U.S. DOE Project DE FE0009284

Statistical Analysis of CO_2 Exposed Wells to Predict Long Term Leakage through the Development of an Integrated Neural-Genetic Algorithm

A Collaborative Project

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Outline

- Objective of Project
- Methodology
- Project Schedule
- Progress Update
  - Software Development
  - Field Work
- Summary

Objective of Project

The overall objective of this project is the development of a novel computer model for predicting long-term leakage risks of wells exposed to CO_2.

The final goal is to deliver DOE and public a useful tool for evaluating the risk of long-term leakage of wells in future CO_2 sequestration projects.

The overall objective is achieved by accomplishing the following specific objectives in different stages of project execution:

- **Create likely leakage scenarios for specific well attributes** (injection wells, producing wells, abandoned wells, and wells subjected to corrosion). The goal of this stage is to understand the major leak mechanisms in different well conditions.
- **Develop a neural-genetic algorithm model to predict leakage risks for CO_2 –exposed wells.** The goal of this stage is to develop a comprehensive computer model ready to be validated using field data.
- **Verify model results by conducting field sampling** including side wall cores samples, pressure testing data, and well logs of existing wells and compare the results with the model's results. This is a stage to verify the accuracy of the computer model with field data.

Methodology

- Advanced Statistical Analysis
  - **Neural-Genetic Algorithm (NGA)** (the Genetic Algorithm will generate initial and new polulations, and the Neural Network will enhance the capacity of the genetic algorithm i.e., model training with field data)
  - **Computer programming** (coding the NGA in a computer language)
  - **Model validation with field data** (comparison of model output and field observations)
- Multidisciplinary Team Work
  - **Guo's group in UL Lafayette** (University of Louisiana at Lafayette)

    - Data collection, leakage of active wells, NGA, field sample analysis, model validation, and risk study.
  - **Nygaard's group in Missouri U. S&T** (Missouri University of Science and Technology)

    - MIT (Mechnical Integrity Testing) and drilling data interpretation, statistical analysis, leakage of abandoned wells, and risk study.
  - **Duguid's group in Schlumberger**

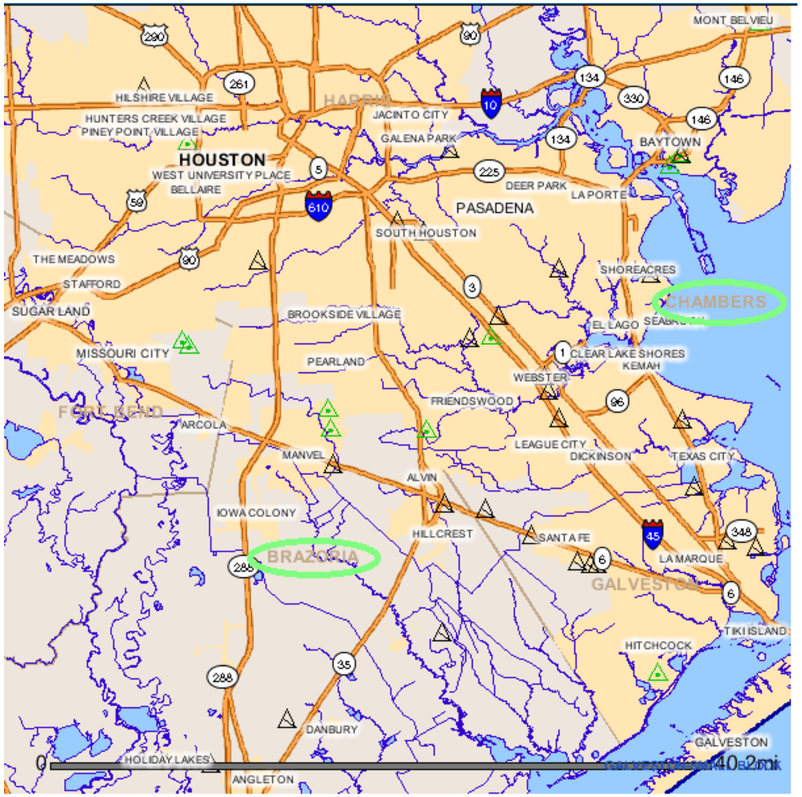
    - Log data interpretation, corrosion leakage, field work, and risk study.

Project Schedule

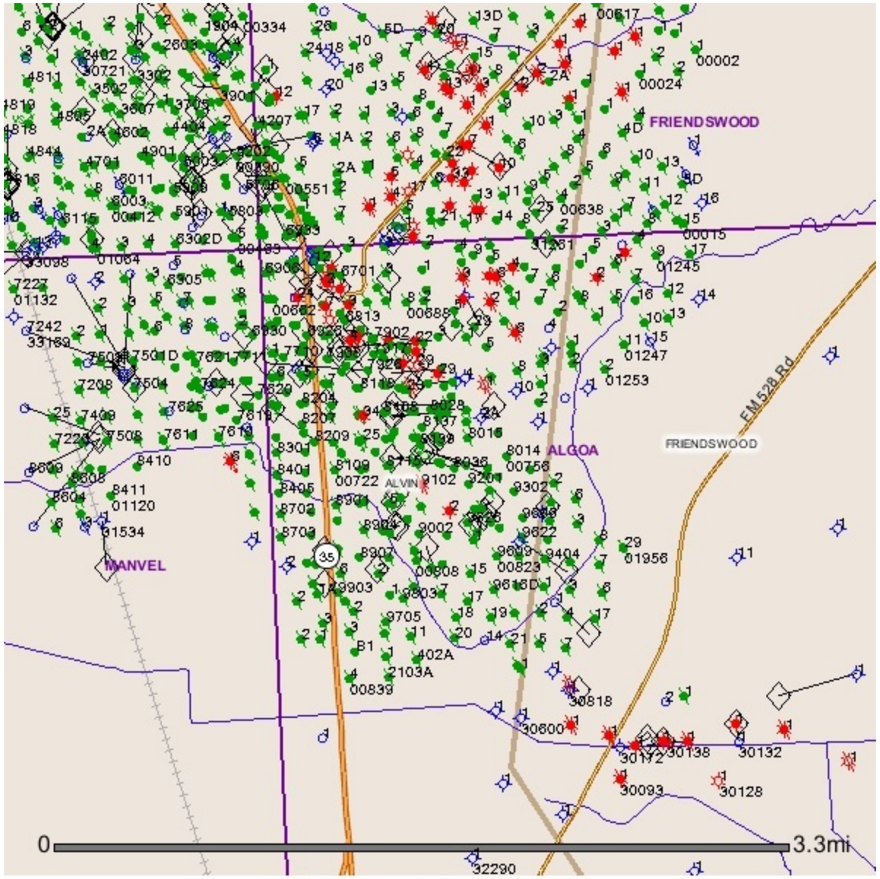
Year	2013				2014				2015				Team Member and Role
Quarter	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
Task 1: Project Management and Planning													Guo (PI), Nygaard (Co-PI), Duguid (Co-PI)
Task 2: Data Mining													Guo (PI), Nygaard (Co-PI), Duguid (Co-PI)
Task 3: Statistical Analysis of Database				Phase I				Phase II					Nygaard (Co-PI)
Task 4: Developing Leakage Scenarios													Guo (PI), Nygaard (Co-PI), Duguid (Co-PI)
Task 5: Constructing Preliminary Neural-Genetic Algorithm													Guo (PI), Sedaghat and Li (programmers)

Year	2014				2015				2016				Team Member and Role
Quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	
Task 6: Constructing Comprehensive Neural-Genetic Algorithm													Guo (PI), Sedaghat and Li (programmers)
Task 7: Field Work Confirmation of Leakage Scenarios													Duguid (Co-PI)
Task 8: Field Sample Analysis				Phase II				Phase III					Guo (PI), Sedaghat and Li (data analysts)
Task 9: Verification of Model with Field and Lab Results													Guo (PI), Sedaghat and Li (data analysts)
Task 10: Risk Study, Mitigation Actions, and Standard Recommendations													Guo (PI), Nygaard (Co-PI), Duguid (Co-PI)

Review of Phase I



Oyster Bayou Oil field



West Hastings Oil Field

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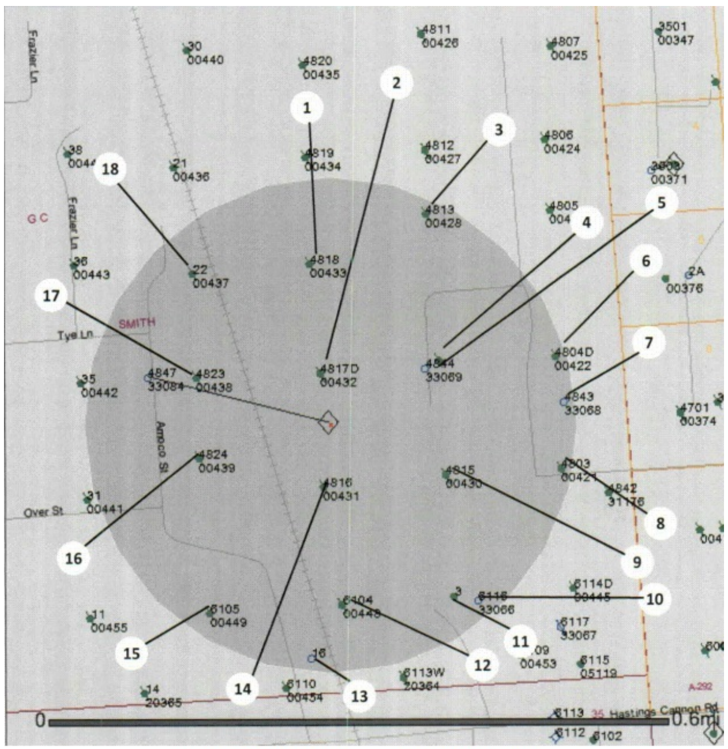


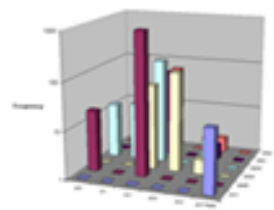
1/4 Mile Radius of Well 4847

Oil Field	CO_2 Injection Wells	Plugged Wells	Subtotal
Oyster Bayou	56	372	428
West Hastings	27	55	82
TOTAL	83	427	510

510 wells with 72 parameter values for each well

- Well's General Information (Type, age, depth, location,...)
- Cementing Information (type, design,...)
- Well abandonment detail (if well has abandoned)
- Completion Information (Completion type, Perforation,...)
- Well integrity Information (MIT, incident reports,...)
- Geomechanical information (Rock stiffness, tectonic stresses,...)
- Other information (geological, regulatory changes,...)

→ **Wells Database** → **Statistical Analysis** → **Combined Genetic Algorithm/ Neural network (Evaluating leakage scenarios)** → **Field Verification (Side-wall cores, VIT, and Logs)** → **Risk Analysis and Workover Candidates Selection**



Progress Update - Phase II

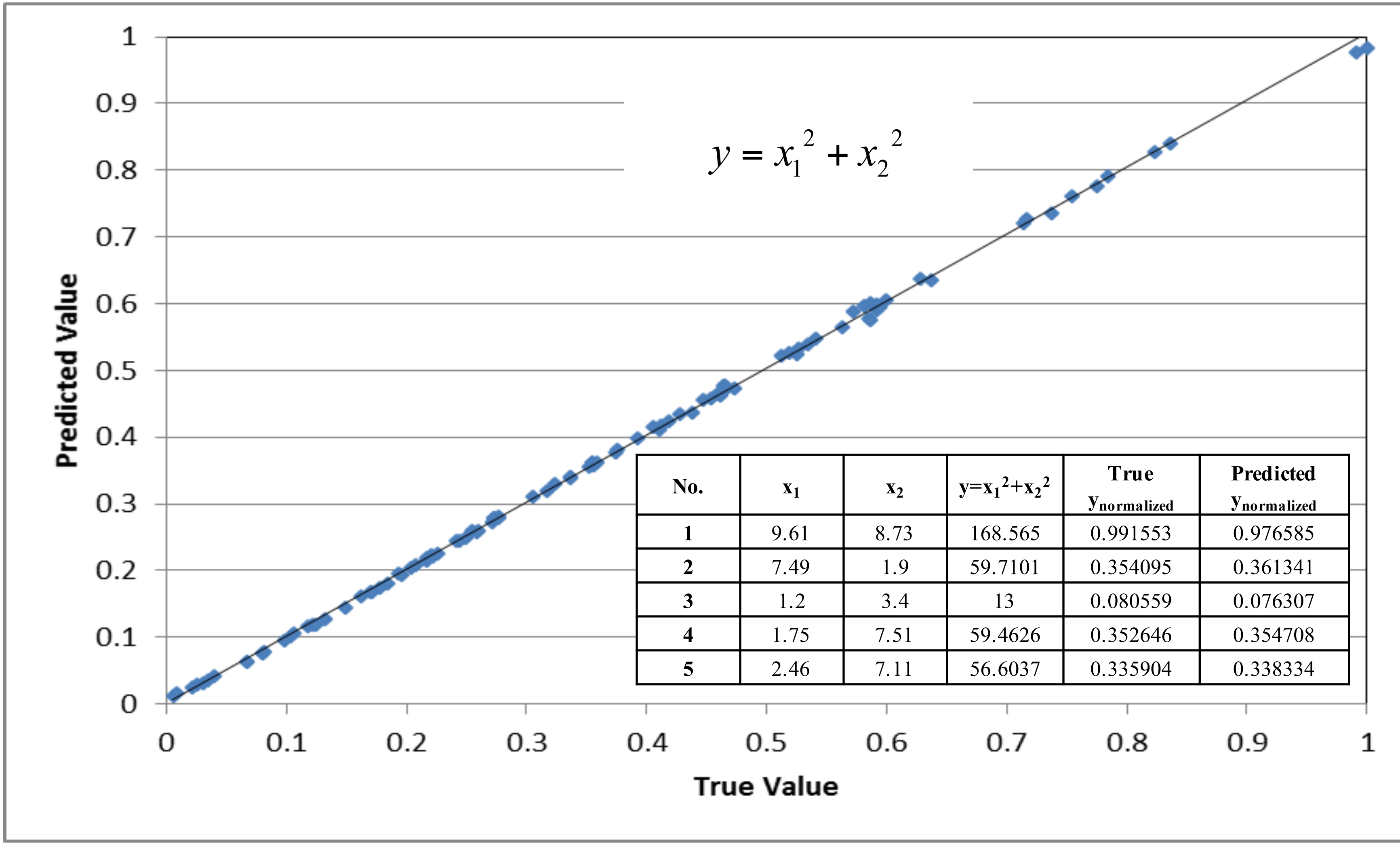
- Software Development

- Neural-Genetic Model for CO2-Explosed wells
- Finite Element Model for well integrity analysis

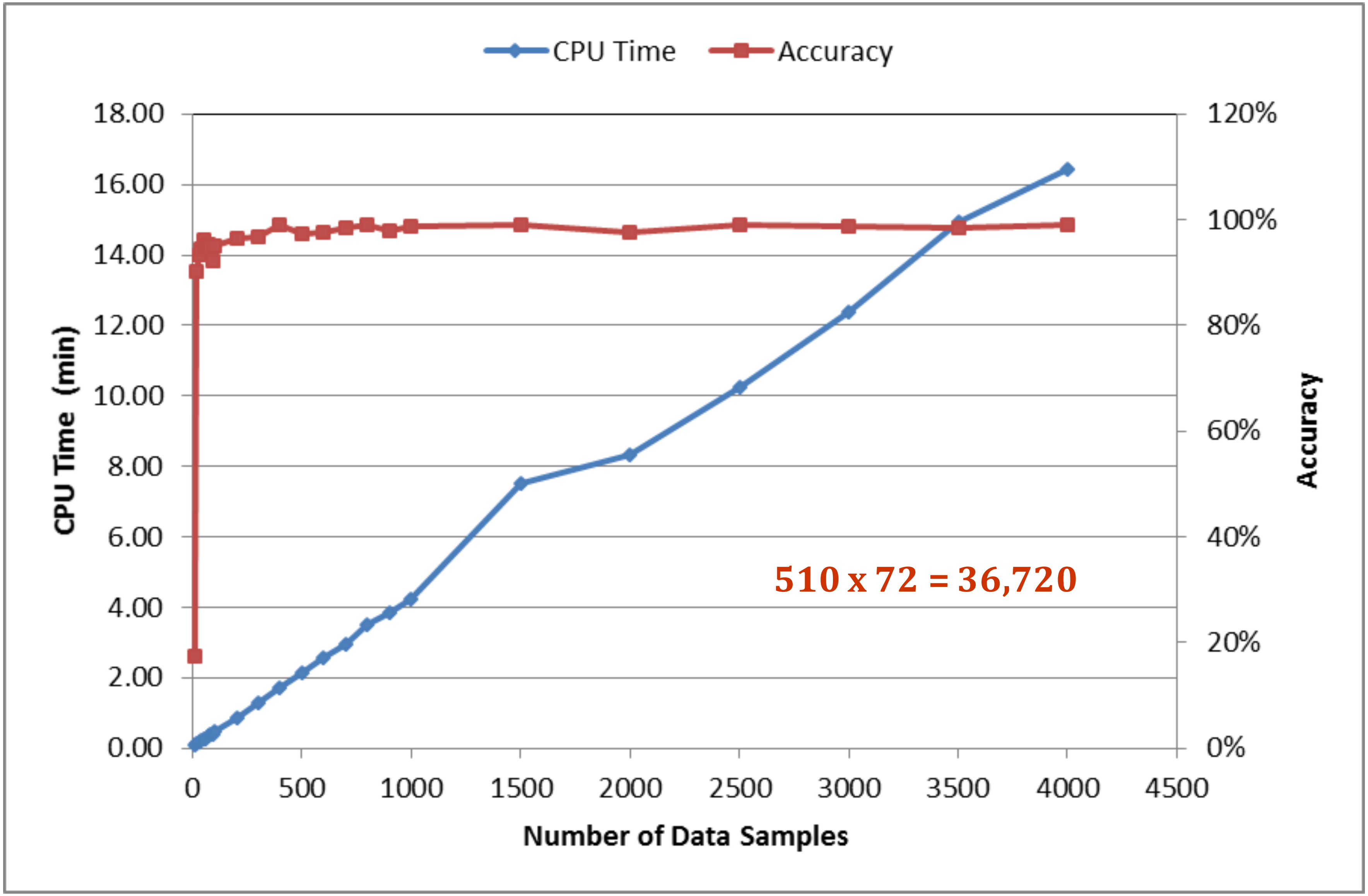
- Field Work

- logs
- Pressure transient tests
- Sidewall core samples

Neural-Genetic Model for CO2-Explosed wells



No.	x_1	x_2	$y=x_1^2+x_2^2$	True $y_{normalized}$	Predicted $y_{normalized}$
1	9.61	8.73	168.565	0.991553	0.976585
2	7.49	1.9	59.7101	0.354095	0.361341
3	1.2	3.4	13	0.080559	0.076307
4	1.75	7.51	59.4626	0.352646	0.354708
5	2.46	7.11	56.6037	0.335904	0.338334



CPU Time
Accuracy
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
120%
100%
80%
60%
40%
20%
0%
CPU Time (min)
Accuracy
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Number of Data Samples
510 x 72 = 36,720

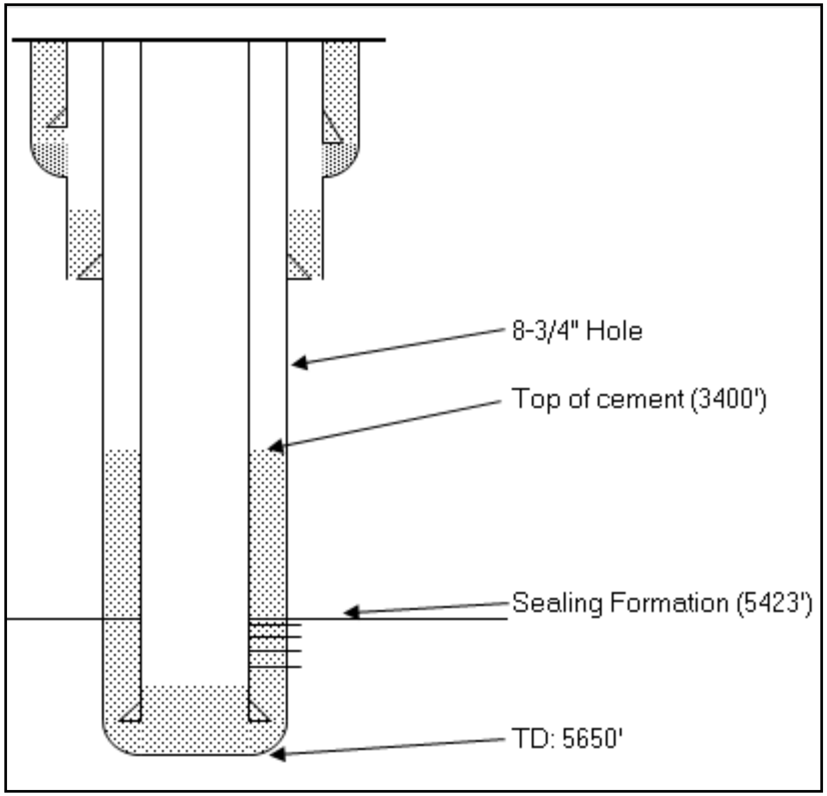
Leakage-safe Probability Index (LPI)

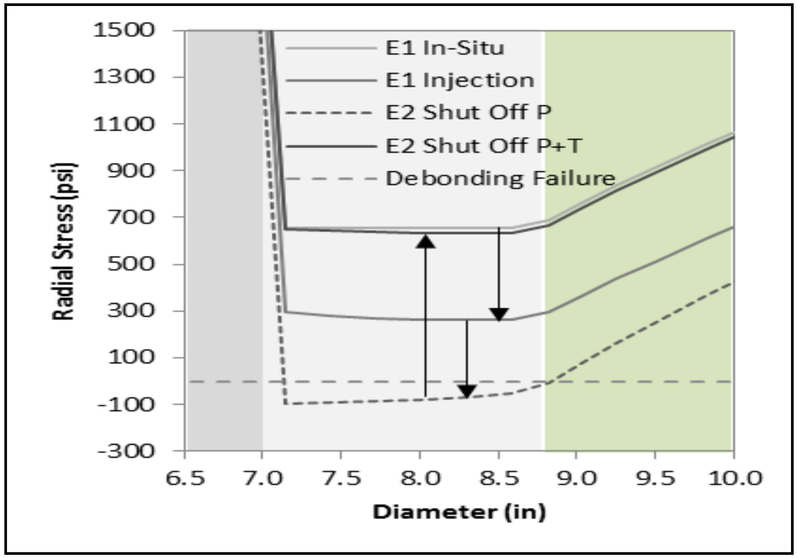
1. Well Schematic Indicator (WSI)
2. Cement Sheath Integrity Indicator (CSII)
3. Cement Type Indicator (CTI)
4. Well Age Indicator (WAI)

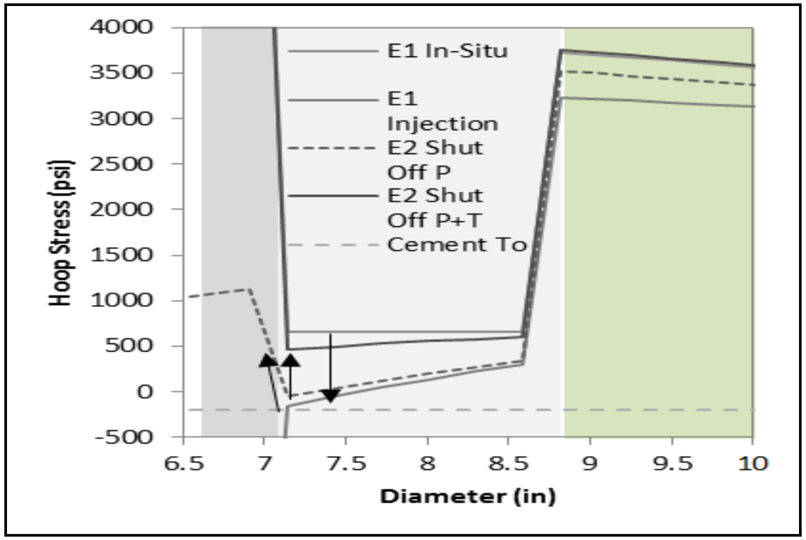
LPI=f(WSI, CSII, CTI, WAI)

Testing
1
0.8
0.6
0.4
0.2
0
LPI
0
3
6
9
12
15
18
21
24
27
30
33
Well Series No.
Target
Testing Output

Finite Element Model for Well Integrity Analysis





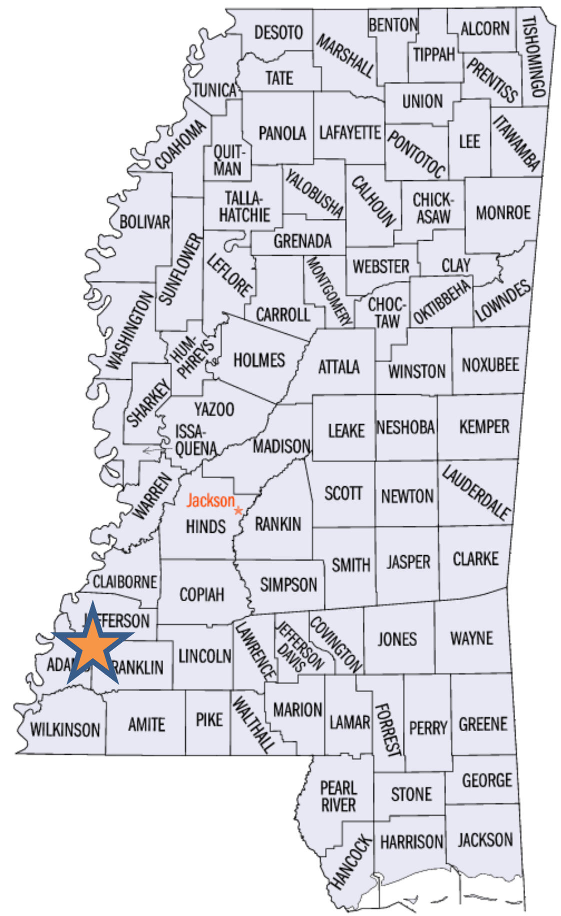


Field Work

Dr. Andrew Duguid

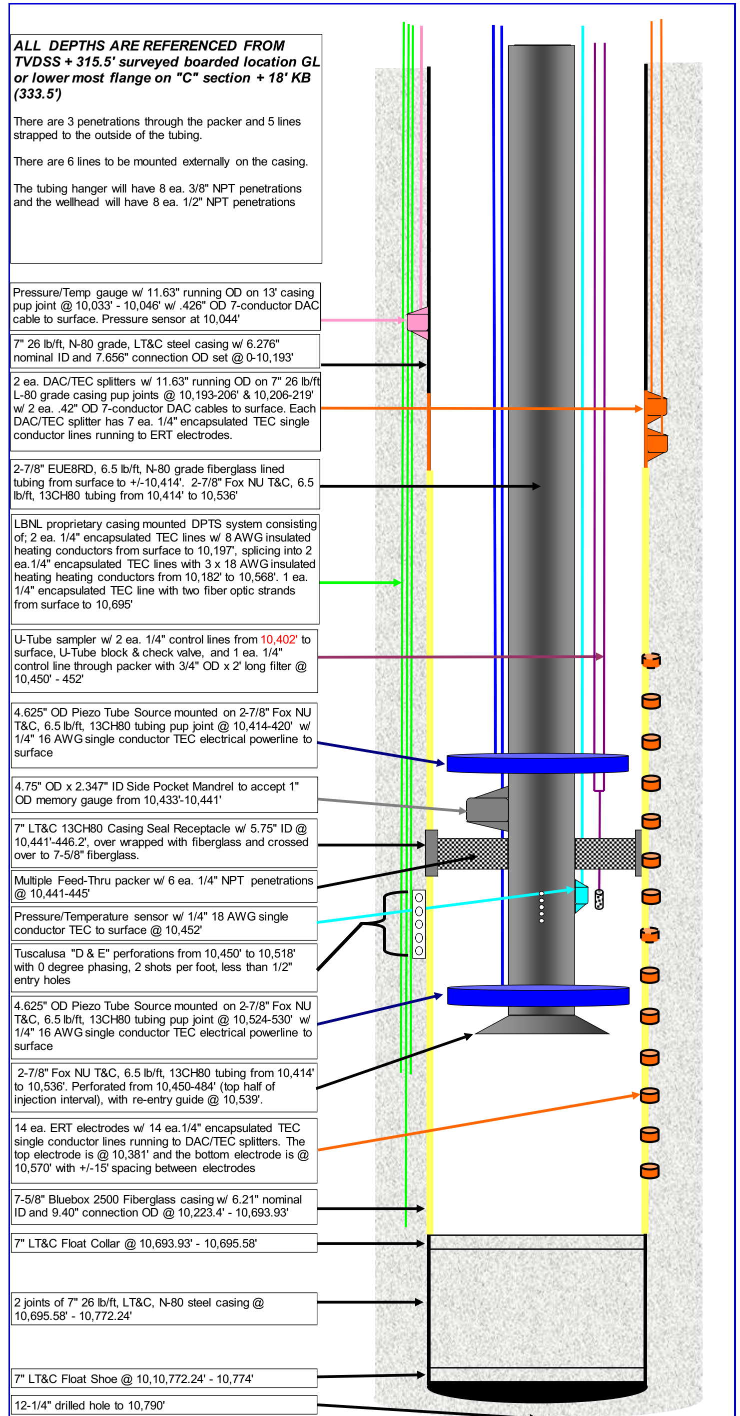
Field Testing at Cranfield Field

- SECARB's Phase II Gulf Coast Stacked Storage Project
- Characterization for Well Integrity
  - To be used in the overall project models
- Two Wells
  - Samples in and above the production zone
- Testing, Logging, and Sampling Tools
  - Isolation Scanner
  - Slim Cement Mapping Tool (SCMT)
  - Cased Hole Formation Dynamics Tester (CHDT)
  - Mechanical Sidewall Coring Tool (MSCT)



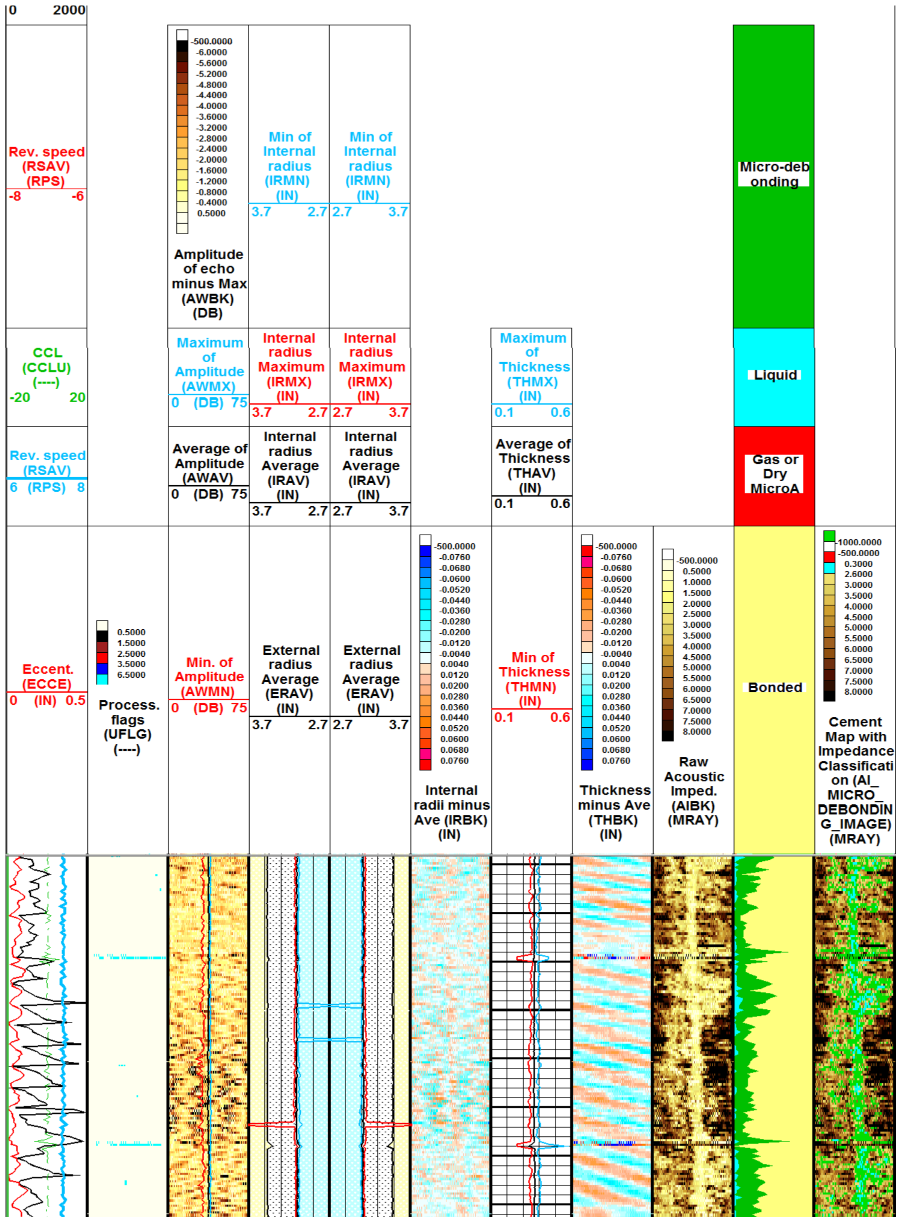
Cranfield CFU31F2 and CFU31F3

- Monitoring Wells
  - Constructed in 2009 and P&A'd 2015
  - Very similar construction
- 7-in 26lb N80 to ~10,200ft
- 7 5/8-in Bluebox 2500 from ~10,200 to ~10,700ft
- 7-in 26lb N80 to ~10,700ft to TD (~10,790ft)
- Electrodes and other jewelry in the well
- 12 ¼-inch bit (large cemented annulus)
- Production reservoir ~10,435ft to ~10,518ft (CFU31F2)

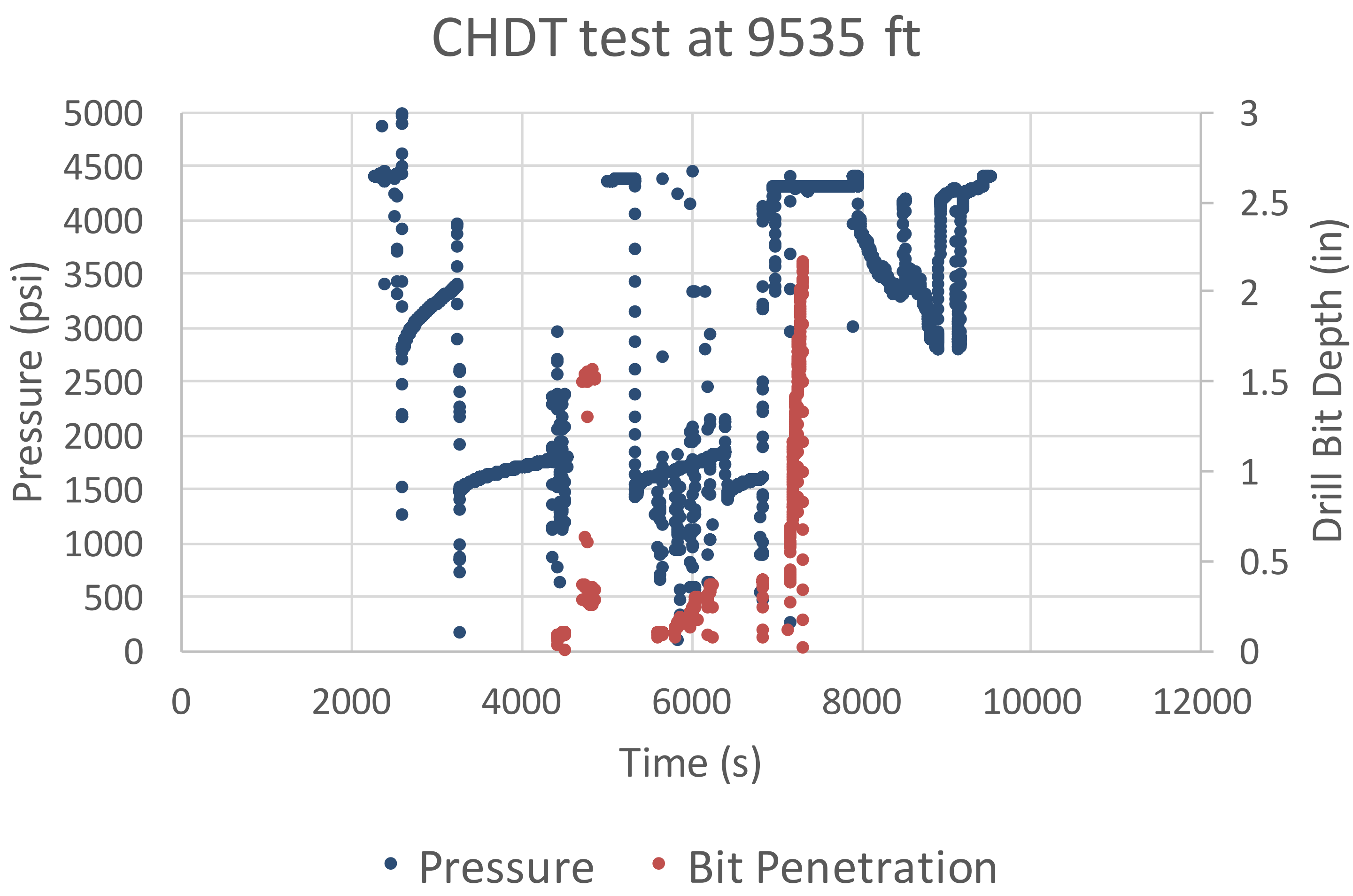


Existing Data

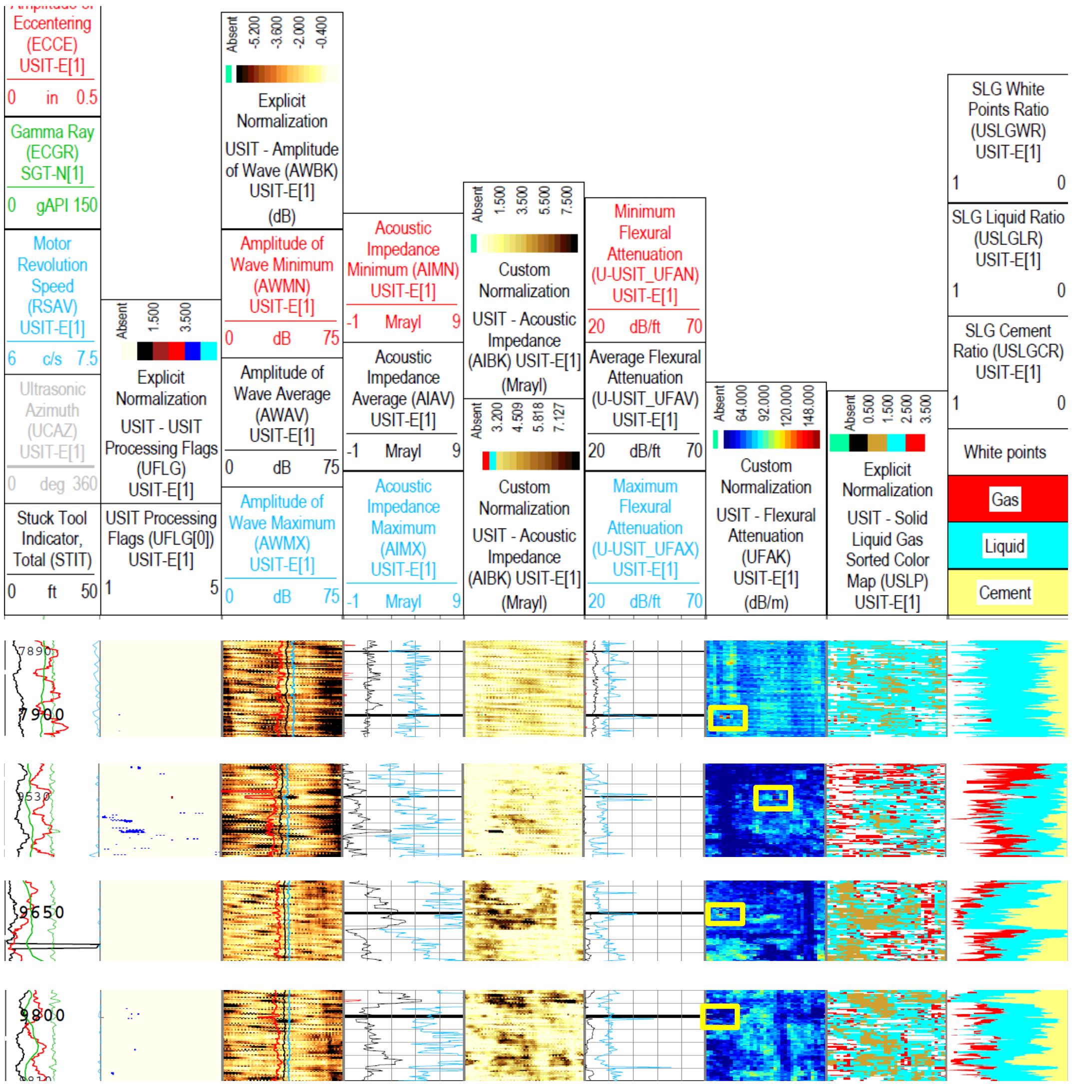
- Reservoir Saturation Tool
  - Gas (CO_2) saturation changes between 2009 and 2015
- Ultrasonic Imager Tool
  - Casing maps, cement maps, solid, liquid, and gas identification, jewelry locations
- Construction Records
  - Joint locations, material changes, electrode locations, gauge locations



CFU31F2 CHDT Testing



CFU31F2 Sidewall Cores



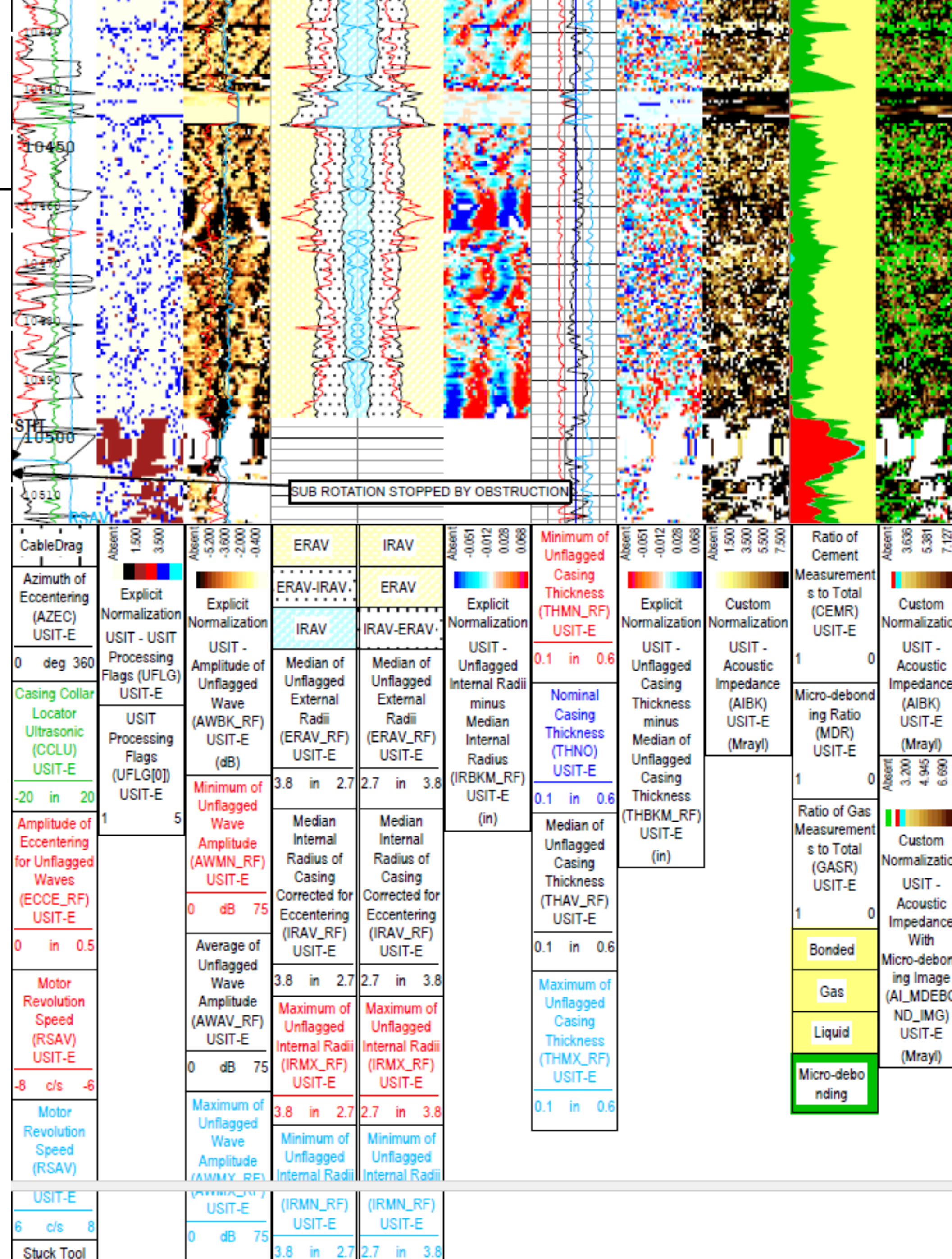
7,900

9,530

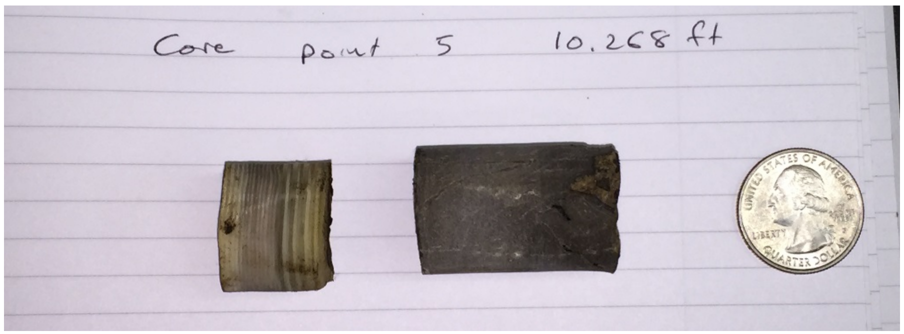
9,800

22
22

CFU31F3 Fiberglass



MSCT Cores in Fiberglass



Summary

1. A Neural-Genetic Model has been developed for predicting leak probability of CO2-Explosed wells.

2. A finite element model has been established for predicting integrity of CO2-injection wells.

3. Field logs/tests/sampling have been run.

4. The next step is to validate models with field data.

Thank You

for Your Attention

Appendix

Anticipated Benefits from the Project

The project will conduct research under DOE's *Fossil Energy Research and Development* Area of Interest 1, Studies of Existing Wellbores Exposed to CO_2.

The project will perform analysis of available industry and regulatory data to assess risks of well failure by various factors such as age of construction, region, construction materials, incident reports, logging and Mechanical Integrity Testing.

The computer model developed in this project will **contribute** to the DOE programs' effort of <u>ensuring 99% CO_2 storage permanence in the injection zone(s) for 1000 years and support the development of Best Practices Manual.</u>

U.S. DOE Project #FE0009284

Organization Chart

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