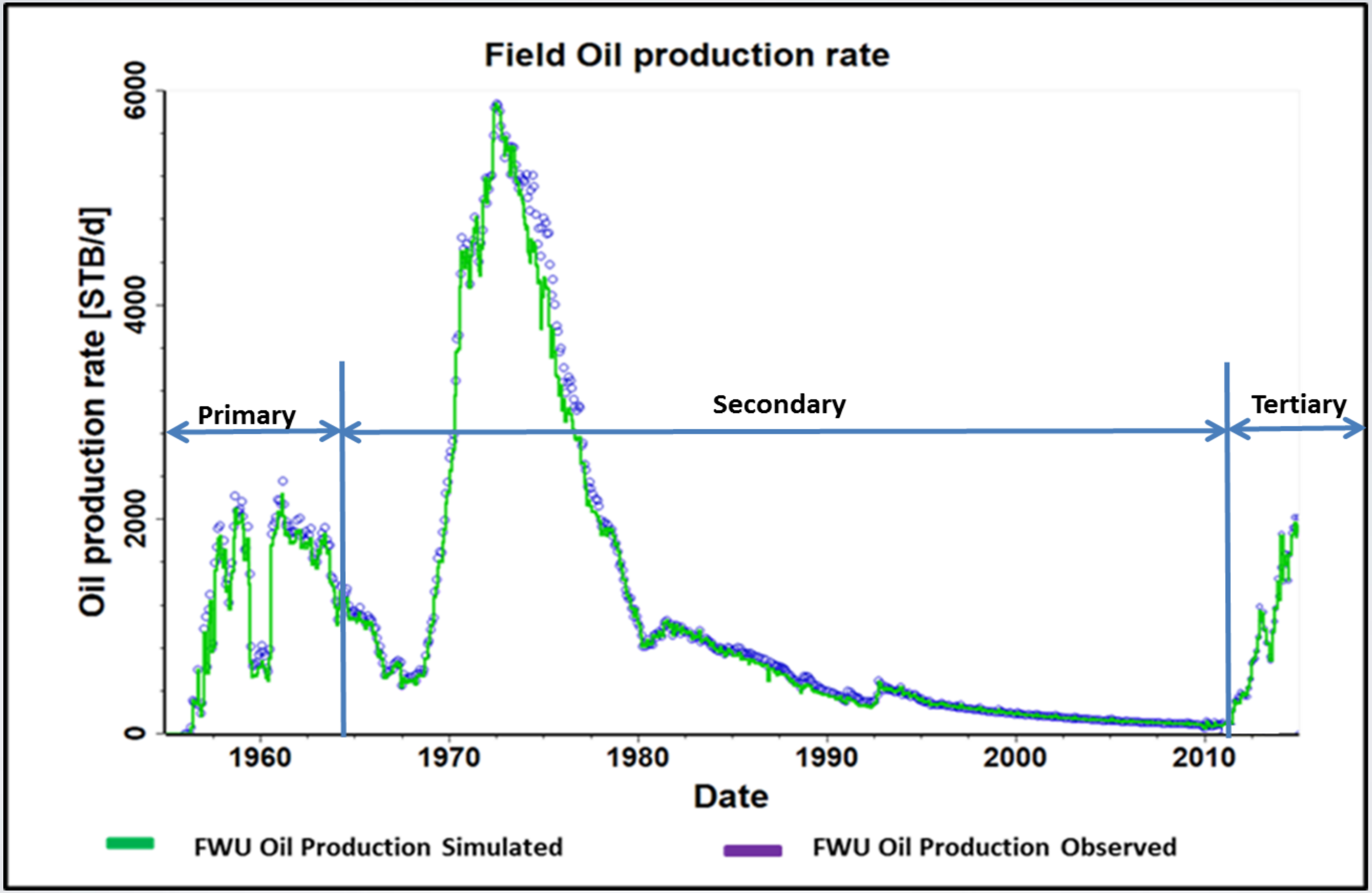
Essential Task: History Matching



Detailed in SPE- 180376

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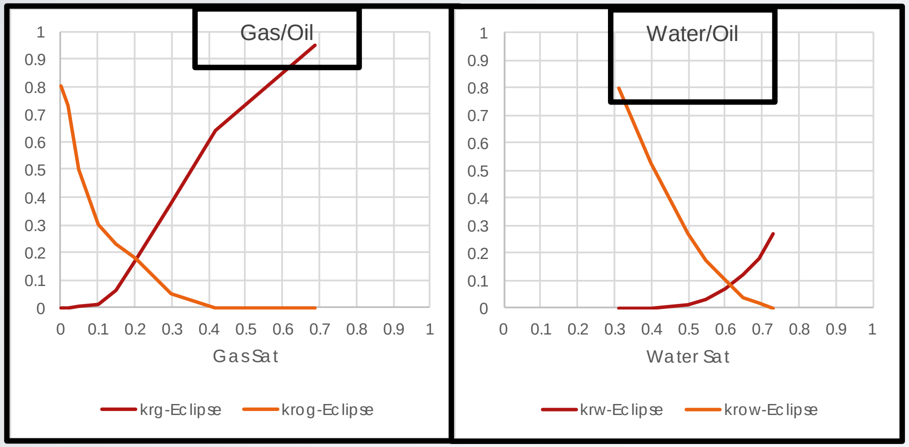
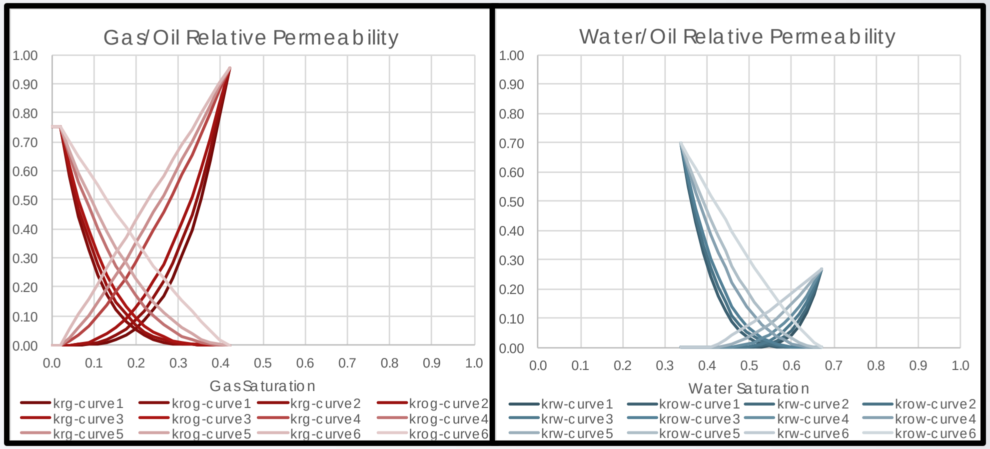
Focus Area: Relative Permeability

Uncertainty Estimation: Impact of choice of three-phase relative permeability model on storage forecasts



Morrow Sandstone relative permeability curve from the Unocal 1988 reservoir simulation study.



Six targeted synthetic relative permeability curves each assigned to hydraulic flow units

Focus Area: Relative Permeability

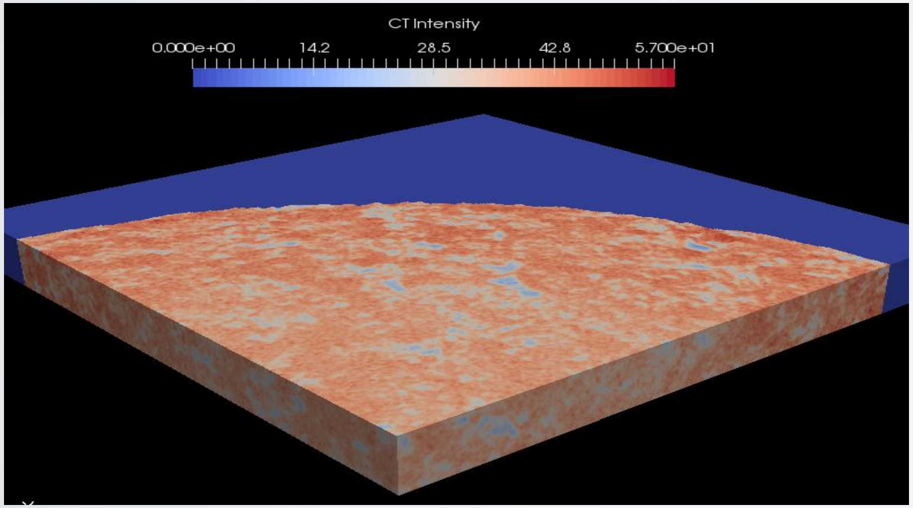
Example Result: Synthetic Relative Permeability Models

Pore-scale modeling

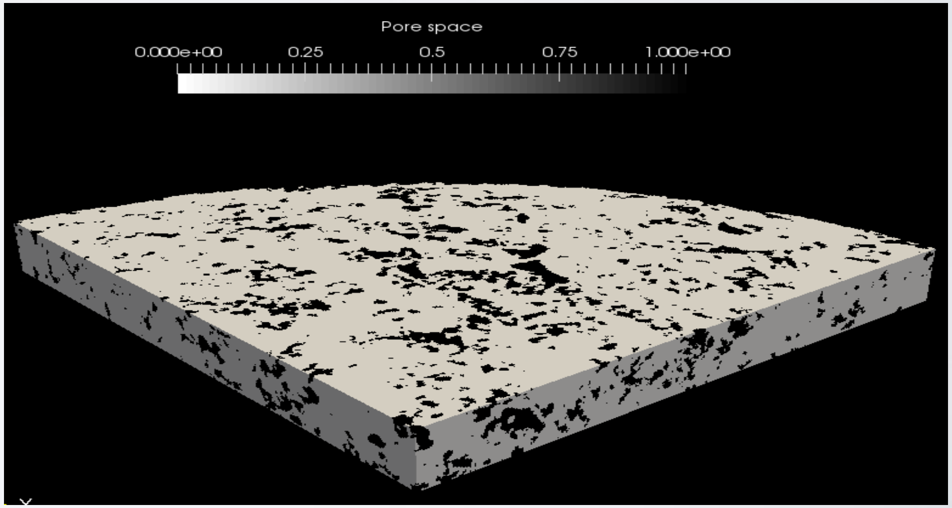
- Relative permeability information
- Inputs for reservoir simulation
- Compliment laboratory studies
- Flexible for statistical analysis

Micro CT imaging as input

- Extract pore matrix
- Cost-effective
- Multi-thresholding for pore matrix
- Alternative to network approximation



Raw CT image



Pore matrix threshold

Simulation: Design, Forecasts, Risk

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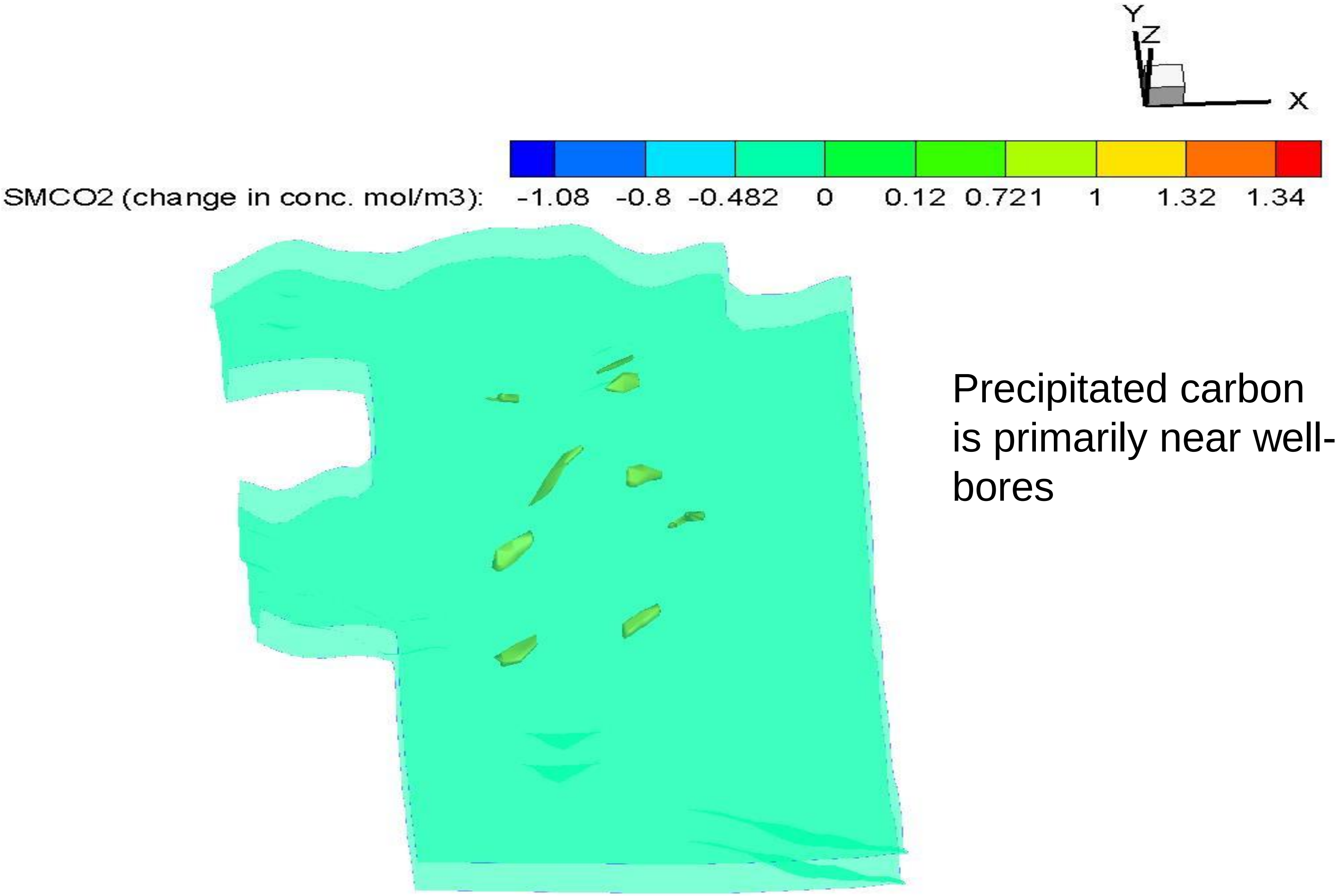
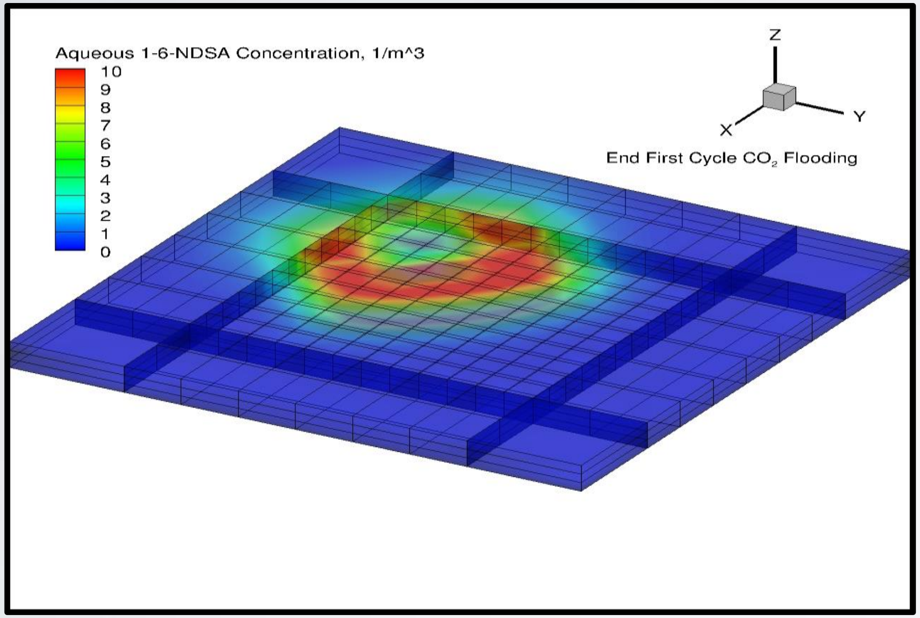
Focus Area: Reactive Transport

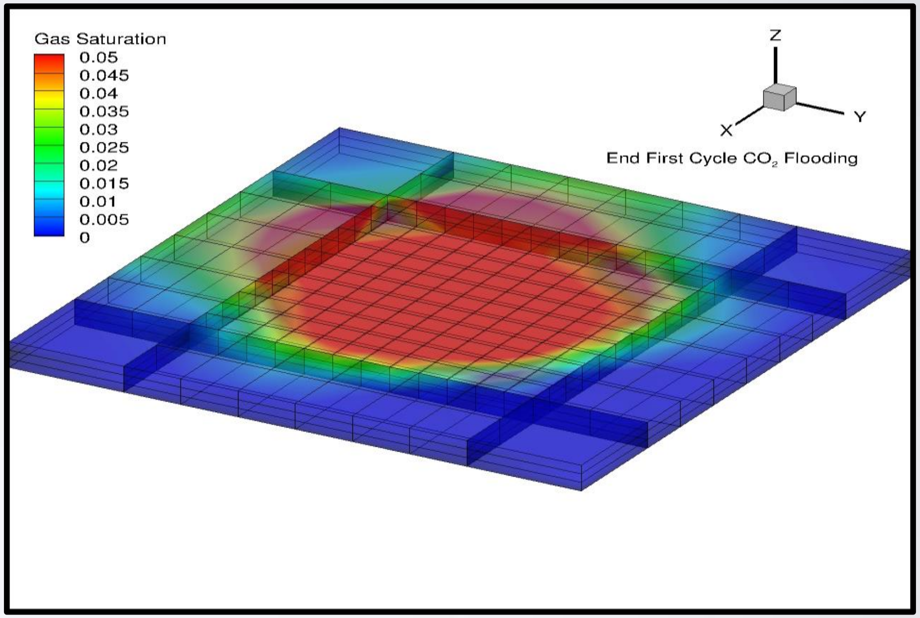


Precipitated carbon is primarily near well-bores

Focus Area: Reactive Transport

Simulation to interpret reactive and conservative tracers



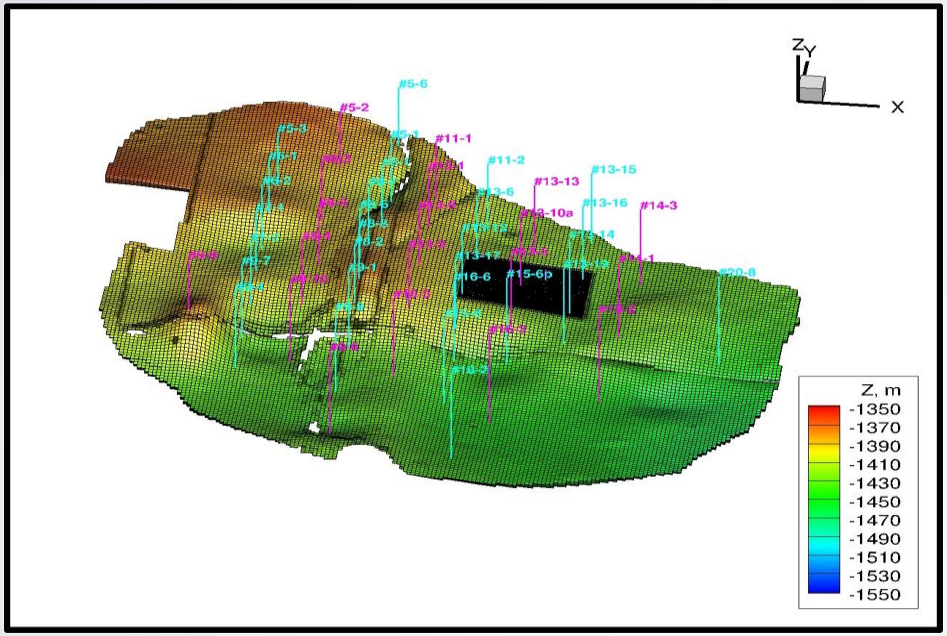


Normalized aqueous tracer concentration between first CO2-water flood transition.

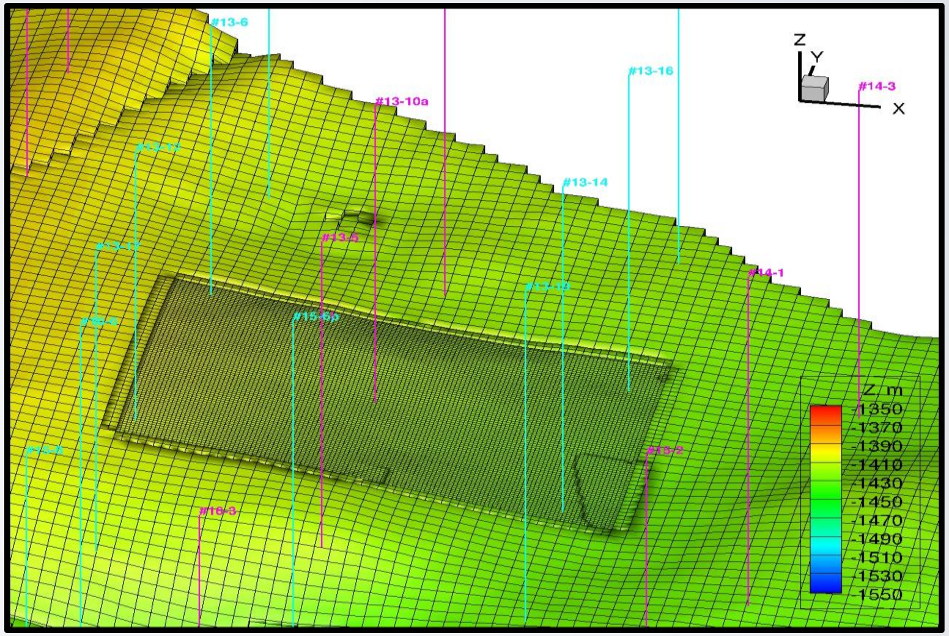
Gas saturation between first CO2-water flood transition.

Focus Area: Reactive Transport

Simulation to interpret reactive and conservative tracers



2x refinement in x- and y-directions around #13-10a, #13-6, #13-12, #13-14, #13-16 for aqueous tracer experiment with injection on 02 May 2014.



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Risk Assesment Workflow

- Risk Management Planning
- Risk Identification (Risk Registry)
- Qualitative Risk Analysis
- Quantitative Risk Analysis
- Risk Response Planning
- Risk Monitoring and Control

Task 1
Overall risk management plan including

- Coordination with other working groups.
- Roles and responsibilities of each personnel
- Budget assignment
- Timing & frequency of risk assessment tasks
- New elements for the risk registry and its potential impacts

Task 2 – Risk Identification

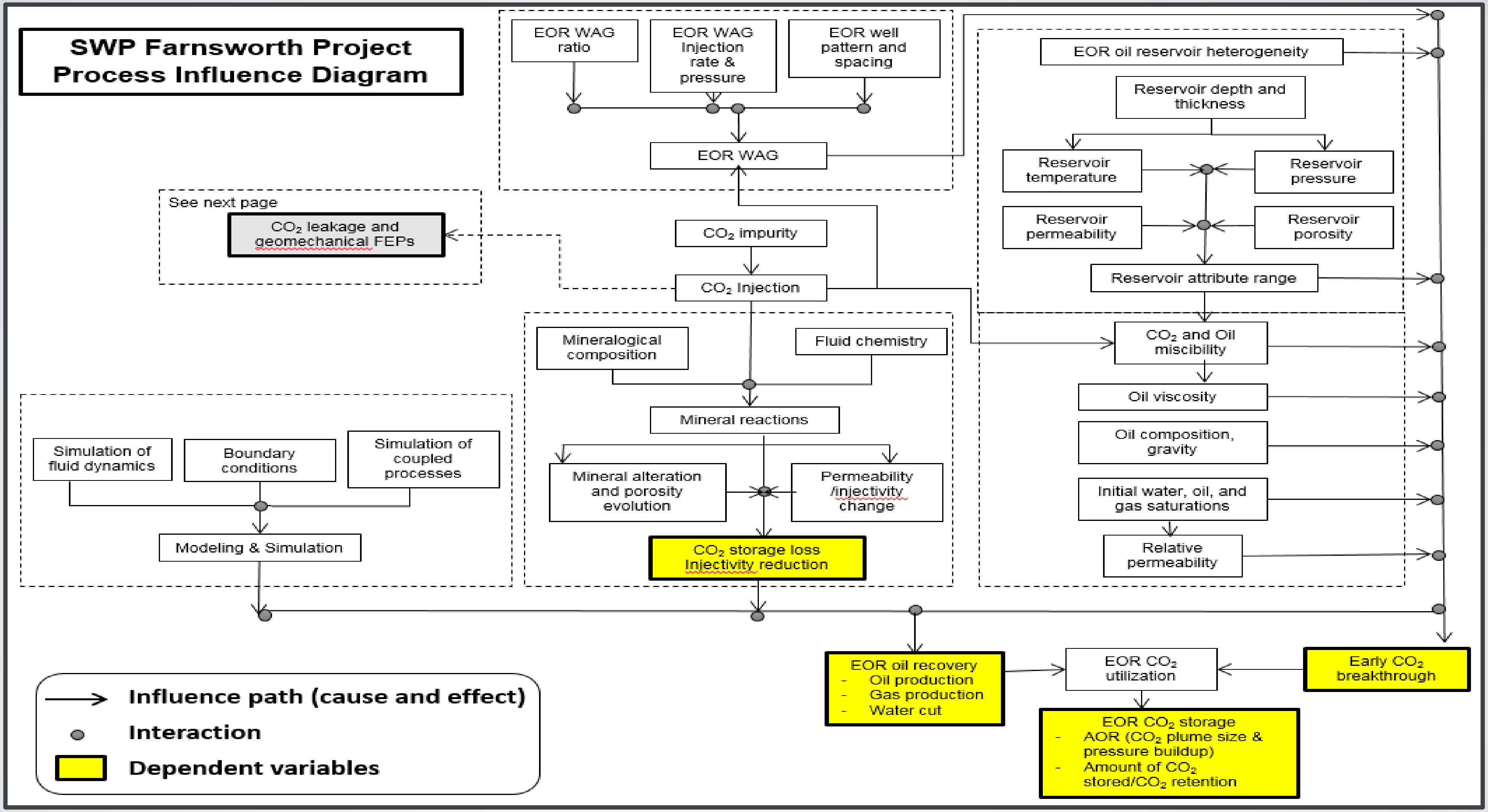
- Identification of specific risk : features, events, and processes (FEPs)
- 2014
  - Web-based online workshop (Jan. 13 and 16, 2014)
  - Expert-weighted risk for ranking
  - Total 405 FEPs identified
  - 23 project experts evaluated 79 initial FEPs, and generated & evaluated 24 new FEPs
- 2015
  - Email survey during (May ~ August 2015)
  - 15 project experts evaluated top 50 FEPs of 2014
- 2016
  - In progress, risk review meeting at end of August

2015 vs. 2014 FEP's Ranking

	2015			2014	
Average	7.32			6.18	
FEP	Risk 2015 Ravg 3xWt	Rank 2015	RANK CHANGE	Risk 2014 wKSY2b	Rank 2014
Price of oil (or other related commodities)	12.26	1	5	7.12	6
EOR oil recovery	11.07	2	35	5.54	37
Operating and maintenance costs	10.26	3	4	7.11	7
EOR injection and production well pattern, spacing	9.19	4	41	5.33	45
EOR early CO2 breakthrough	8.85	5	20	5.88	25
Simulation of geomechanics	8.67	6	3	7.03	9
CO2 supply adequacy	8.65	7	-5	7.86	2
Accidents and unplanned events	8.63	8	10	6.42	18
Execution strategy	8.52	9	12	6.22	21
Over pressuring	8.39	10	0	7.03	10
EOR oil reservoir heterogeneity	8.33	11	8	6.35	19
Competition	8.30	12	37	5.29	49
Release of compressed gases or liquids	8.30	13	-10	7.80	3
Seal failure	8.24	14	8	6.04	22
Reservoir heterogeneity	7.91	15	1	6.59	16
Defective equipment	7.89	16	32	5.31	48
Simulation of fluid dynamics	7.87	17	-2	6.65	15
CO2 legislation	7.70	18	11	5.78	29
Simulation of coupled processes	7.68	19	-14	7.46	5
Modeling and simulation - software	7.55	20	-3	6.54	17
CO2 containing H2S	7.35	21	-8	6.68	13
EOR viscosity relations	7.33	22	25	5.32	47
Leaks and spills (not CO2, H2S, CH4)	7.33	23	21	5.40	44
Permit modifications	7.22	24	16	5.50	40
Seismic method	7.17	25	-13	6.73	12
Blowouts	7.10	26	-18	7.05	8
Contracting	7.09	27	15	5.50	42
On-road driving	7.07	28	7	5.60	35
Workover	7.00	29	1	5.75	30
Moving equipment	6.93	30	9	5.52	39
Well lining and completion	6.90	31	7	5.52	38
Geomechanical characterization	6.88	32	-28	7.56	4
Seismic surveys	6.61	33	17	5.28	50

- Triple-weighted expert ranking
- Two major things causing the changes
  - ✓ Oil price
  - ✓ Project operations, progress, and experience over one year
- Rankings in EOR activities ↑
- Rankings in Modeling/simulation parameters and Geomechanical characterization ↓
- 14 FEPs changing at least 20 positions → requires comprehensive evaluation in 2016

Qualitative Risk Analysis (Task 3)



SWP Farnsworth Project
Process Influence Diagram

EOR WAG ratio

EOR WAG Injection rate & pressure

EOR well pattern and spacing

EOR WAG

See next page

CO_2 leakage and geomechanical FEPs

CO_2 impurity

CO_2 Injection

EOR oil reservoir heterogeneity

Reservoir depth and thickness

Reservoir temperature

Reservoir pressure

Reservoir permeability

Reservoir porosity

Reservoir attribute range

CO_2 and Oil miscibility

Oil viscosity

Oil composition, gravity

Initial water, oil, and gas saturations

Relative permeability

Mineralogical composition

Fluid chemistry

Mineral reactions

Mineral alteration and porosity evolution

Permeability /injectivity change

CO_2 storage loss
Injectivity reduction

Simulation of fluid dynamics

Boundary conditions

Simulation of coupled processes

Modeling & Simulation

EOR oil recovery
- Oil production
- Gas production
- Water cut

EOR CO_2 utilization

Early CO_2 breakthrough

EOR CO_2 storage
- AOR (CO_2 plume size & pressure buildup)
- Amount of CO_2 stored/CO_2 retention

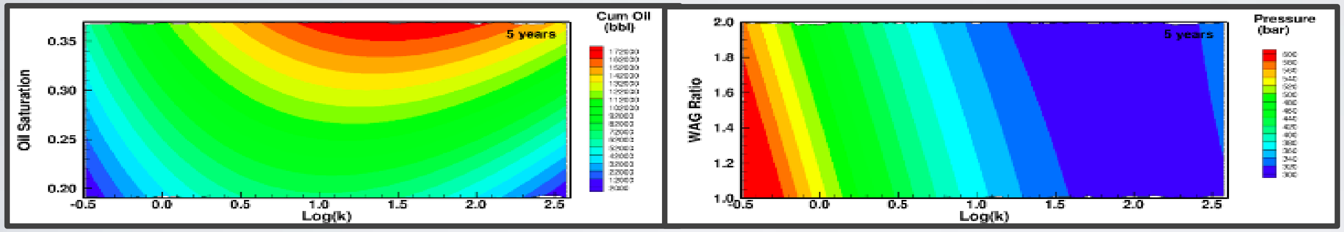
→ **Influence path (cause and effect)**

● **Interaction**

🟨 **Dependent variables**

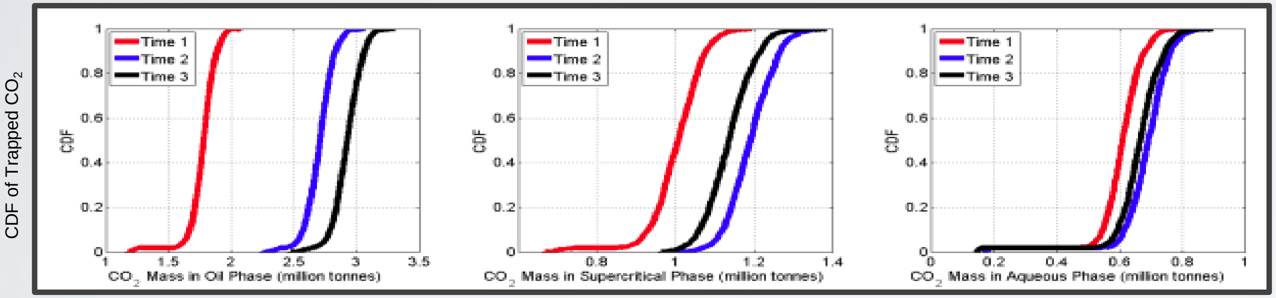
Quantitative Risk Analysis (Task 4)

Risk Assessment of CO_2 Storage and Oil Recovery in FWU using RSM



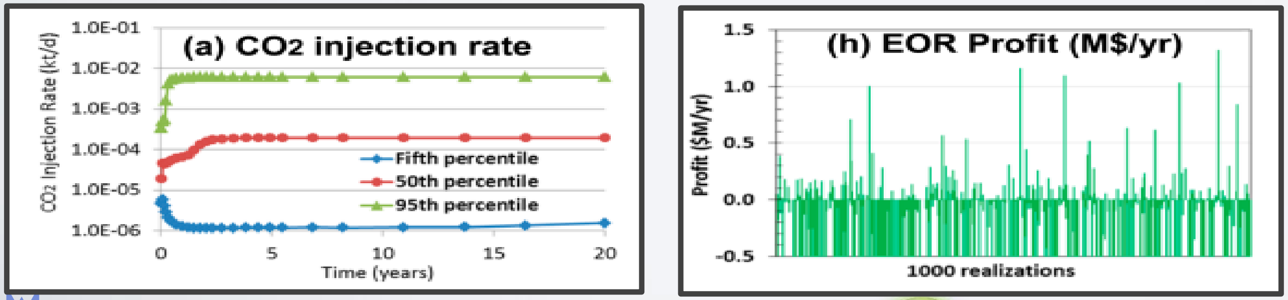
(Pan et al., 2016)

Uncertainty Analysis of Trapping Mechanism using PCE



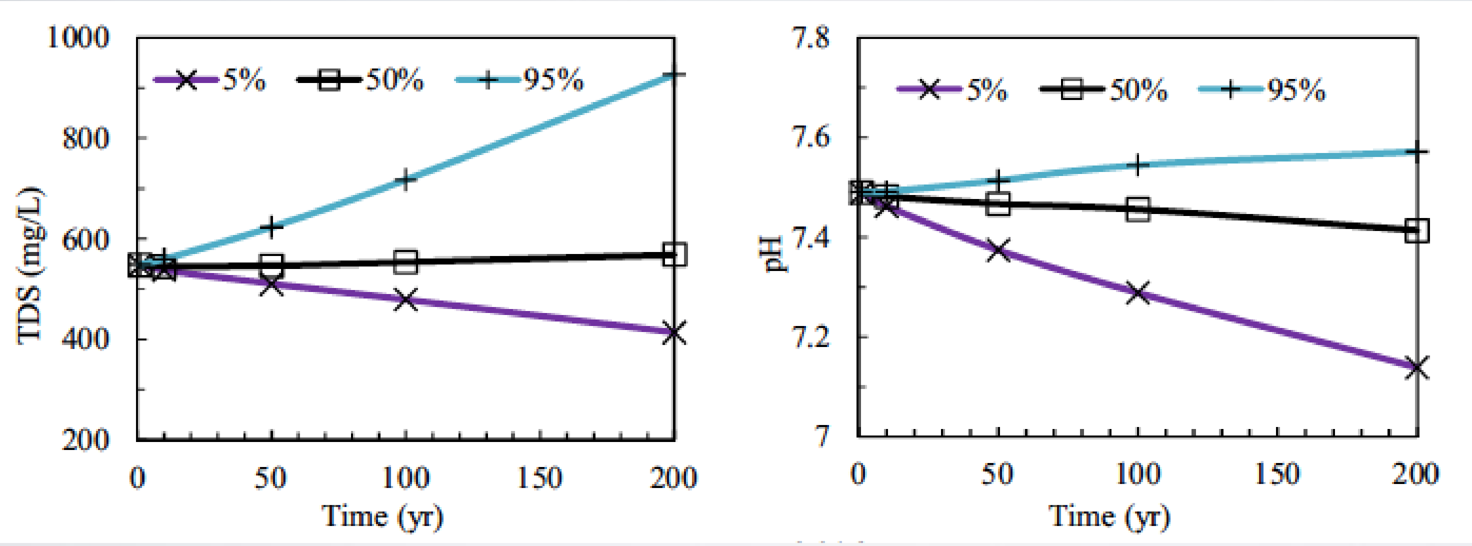
(Jia et al., 2016)

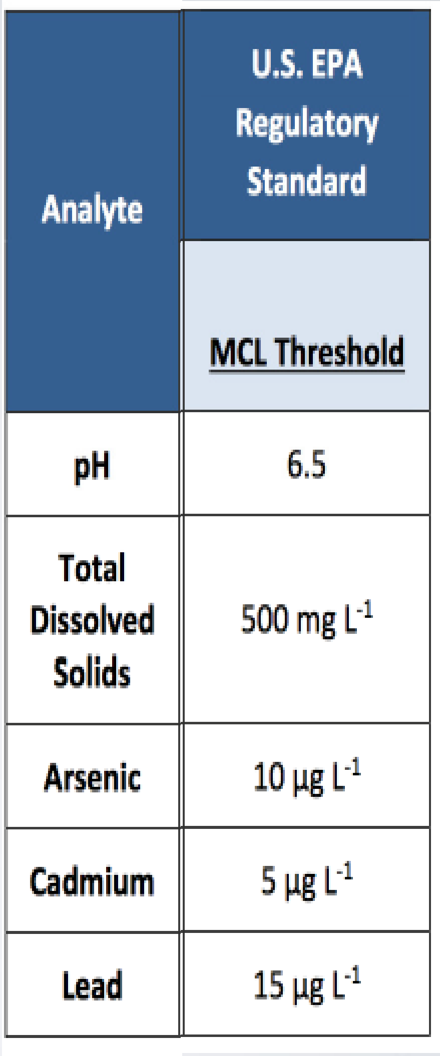
Risk Analysis and Response-surface-based Economic Model



(Dai et al., 2016)

Quantitative Risk Analysis (Task 4)





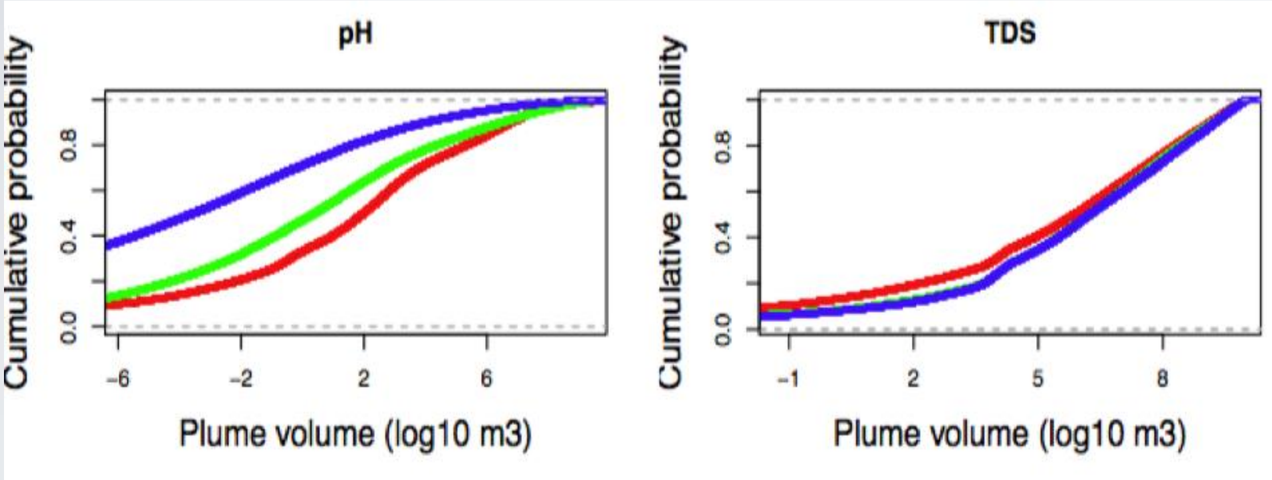
Analyte	U.S. EPA Regulatory Standard
	MCL Threshold
pH	6.5
Total Dissolved Solids	$500\ mg\ L^{-1}$
Arsenic	$10\ \mu g\ L^{-1}$
Cadmium	$5\ \mu g\ L^{-1}$
Lead	$15\ \mu g\ L^{-1}$

Forecasted water quality impacts (as *f*(time)) to the Ogallala USDW, via conventional reactive transport simulation.

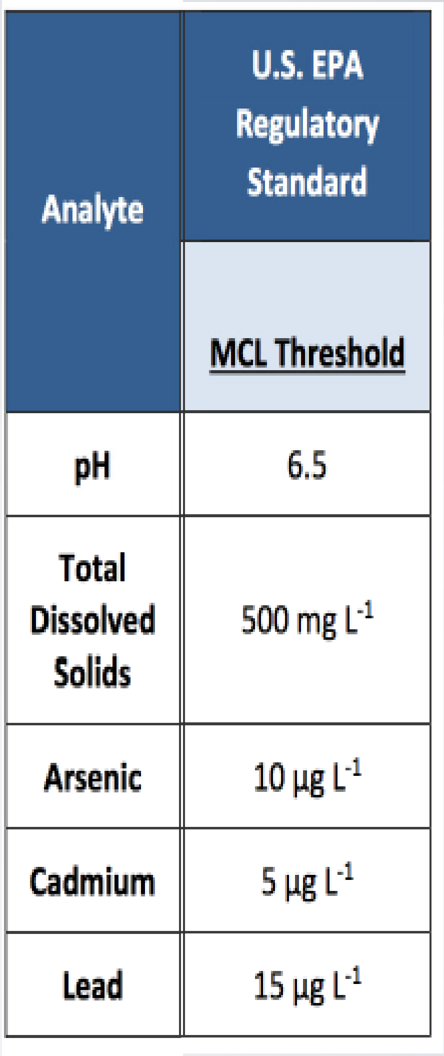
Xiao, T., McPherson, B., Pan, F., Esser, R., Jia, W. (2016). Potential Chemical Impacts of CO_2 Leakage on Underground Source of Drinking Water (USDWs) Assessed by Quantitative Risk Analysis. ***International Journal of Greenhouse Gas Control***, 50, 305-316

Probabilistic Analyses - NRAP's AIM Tool

Cumulative distribution function of impacts on aquifer (pH, TDS) due to three levels of leakage

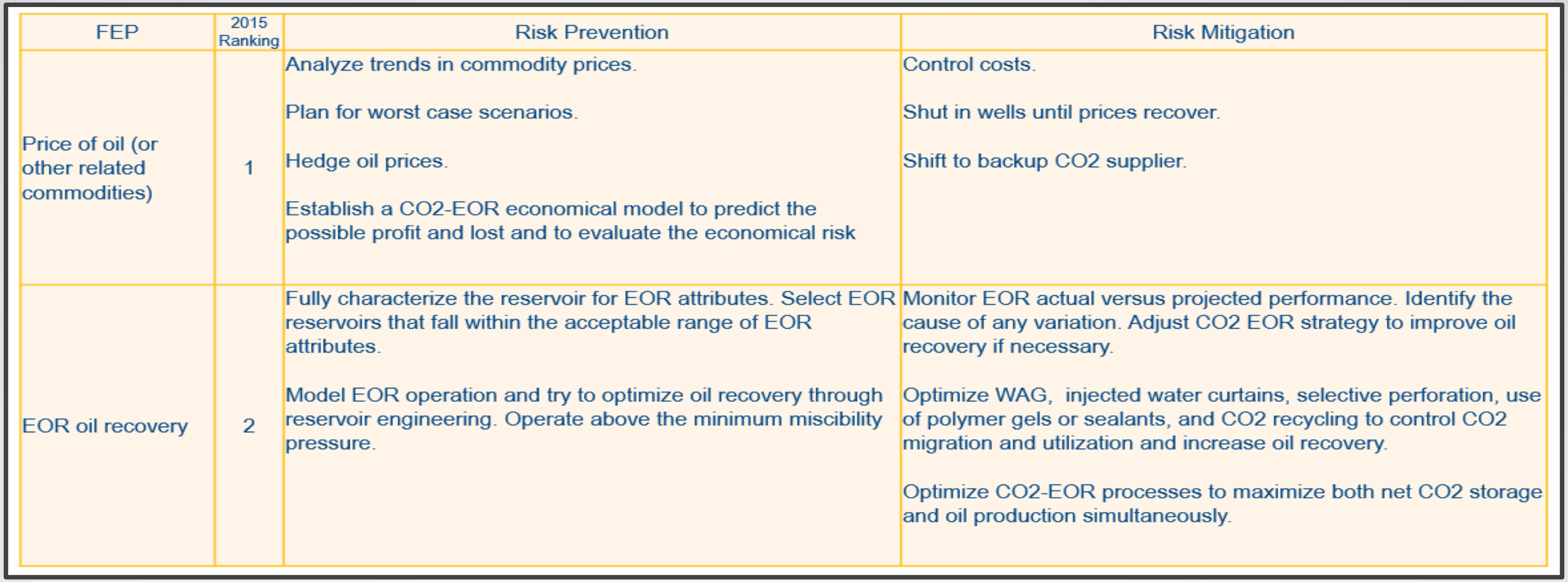


Forecasted water quality impacts (as CDFs) to the Ogallala USDW, via NRAP's AIM tool.



Analyte	U.S. EPA Regulatory Standard
	MCL Threshold
pH	6.5
Total Dissolved Solids	500 mg L^{-1}
Arsenic	10 µg L^{-1}
Cadmium	5 µg L^{-1}
Lead	15 µg L^{-1}

Risk Response Planning (Task 5)

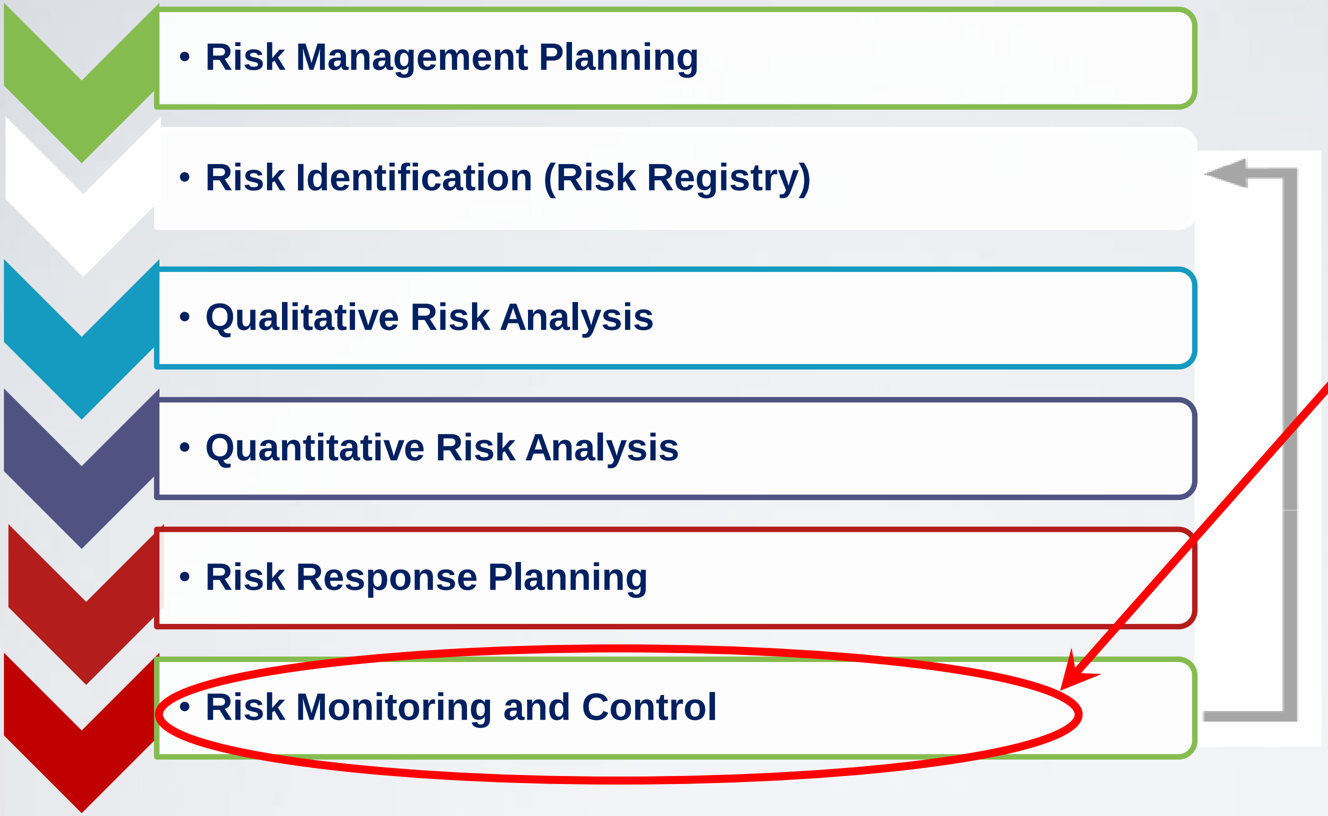


FEP	2015 Ranking	Risk Prevention	Risk Mitigation
Price of oil (or other related commodities)	1	Analyze trends in commodity prices. Plan for worst case scenarios. Hedge oil prices. Establish a CO2-EOR economical model to predict the possible profit and lost and to evaluate the economical risk	Control costs. Shut in wells until prices recover. Shift to backup CO2 supplier.
EOR oil recovery	2	Fully characterize the reservoir for EOR attributes. Select EOR reservoirs that fall within the acceptable range of EOR attributes. Model EOR operation and try to optimize oil recovery through reservoir engineering. Operate above the minimum miscibility pressure.	Monitor EOR actual versus projected performance. Identify the cause of any variation. Adjust CO2 EOR strategy to improve oil recovery if necessary. Optimize WAG, injected water curtains, selective perforation, use of polymer gels or sealants, and CO2 recycling to control CO2 migration and utilization and increase oil recovery. Optimize CO2-EOR processes to maximize both net CO2 storage and oil production simultaneously.

Established risk prevention and mitigation treatments for top 50 FEPs and 10 black swans.

As NRAP moves into its Phase 2, collaboration on mitigation plans will be critical!

Risk Monitoring and Control (Task 6)



- **Risk Management Planning**
- **Risk Identification (Risk Registry)**
- **Qualitative Risk Analysis**
- **Quantitative Risk Analysis**
- **Risk Response Planning**
- **Risk Monitoring and Control**

- Keep tracking of existing and new risks
- Review of mitigation activities (response plan) and their effectiveness
- Iterative process

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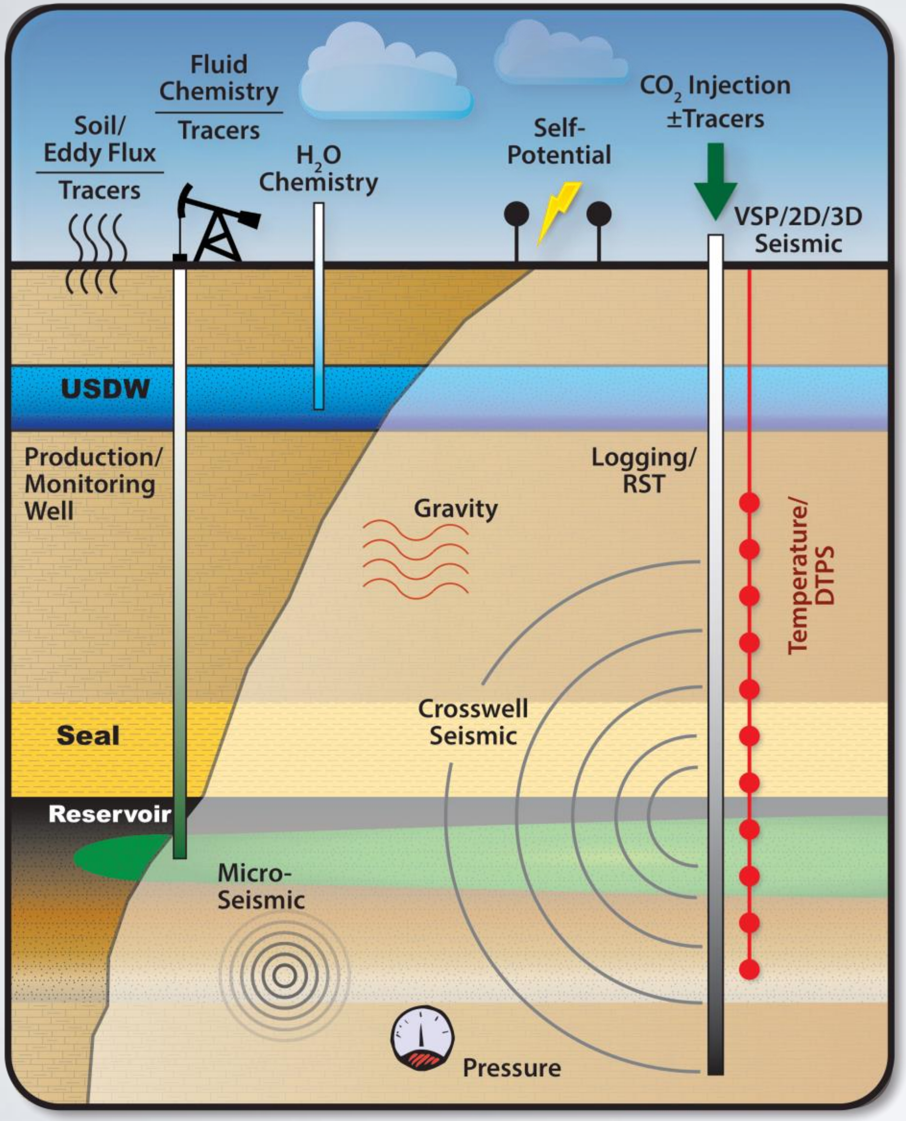
Monitoring (MVA)

As a demonstration project a comprehensive monitoring strategy is in place:

- **Monitoring** – understand CO_2 plume movement over short and long time periods
  - ***Direct monitoring*** tests repeat air and water samples for seeps, leaks, and well-bore failures
  - ***Seismic MVA*** utilizes time lapse seismic data at a variety of scales to image the CO_2 plume over time
- **Verification** – assurance that CO_2 stays in target reservoir, doesn't make it back to atmosphere
- **Accounting** – Accurately measure amount of stored carbon including storage mechanisms

Direct Monitoring Strategy



Detecting CO_2 at Surface:

- Surface soil CO_2 flux
- Atmospheric $CO_{2/}CH_4$ eddy flux
- Gas phase tracers

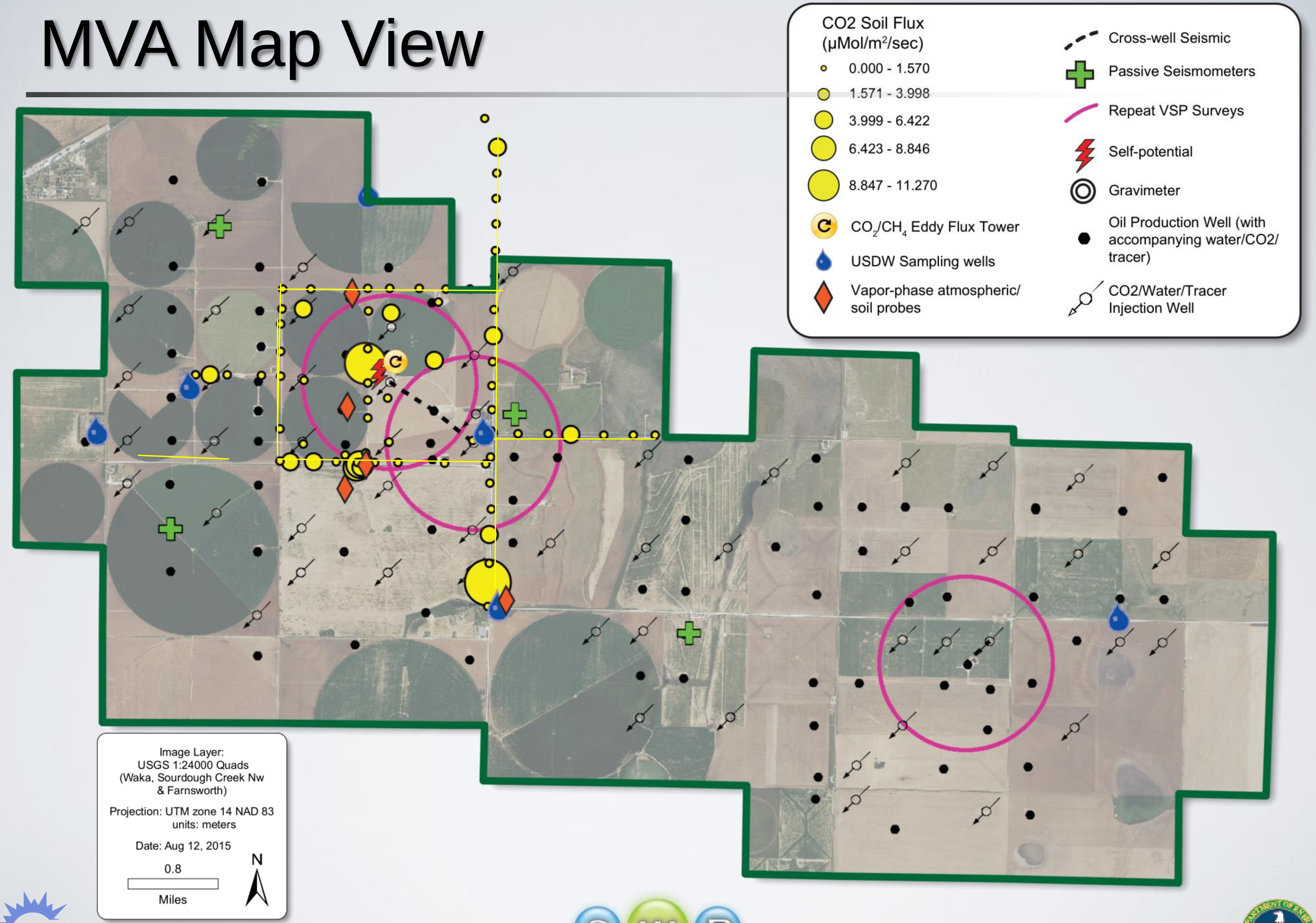
Detecting CO_2 and/or other fluid migration in Target/Non-Target Reservoirs:

- Groundwater chemistry (USDWs)
- Water/gas phase tracers

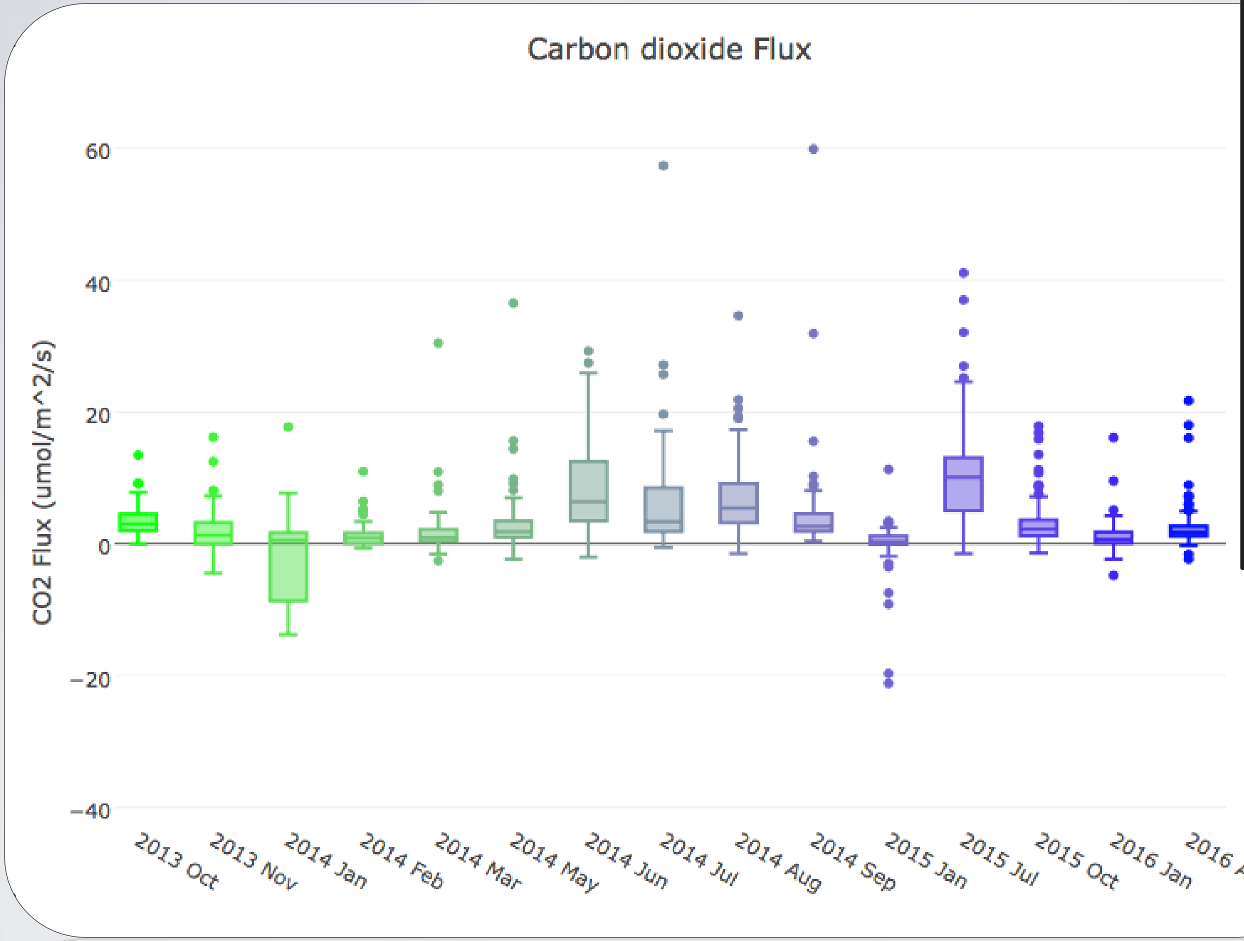
Tracking CO_2 Migration and Fate:

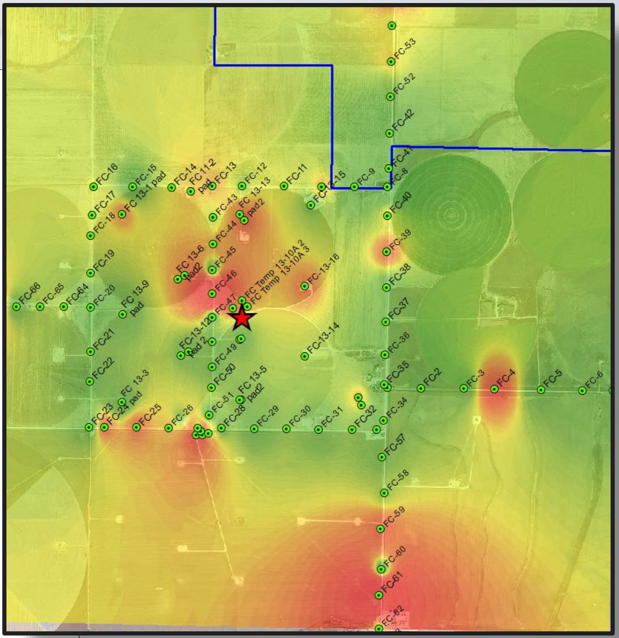
- *In situ* pressure & temperature
- 2D/3D seismic reflection surveys
- VSP and Cross-well seismic
- Passive seismic

MVA Map View


CO2 Soil Flux
(µMol/m²/sec)
0.000 - 1.570
1.571 - 3.998
3.999 - 6.422
6.423 - 8.846
8.847 - 11.270
CO₂/CH₄ Eddy Flux Tower
USDW Sampling wells
Vapor-phase atmospheric/ soil probes
Cross-well Seismic
Passive Seismometers
Repeat VSP Surveys
Self-potential
Gravimeter
Oil Production Well (with accompanying water/CO2/ tracer)
CO2/Water/Tracer Injection Well
Image Layer:
USGS 1:24000 Quads
(Waka, Sourdough Creek Nw & Farnsworth)
Projection: UTM zone 14 NAD 83
units: meters
Date: Aug 12, 2015
0.8
Miles
N

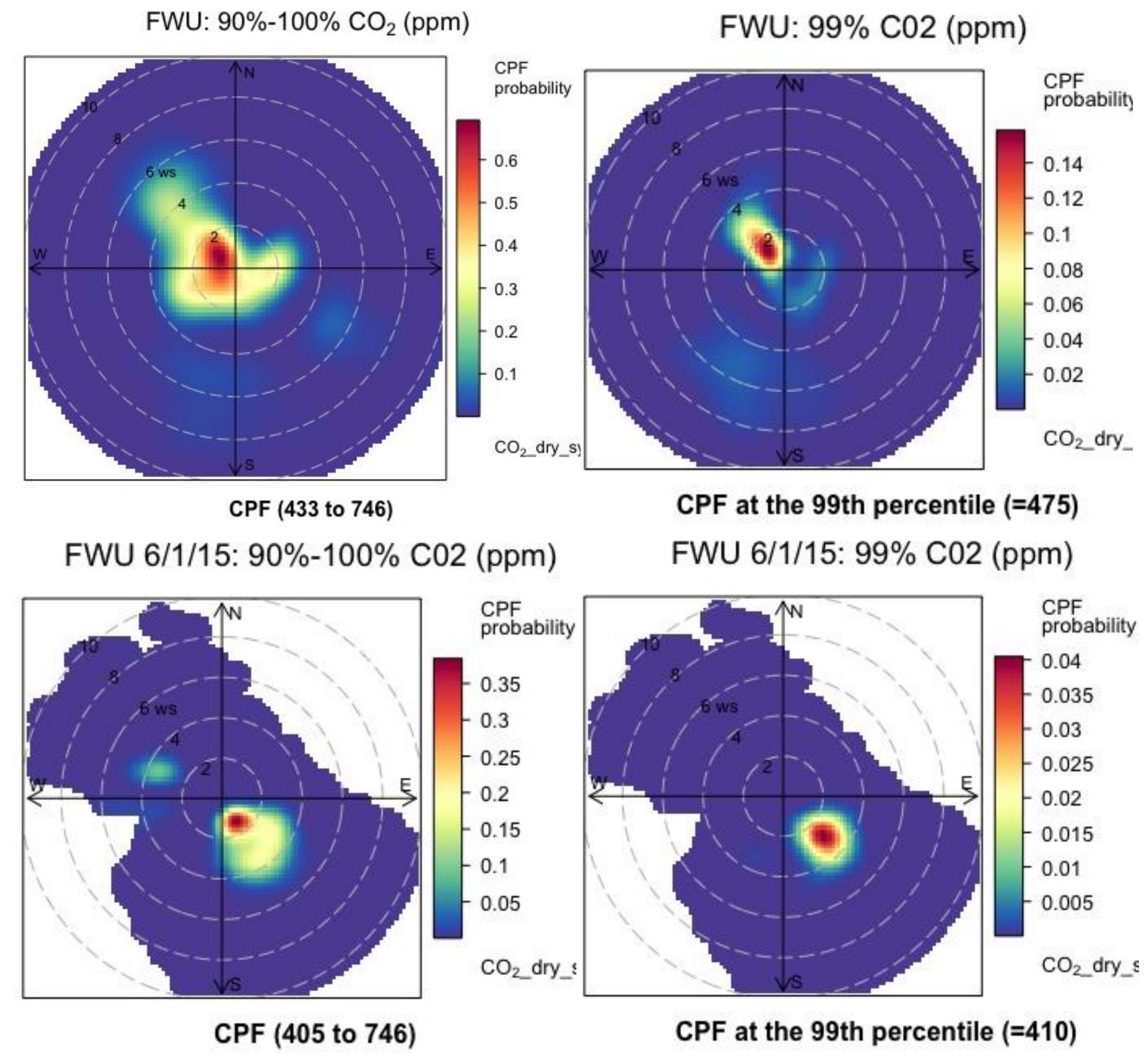
SWP CO_2 Flux – Soil Flux Results





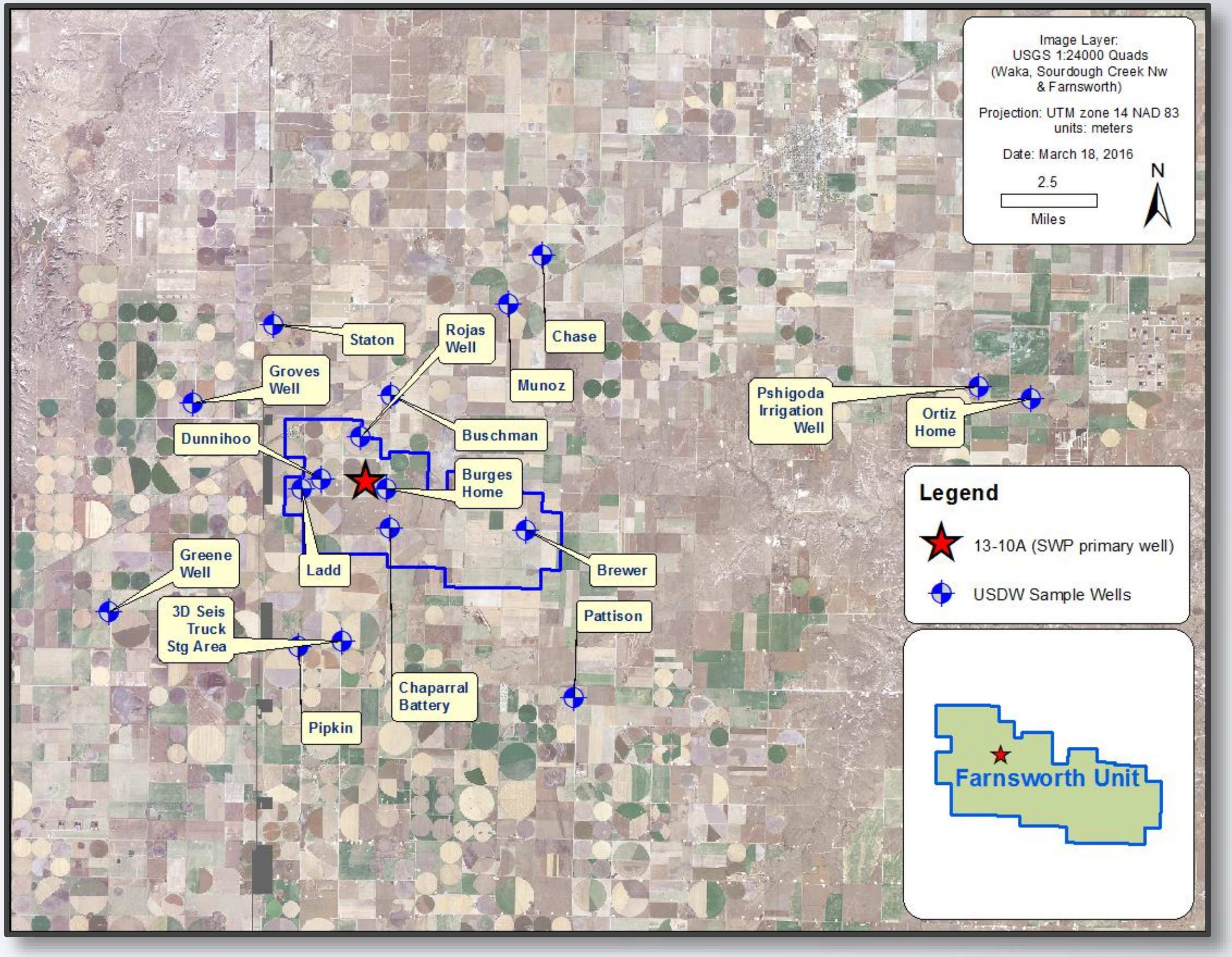
SWP CO_2 Flux – Eddy Covariance

- FWU Data
  - Top: All data. Looking at 90%-100% concentration CO_2 (left) and 99% CO_2 (right)
  - Bottom: 6/1/2015. Looking at 90%-100% concentration CO_2 (left) and 99% CO_2 (right)



SWP MVA Overview – Near Surface Monitoring

- USDW
  - Quarterly sampling of Ogallala aquifer to monitor for brine, oil and/or CO_2 leakage from depth.
  - Major Cations/ Anions
  - pH
  - Conductivity
  - Alkalinity
  - Oxidation and Reduction Potentials (ORP)
  - Inorganic Carbon (IC) and Organic Carbon (OC)
  - Trace Metals
  - Isotopes (^{13}C, ^{18}O, and D)



SWP MVA Overview – Near Surface Monitoring

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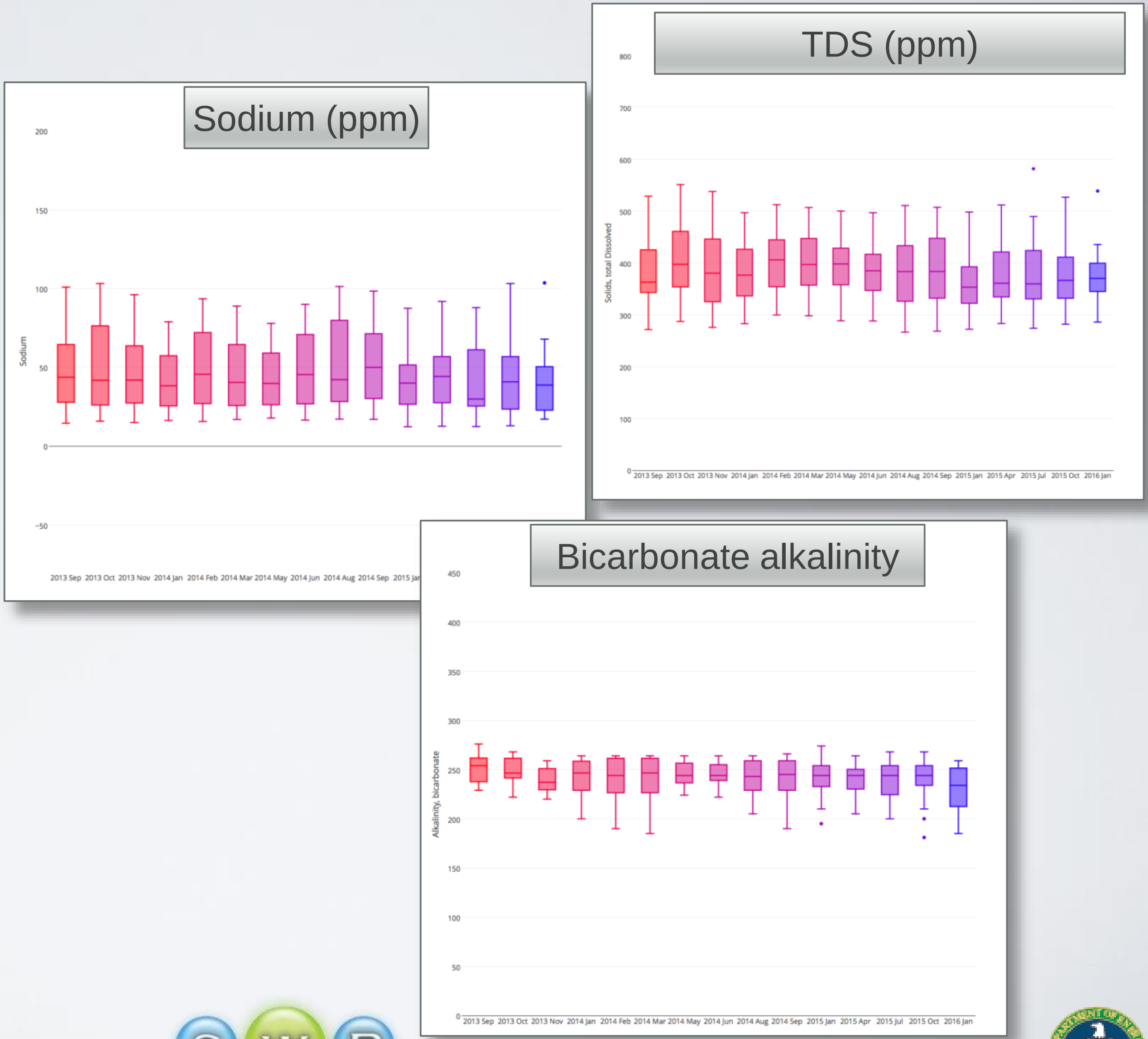
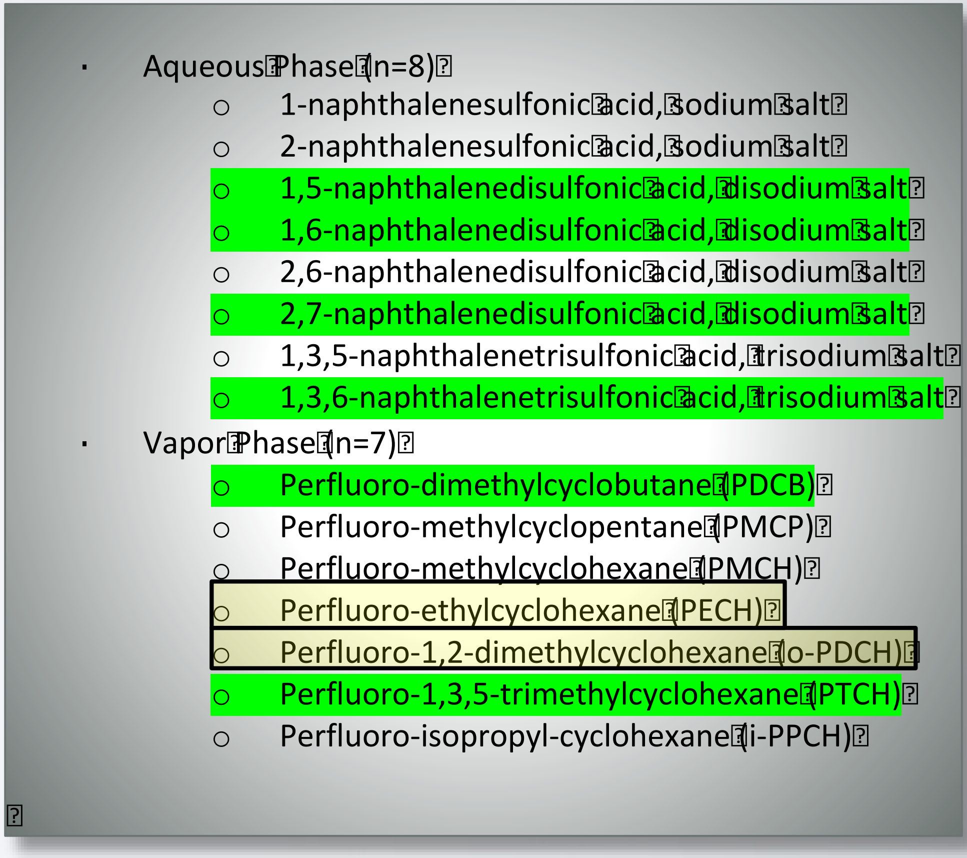


SWP MVA Overview – Tracer Studies

- Tracers – Aqueous- and Vapor-Phase
  - Aqueous Phase: naphthalene sulfonates; conservative tracers that follow water phase (Pete Rose – University of Utah).
  - Up to 8 unique aqueous-phase tracers available.
  - Vapor Phase: perfluorocarbons; conservative tracers that follow gas phase (Rod Diehl – NETL).
  - Up to 7 unique vapor-phase tracers available.
  - Oil Phase: Not planned at this time.

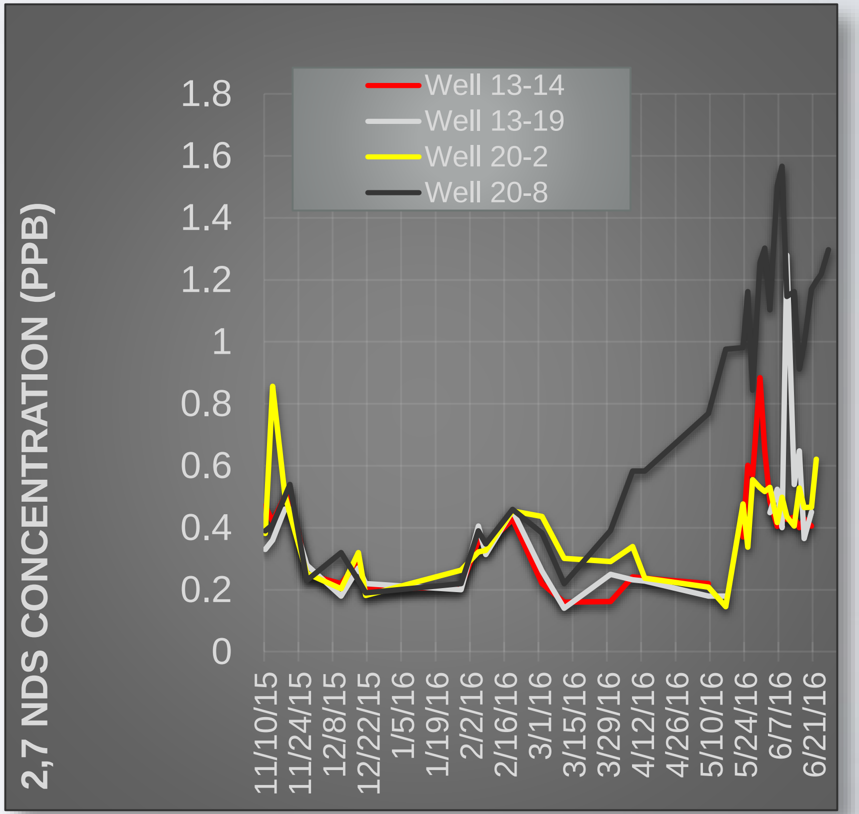
Tracer suite available for use at the FWU; green highlighted tracers already injected at FWU.



- Aqueous Phase (n=8)
  - 1-naphthalenesulfonic acid, sodium salt
  - 2-naphthalenesulfonic acid, sodium salt
  - 1,5-naphthalenedisulfonic acid, disodium salt
  - 1,6-naphthalenedisulfonic acid, disodium salt
  - 2,6-naphthalenedisulfonic acid, disodium salt
  - 2,7-naphthalenedisulfonic acid, disodium salt
  - 1,3,5-naphthalenetrisulfonic acid, trisodium salt
  - 1,3,6-naphthalenetrisulfonic acid, trisodium salt
- Vapor Phase (n=7)
  - Perfluoro-dimethylcyclobutane (PDCB)
  - Perfluoro-methylcyclopentane (PMCP)
  - Perfluoro-methylcyclohexane (PMCH)
  - Perfluoro-ethylcyclohexane (PECH)
  - Perfluoro-1,2-dimethylcyclohexane (o-PDCH)
  - Perfluoro-1,3,5-trimethylcyclohexane (PTCH)
  - Perfluoro-isopropyl-cyclohexane (i-PPCH)

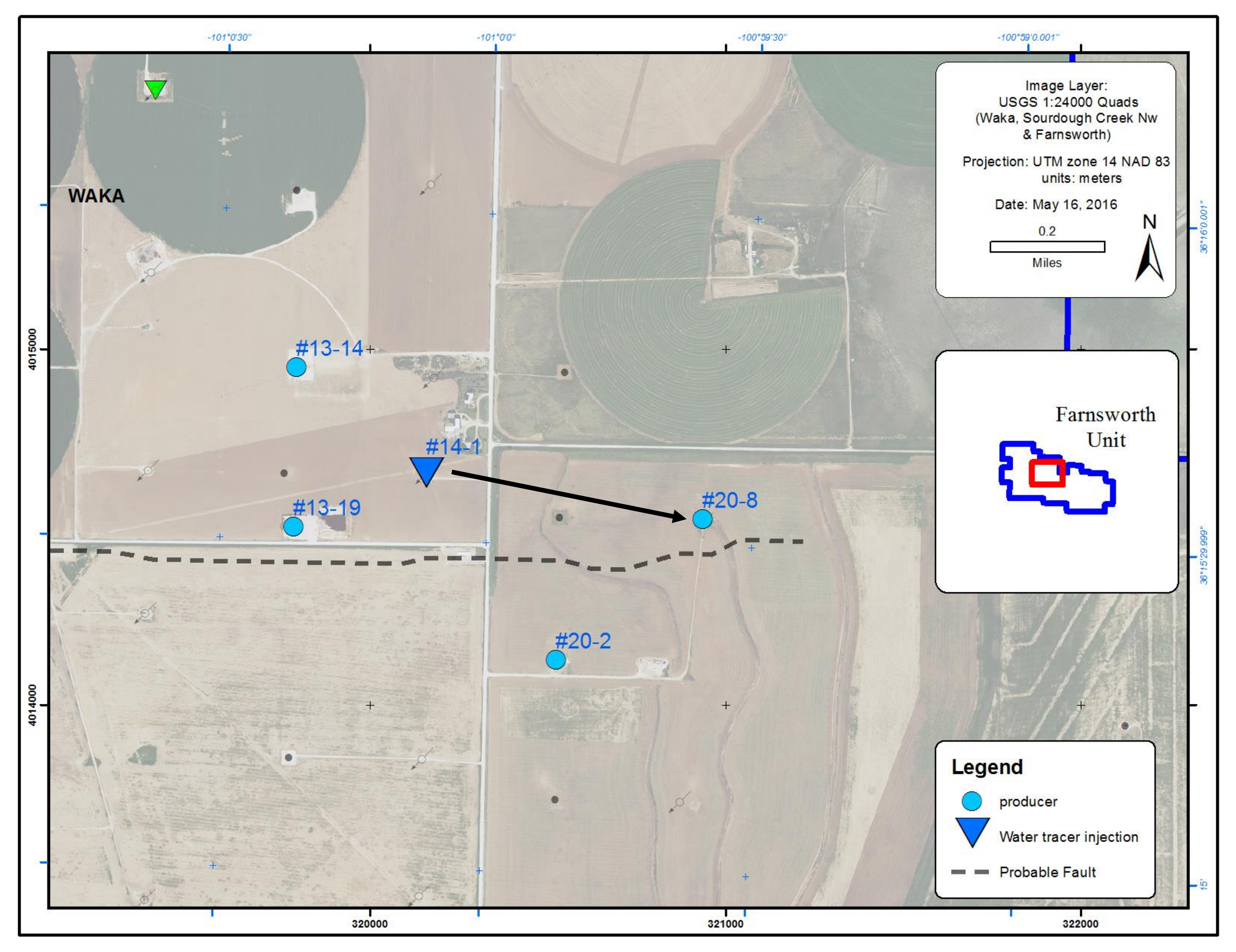
SWP MVA Overview – Aqueous Tracers

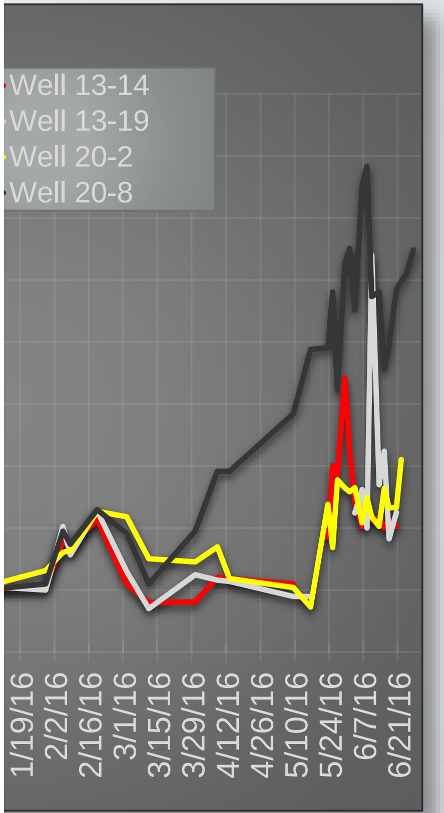
- **Tracers – Aqueous-phase Injection #1**
  - Three FWU wells (on water flood) tagged with unique tracers in May, 2014
  - Additional ~3 days of water injection, followed by CO_2 flood
  - Never observed breakthrough!
- **Tracers – Aqueous-phase Injection #2**
  - FWU well (on water flood) tagged with tracer in October, 2015
    - Well #14-1: 2,7-Naphthalenedisulfonic acid, disodium salt
    - 2 to 4 times the amount of NPT injected into previous wells
  - No switch to CO_2
  - Breakthrough for FWU #20-8



SWP MVA Overview – Aqueous Tracers

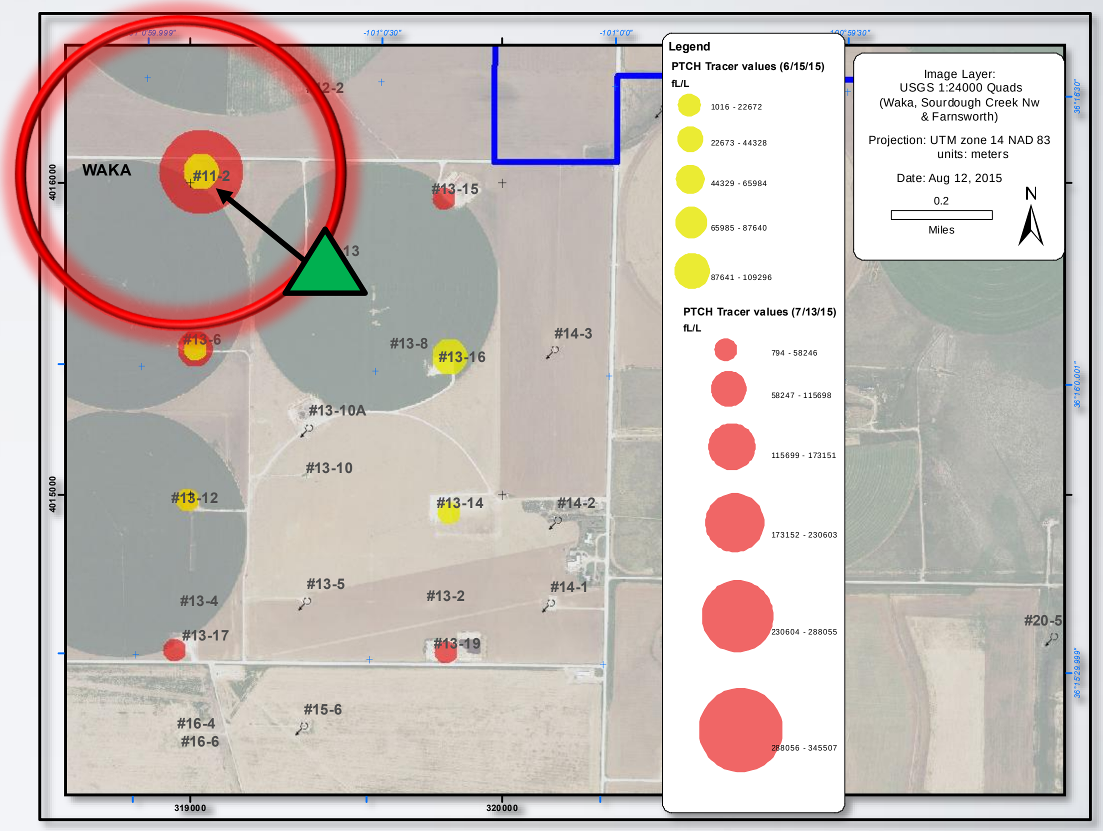
acers in





SWP MVA Overview – Gas Phase Tracers

- Tracers – Vapor-Phase Injection #1
  - FWU well (on CO_2 flood) tagged with tracer in May, 2015
    - Well #13-13: PTCH (2 kg)
  - Additional ~30 days of CO_2 injection
  - Every other week to weekly sampling of production wells
  - "Breakthrough" after 2 to 4 weeks! (fast path or "short circuit" between 13-13 and 11-2)

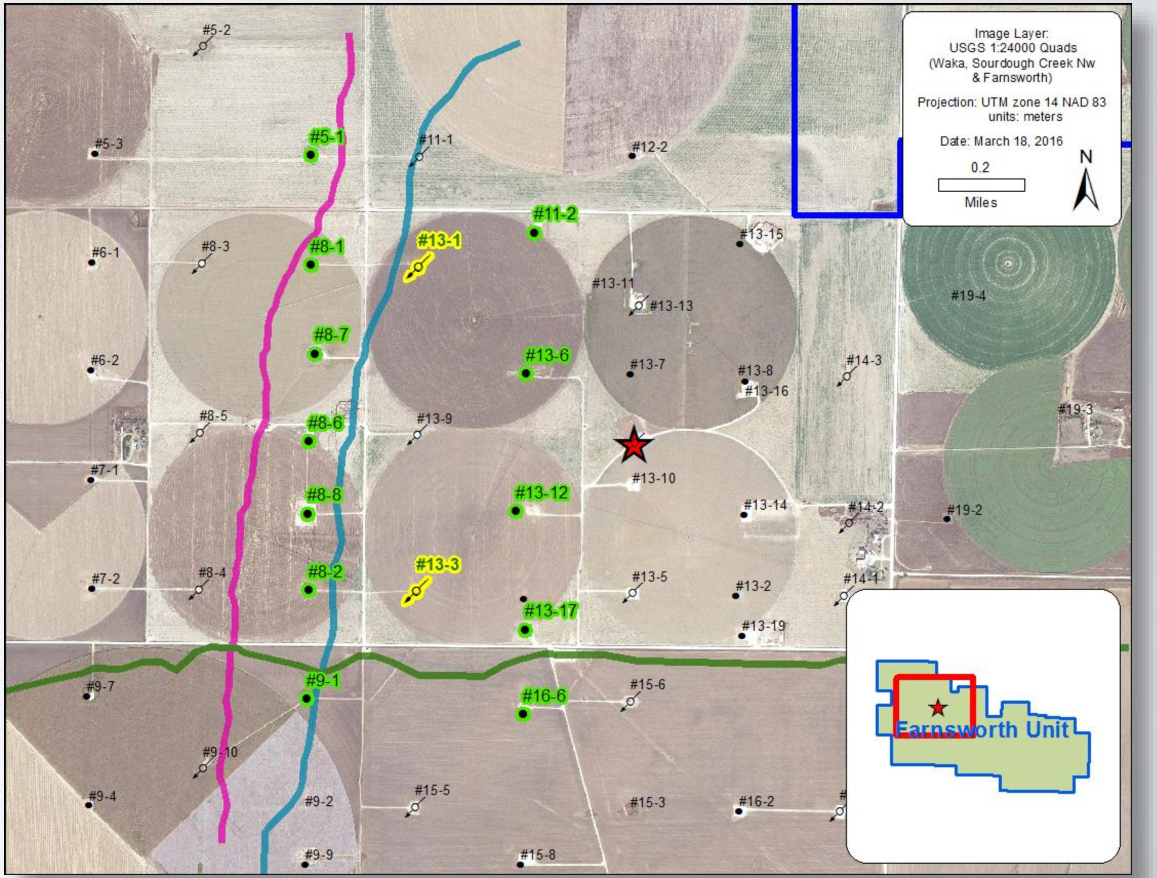


SWP MVA Overview – Gas Phase Tracers

- Tracers – Vapor-Phase Injection #2
  - FWU well (on CO_2 flood) tagged with tracer in November, 2015
    - Well #13-10A: PDCB (1kg)
  - Additional ~30 days of CO_2 injection
  - High frequency sampling (wells & recycled CO_2)
  - Modification of sampling procedures
  - Waiting for break-through

SWP MVA Overview – Gas Phase Tracers

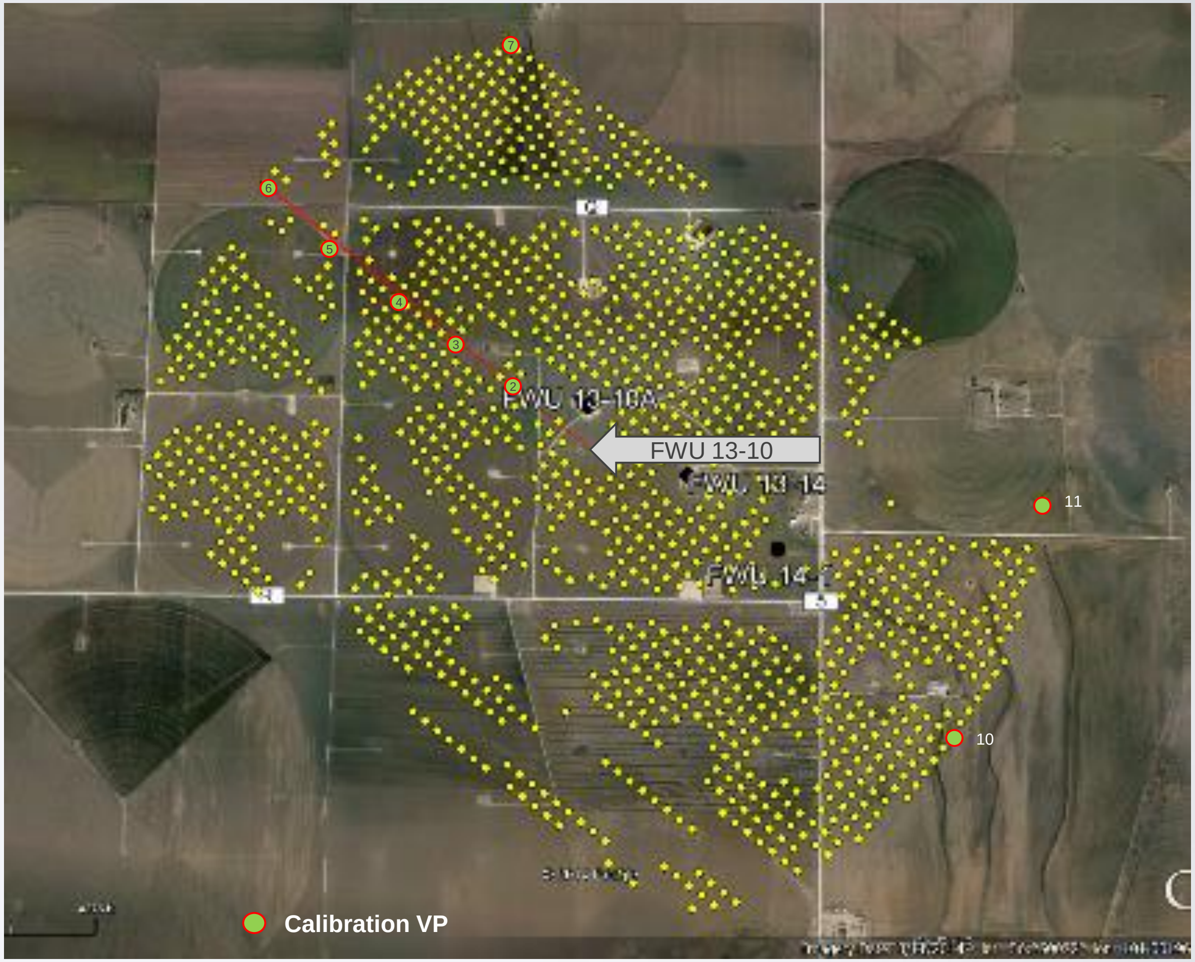
- Tracers – Vapor-Phase Injection #3
  - Two additional FWU wells (on CO_2 flood) tagged with tracer in May, 2016
    - Well #13-1: PMCH (0.5kg)
    - Well #13-3: PECH (0.5 kg)
  - Evaluate influence of faults.
  - High frequency sampling (12 wells & recycled CO_2)
  - No breakthrough after 2 months



SWP MVA Overview – Time Lapse 3D VSP

Data Acquired February 2014 and January 2015

- Processed by WesternGeco and delivered June 2015
- Processing 1st and second 13-10a VSPs with ~30,000 Metric tonnes CO2 injected
- Excellent repeatability
- Acquired calibration VSP data for micro-seismic array
- Cursory differencing inconclusive



SWP MVA Overview – Time Lapse 3D VSP

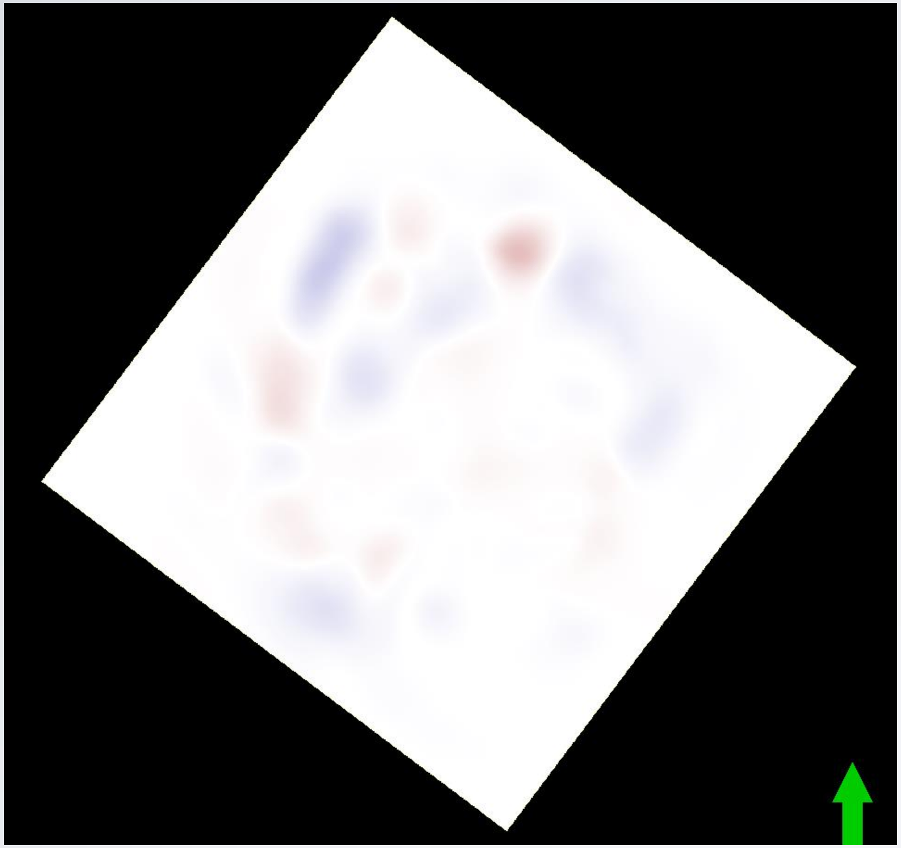
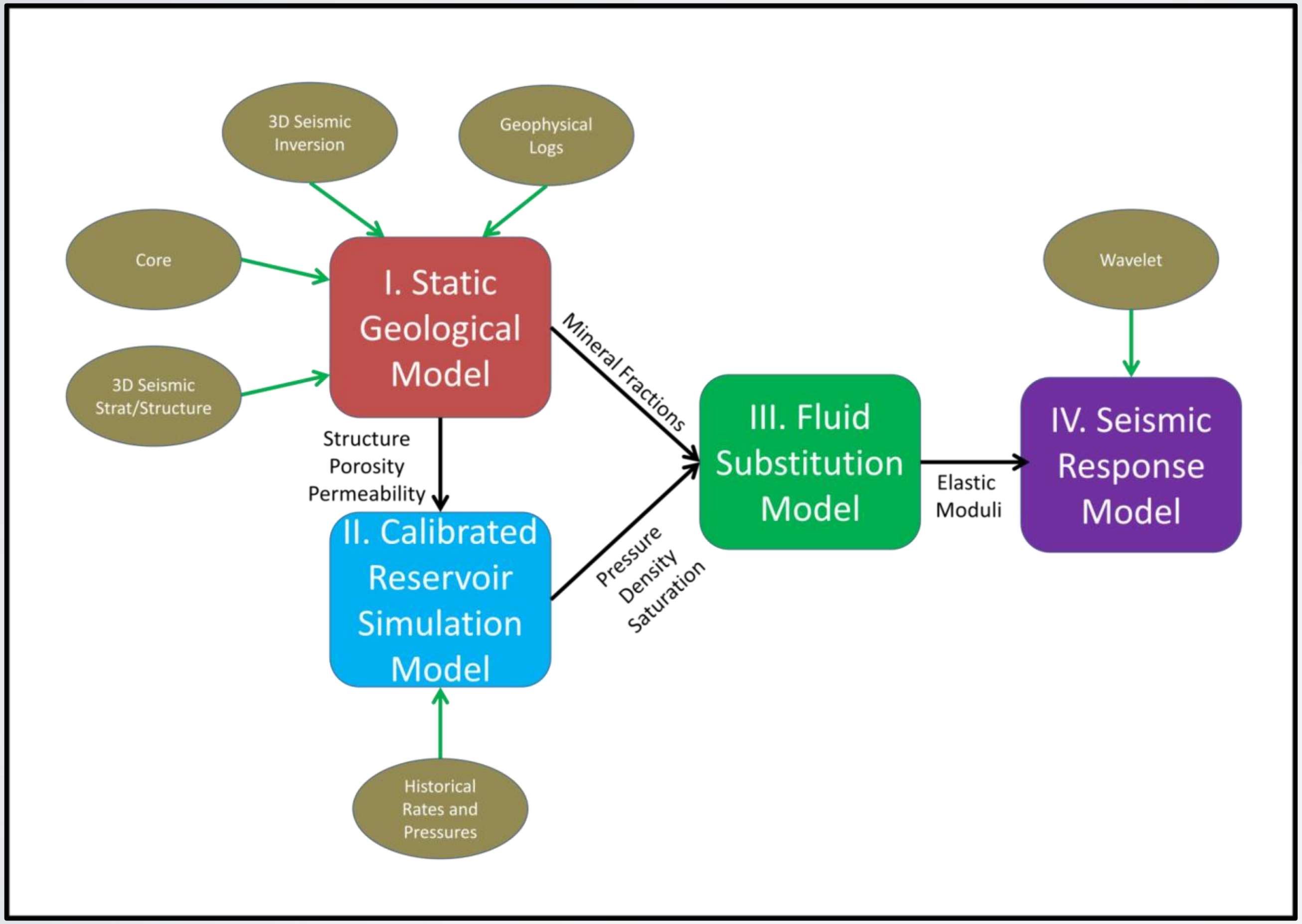


IMAGE DIFFERENCE SLICES
AT SRD DEPTH 7800 FT.

- **Model can be populated with fluids for multiple cases**
  - **Post waterflood**
  - Post 30,000 tonnes injection, etc.
- **Fluid filled models can have synthetic seismic generated from them**
  - Can difference to find expected response at varying CO2 injection levels
  - Useful for determining detection thresholds
  - Help determine timing of future VSP repeats

SWP MVA Overview – Time Lapse 3D VSP

Fluid Substitution modeling – work flow



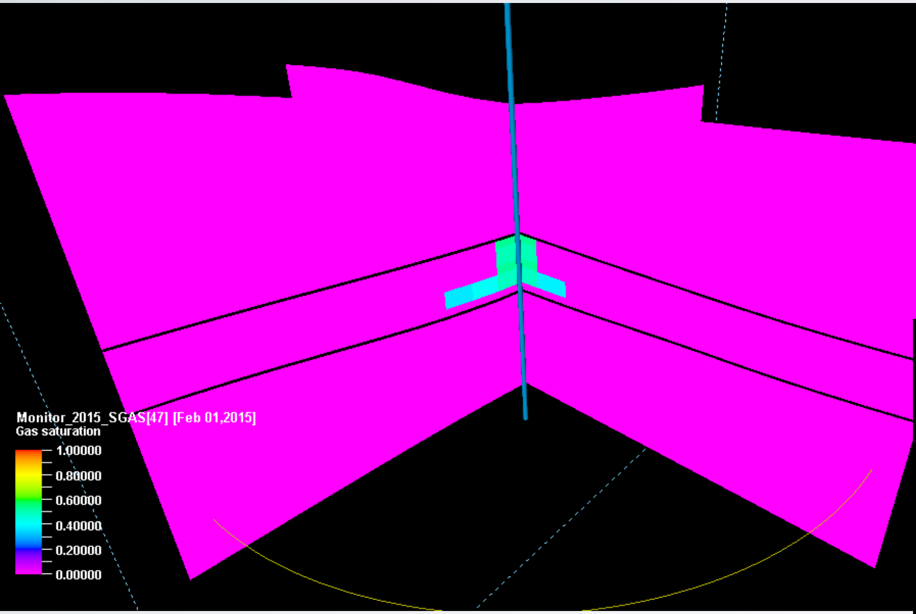
I. Modeling begins by development of a static geologic model using all available data such as logs, core, inversion, and seismic stratigraphy and structure

II. The fine scale geologic model is history matched, and then used to predict the fluid state of the reservoir at various times corresponding to different CO2 injection volumes

III. The fluid substitutions can change the elastic properties of the rock, which can then impact the seismic response

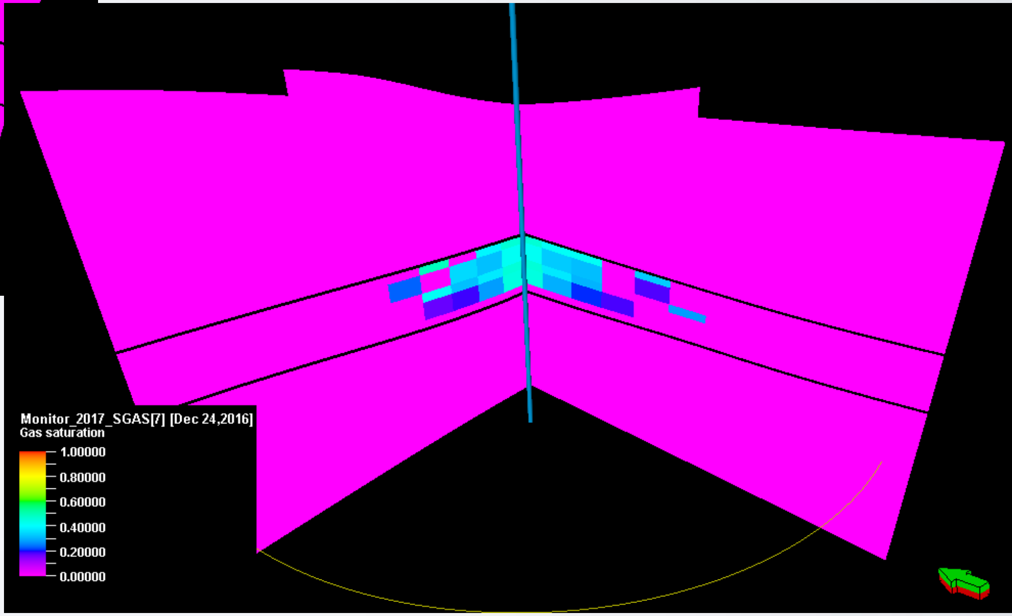
SWP MVA Overview – Time Lapse 3D VSP

Property Changes – CO_2 Saturation



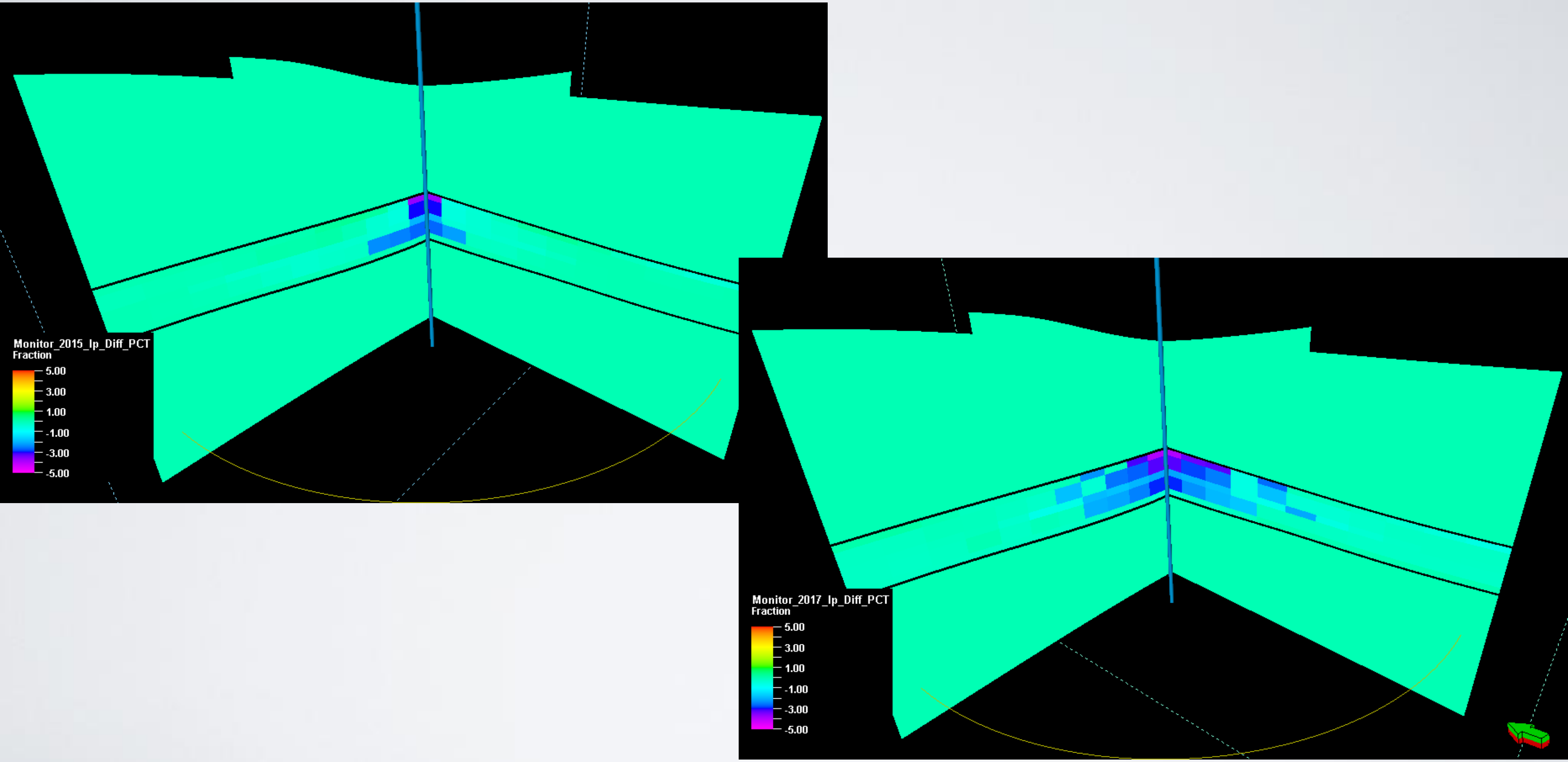
2015 Monitor

Proposed 2017 Monitor



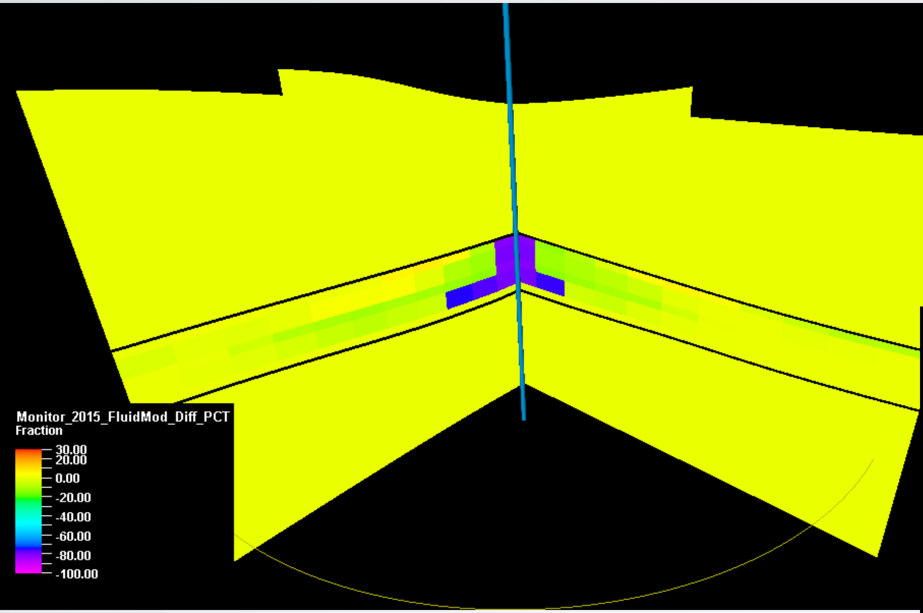
SWP MVA Overview – Time Lapse 3D VSP

Property changes - % Acoustic impedance



SWP MVA Overview – Time Lapse 3D VSP

Property changes - % fluid modulus



2015 Monitor

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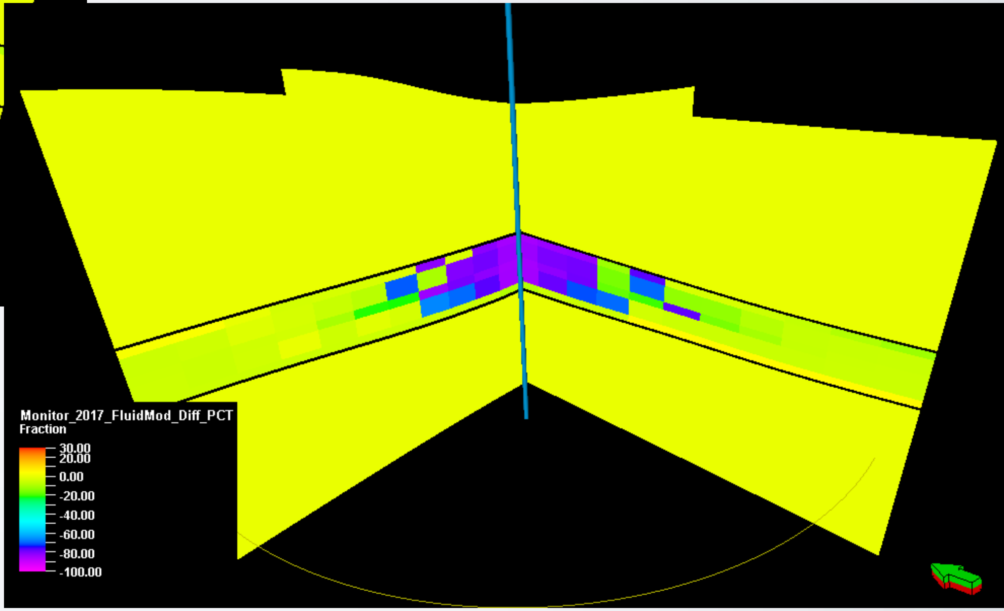
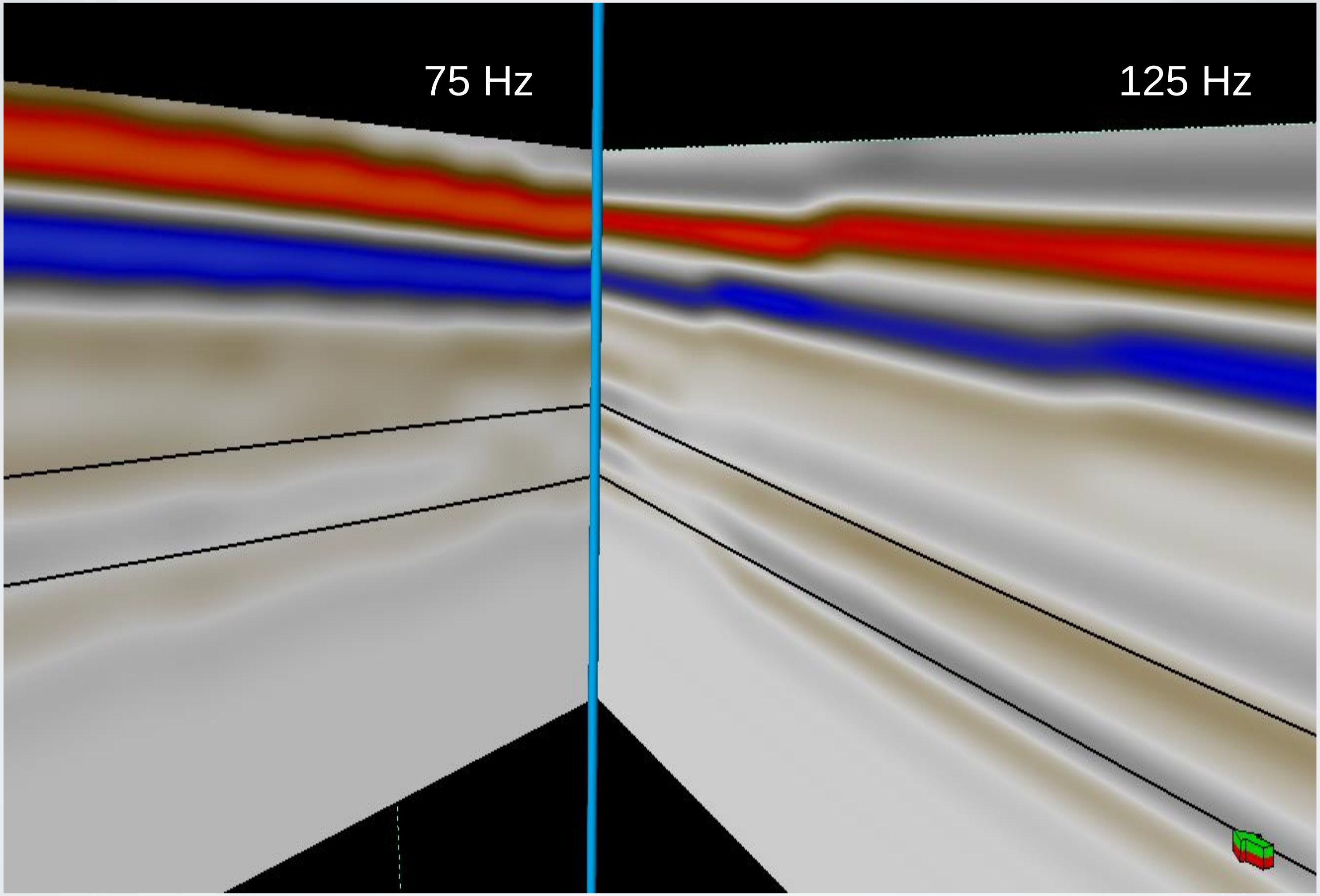


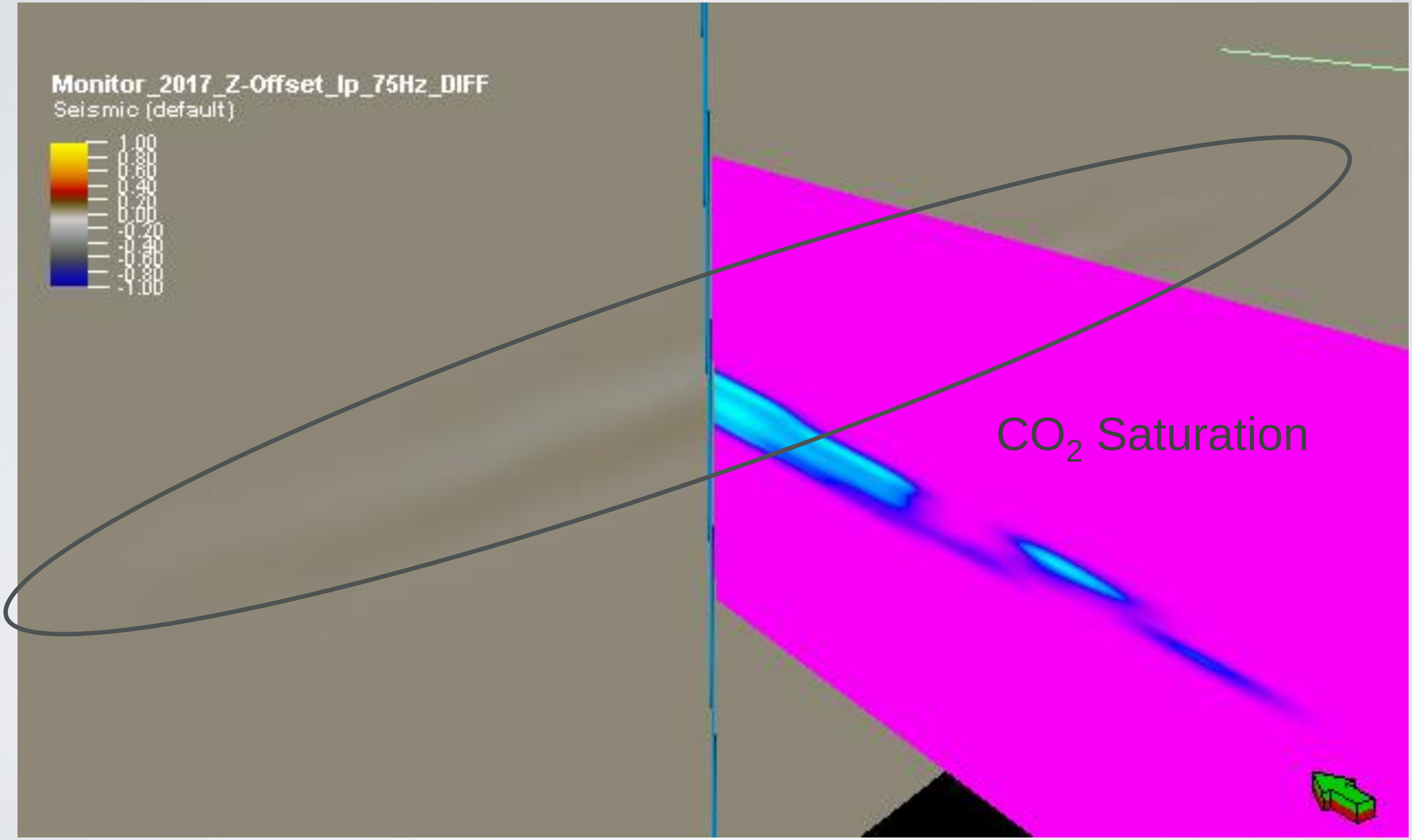
SWP MVA Overview – Time Lapse 3D VSP

Modeled (synthetic) seismic survey



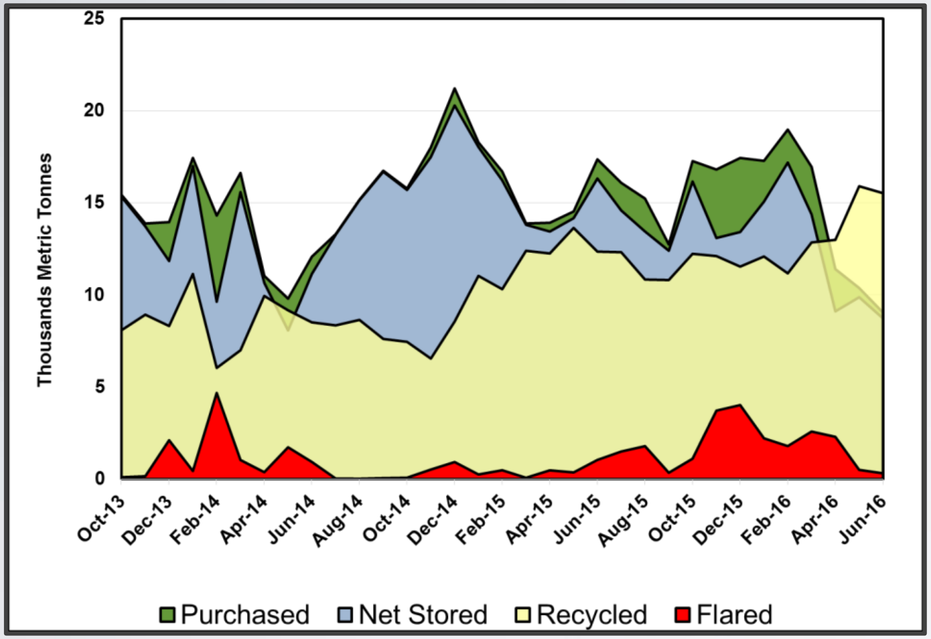
SWP MVA Overview – Time Lapse 3D VSP

Proposed 2017 Monitor Survey (75 HZ)



CO_2 Saturation

SWP MVA Overview – Accounting

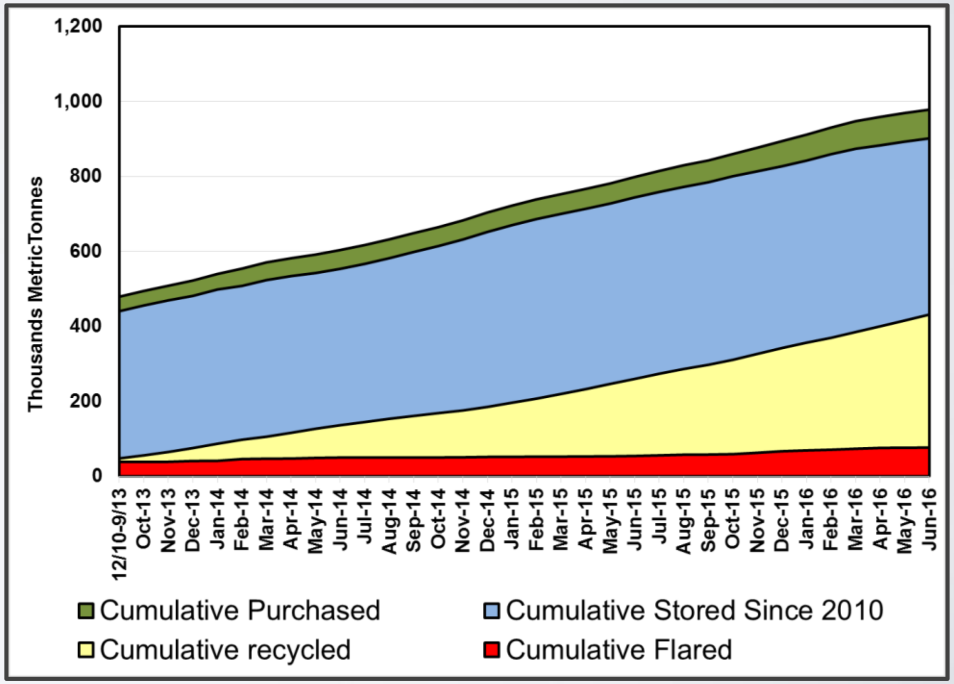


Monthly accounting since October of 2013

92.2% of purchased CO_2 still in the system

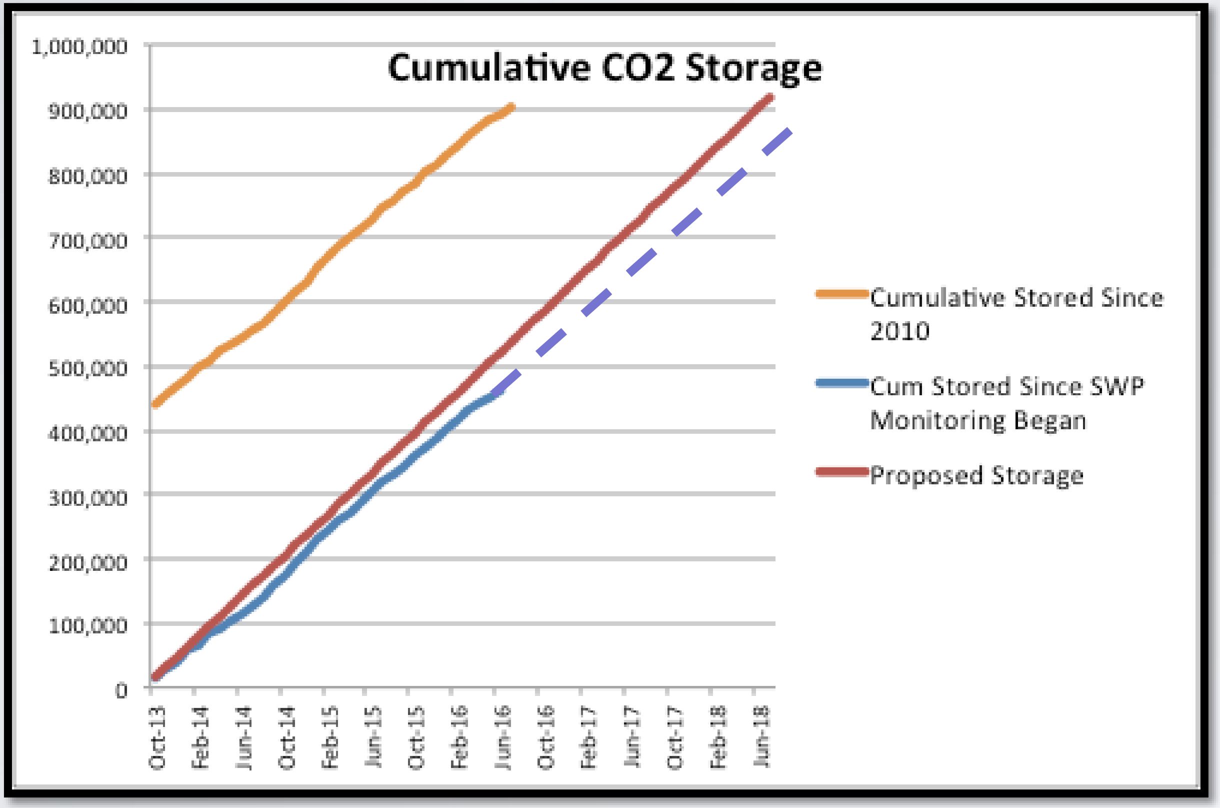
Cumulative CO_2 storage since December 2010

92.1% of purchased CO_2 has been stored



SWP MVA Overview – Accounting

CUMULATIVE CO_2 UTILIZATION THROUGH 7/2016

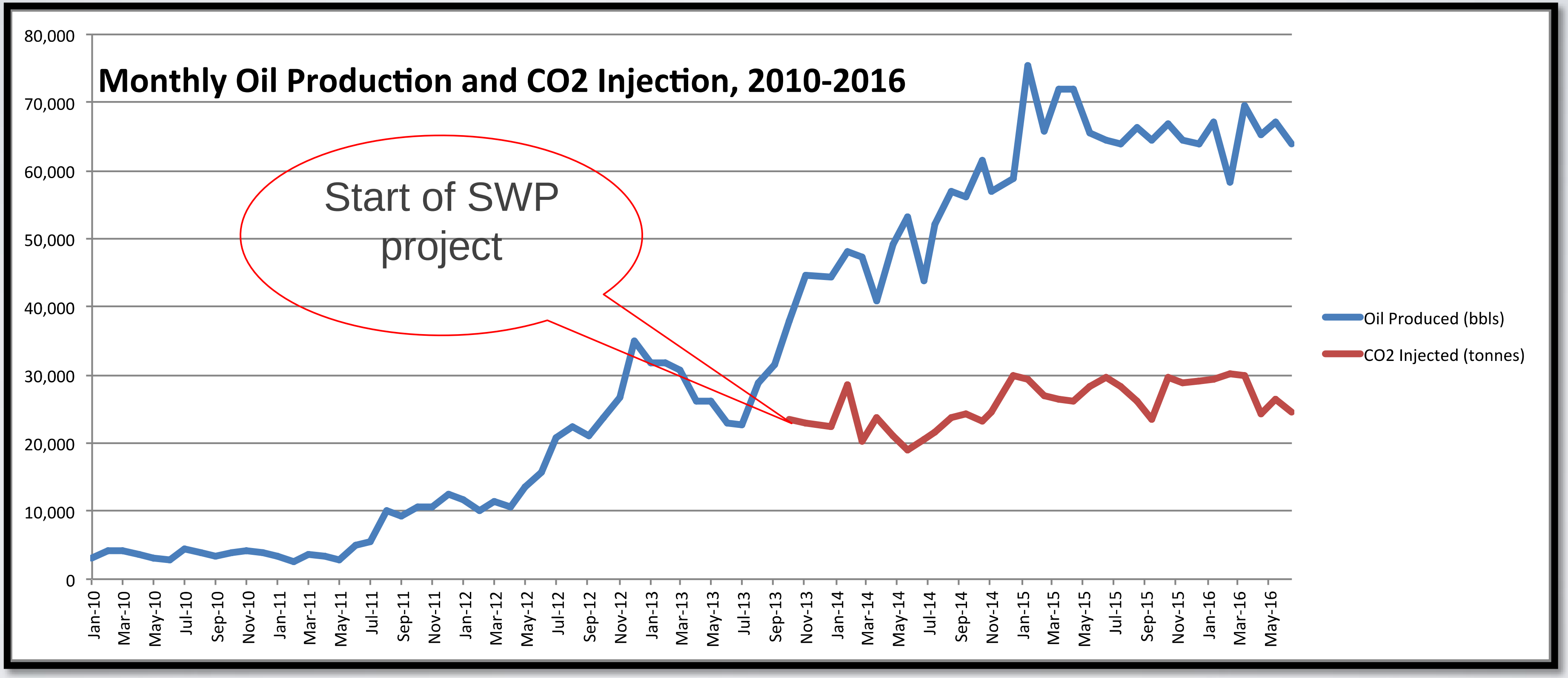


Cumulative	Phase III	FWU Total
Purchased	499,100	978,278
Produced	383,771	470,338
Recycled	346,665	394,570
Flared	38,059	76,721
Injected	845,765	1,372,848
Net Stored	**461,040**	**901,556**

*all figures in tonnes

SWP MVA Overview – Accounting

MONTHLY OIL PRODUCTION THROUGH 7/2016



Monthly Oil Production and CO2 Injection, 2010-2016

Start of SWP project

Conclusions and Ongoing Work

- The Southwest Partnership's demonstration project at Farnsworth field highlights enhanced recovery with ~92% carbon storage
- Extensive characterization, modeling, simulation, and monitoring studies have demonstrated long term storage security
- Continuous geologic characterization;
- Annual updated geo-model;
- Continuous history match;
- Continuous monitoring (ongoing);
- New risk registry and assessment;
- Effective best practices for CCS must include an adequate MVA program
- ***To date and after nearly 3 years of monitoring no leaks to the atmosphere, ground water, or secondary reservoirs have been detected at Farnsworth using a wide array of detection technologies***

Acknowledgements

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