Quarterly Research Performance Progress Report

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Project Title	**THE EAGLE FORD SHALE LABORATORY: A FIELD STUDY OF THE STIMULATED RESERVOIR VOLUME, DETAILED FRACTURE CHARACTERISTICS, AND EOR POTENTIAL**
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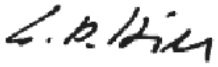
Signature of Principal Investigator:	 Dan Hill

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1. INTRODUCTION

Multi-stage hydraulic fracturing of unconventional reservoirs, implemented in tens of thousands of wells, has been the enabling technology for the tremendous growth in oil and gas production in the U.S. in the past decade. Throughout this development, much of the technology has resulted from expensive trial and error approaches applied in the field. This approach continues today, even as the technology is evolving rapidly. In spite of the thousands of wells drilled and hydraulically fractured, and the billions of dollars spent, the industry is still in the dark about fundamental features of the created fracture systems, such as the stimulated reservoir volume and the complexity of the fracture system that was created. Without this basic knowledge of the true stimulated reservoir volume, operators cannot optimize key development parameters including well spacing and vertical placement of laterals. Meanwhile, as stimulation methods continue to improve rapidly allowing significant improvements in stimulated volume, a very large fraction of the recoverable oil remains in the ground after initial production. Therefore, operators have recently started to explore options for enhanced recovery from existing wells, via two methods, (1) the "re-fracturing" of wells that have been hydraulically fractured during the past decades based on "old" less-than-optimal stimulation technology, and (2) the injection of natural gas to significantly enhance oil recovery after initial production. In each of these areas crucial for effective and sustained production from unconventional reservoirs—better understanding of fracture characteristics created from state-of-the-art stimulation, optimized re-fracturing of legacy wells, improving sweep efficiency of shale EOR—there is a clear need for more and better field diagnostic experiments.

This project, led by Texas A&M University, will conduct a science-based field laboratory project in the Eagle Ford Shale Formation. Utilizing newly-developed monitoring solutions, the project team will deliver unprecedented comprehensive high-quality field data to improve scientific knowledge of three important stages of unconventional oil production from shales: (1) a Refracturing Stage where a previously fractured legacy well will be re-stimulated for improved production, (2) a new Stimulation Stage where the most advanced hydraulic fracturing and geosteering technology will be applied in two new production wells, and (3) a Gas-EOR (enhanced oil recovery) Phase where the refractured well will be later tested for the efficiency of Huff and Puff gas injection as an EOR method. Field monitoring will be complemented by laboratory testing on cores and drill cuttings, and coupled modeling for design, prediction, calibration, optimization, and code validation.

This quarterly research progress report is intended to provide a summary of the work accomplished under this project during the first quarter of the first budget period (April 1st, 2018 - June 30th, 2018). Summarized herein is a description of the project accomplishments to date, which include evaluation of existing candidate site data; final selection of the field test site; preliminary work on the design of the observation wells; and ongoing modeling and simulation efforts for the design of the active source and passive monitoring arrays. Also summarized herein is a summary of the

project's milestone status, along with the budgetary information corresponding to this reposting period.

2. ACCOMPLISHMENTS

2.1. Project Goals

The ultimate objective of this project is to help improve the effectiveness of shale oil production by providing new scientific knowledge and new monitoring technology for both initial stimulation/production as well as enhanced recovery via refracturing and EOR. This project will develop methodologies and operational experience for optimized production of oil from fractured shale, an end result that would allow for more production from fewer new wells using less material and energy. While aspects of the proposed project are site-specific to the Eagle Ford formation, there will be many realistic and practical learnings that apply to other unconventional plays, or even apply to other subsurface applications such as unconventional gas recovery and geologic carbon sequestration and storage. The main scientific/technical objectives of the proposed project are:

- Develop and test new breakthrough monitoring solutions for hydraulic fracture stimulation, production, and EOR. In particular, for the first time in unconventional reservoirs, use active seismic monitoring with fiber optics in observation wells to conduct: (1) real-time monitoring of fracture propagation and stimulated volume, and (2) 4D seismic monitoring of reservoir changes during initial production and EOR from the refractured well.
- Improve understanding of the flow, transport, mechanical and chemical processes during and after stimulation (both initial and refracturing) and gain insights into the relationship between geological and stress conditions, stimulation design, and stimulated rock volume
- Assess spatially and temporally resolved production characteristics and explore relationship with stimulated fracture characteristics.
- Evaluate suitability of refracturing to achieve dramatic improvements in stimulation volume and per well resource recovery.
- Evaluate suitability of gas-based EOR Huff and Puff methods to increase per well resource recovery.
- Optimize drilling practices in the Eagle Ford shale based on surface monitoring and near-bit diagnostic measurements during drilling.
- Conduct forward and inverse modeling to test reservoir and fracture models and calibrate simulations using all monitored data. Ultimately, provide relevant guidance for optimized production of oil from fractured shale.
- Disseminate research and project results among a broader technical and scientific audience, and ensure relevance of new findings and approaches across regions/basins/plays.

The project will start with the refracturing of a legacy well that was initially stimulated using now outdated fracturing technology (Task 2). The recipient will drill, complete, and instrument one vertical and one horizontal observation strategically located on both sides of the legacy well to allow for real-time cross-well monitoring of evolving fracture characteristics and stimulated volume. These observation wells will also be used for the other two main project stages, involving a new state-of-the art stimulation effort (Task 3) and a Huff and Puff EOR test (Task 4). Task 3

will be conducted in two new wells of opportunity drilled; these wells will be situated parallel to the horizontal observation well on the other side of the refracturing well. Task 4 will be conducted in the refractured legacy well, testing the efficiency of a Huff and Puff process with natural gas injection for EOR. As described below, each main task comprises various field activities complemented by laboratory testing and coupled modeling for design, prediction, calibration, and code validation. In addition to the three main tasks aligned with refracturing, new stimulation, and EOR, the work plan also comprises Task 1 (Project Management and Planning) and Task 5 (Integrated Analysis, Lessons Learned, Products, and Reporting). The project milestones, description of tasks and subtasks, and current milestone status are shown in **Table 1**.

2.2. Accomplishments

The core research team has been primarily focused on the evaluation of potential field test sites for the project, recruiting and negotiating with potential industry partners, and working on the design and instrumentation of the observation wells.

The field test site selection has been finalized. An initial assessment of existing site data has also been completed (in support of Milestone A of the PMP). The chosen field test site was selected due to the large amount of available data including the following:

- Existing surface microseismic survey
- Existing well logs (including lateral section logs)
- Comprehensive refracture candidate well documentation (deviation surveys, casing diagrams, and completion reports)

The team has successfully negotiated the participation of five (5) industry partners within the project JIP. Section 5 of this report summarizes the JIP partner updates.

Weekly update meetings have been held between Texas A&M University, WildHorse Resource Development, and Lawrence Berkeley National Laboratory. The following summarizes the team's progress to date in relation to the Project Management Plan (PMP):

- Task 1 – Project Management and Planning
  - ✓ PMP and DMP: **Activity has been completed.**

- Task 2 – Phase 1: Evaluation of Refracturing
  - ✓ Subtask 2.1 – Evaluation of Existing Data and Design of Observation Wells
    - *Activity 2.1.1 Evaluation of Existing Data:* **Activity has been completed.**
    - *Activity 2.1.2 Design of the Active Source and Passive Monitoring Arrays:* **Activity is ongoing (See Section 2.2.2).**
    - *Activity 2.1.3 Engineering of Integrated Monitoring Completion:* **Activity is ongoing (See Section 4).**

- Technical Go/No Go Decision Point 1
  - ✓ The EFSL test site has been selected (See Section 2.2.1).

Activity has been completed.

2.2.1. Field Test Site Selection

Selection of the field test site location has been finalized. The GPS coordinates for the site are 30.6025, -96.6416. As can be seen in **Figure 1(a)**, the test site is located 6 miles due northwest of Caldwell, in Burleson County, TX. The site is also conveniently located approximately 18 miles due east of Texas A&M University campus.

The site is host to a three well pad, namely *Bronco Unit EB A 1H*, *Bronco Unit EB A 2H*, and *Bronco Unit EB A 3H* (API:42-051-33922, API:42-051-33923, and API:42-051-33919, respectively). The wellbore of the *A 1H* is collapsed and unusable. Wells *A 2H*, and *A3H* are currently on production, and are planned to be refractured; however the candidate study well for Phase 1 of the project (refracture study) was chosen to be the *A 3H* well.

Figure 1(b) shows a top view illustration of the refracture candidate wells, with the *A 1H* in gray; the *A 2H* in green; the *A 3H* in blue; the planned vertical observation well (VOW) as a red cross; the planned horizontal observation well (HOW) as a red dashed line; and both planned new producers (NP1, NP2) for Phase 2 of the project in yellow dashed lines.

Additional description of the surface location for each well and the associated project subtasks is shown in **Figure 2** in the Appendix.

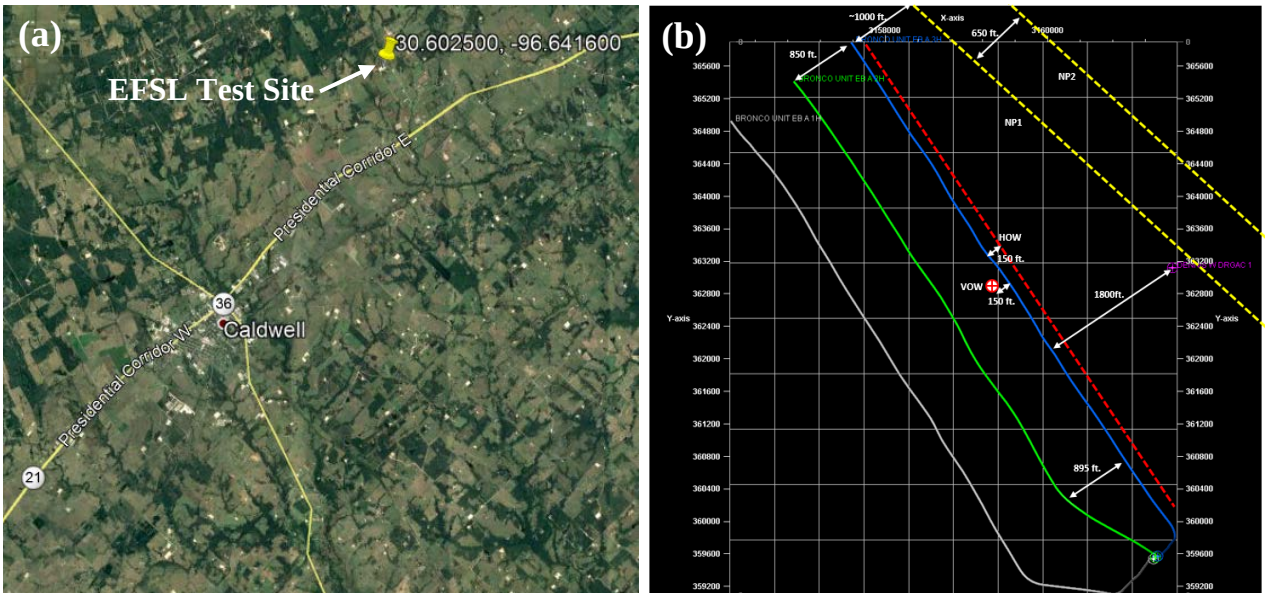

Figure 1: Test Site Location and Test Well Schematic.

(a) Map showing the location and GPS coordinates of the EFSL field test site (yellow pin); (b) Top view illustration of EFSL test site refracture candidate wells (green and blue), planned observation wells (red), and planned new producers (yellow).

2.2.2. Modeling and Numerical Simulation Efforts

The Lawrence Berkeley National Lab (LBNL) team has completed the modeling and simulation work described in Activity 2.1.3 of the EFSL Proposal. Work completed by the LBNL team includes but is not limited to the following:

- Sonic velocity model construction for selected EFSL test site
- Integration of existing legacy well data (microseismic, fracture modeling, completion data)
- Simulation of Surface Orbital Vibrator (SOV) response
- Simulation of Continuous Active Seismic Source Monitoring (CASSM) response
- Simulation of Z-Trac™ downhole seismic source response

2.3. Opportunities for Training and Professional Development.

Nothing to Report

2.4. Dissemination of Results to Communities of Interest

Nothing to Report

2.5. Plan for Next Quarter

Building on the current progress achieved by the research team, work planned for the next quarter will include, but is not limited to, the following:

- Continue negotiation of in-kind services with Baker Hughes.
- Continue work related to the HOW and the VOW in support of Subtask 2.2, 2.3, and 2.5:
  - ✓ Surface location selection.
  - ✓ Planning for permitting.
  - ✓ Vertical pilot and well path design (for HOV).
  - ✓ Casing design to accommodate coring and subsequent instrumentation.
- Continue ongoing design and planning for surface monitoring in support of Subtask 2.5:
  - ✓ SOV surface location determination, planning, and permitting.

2.6. Summary of Tasks for Next Quarter

The following provides a summary of the tasks and subtasks to be performed in Q2:

- Task 1 – Project Management and Planning (ongoing)
- Task 2 – Phase 1: Evaluation of Refracturing
  - ✓ Subtask 2.1 – Evaluation of Existing Data and Design of Observation Wells
    - *Activity 2.1.2 Design of the Active Source and Passive Monitoring Arrays*
      Activity is ongoing (See Section 2.2.2).
    - *Activity 2.1.3 Engineering of Integrated Monitoring Completion*
      Activity is ongoing (See Section 4).
- Special Reporting Requirements
  - ✓ Update and finalize Environmental Questionnaire (EQ).
    Activity is ongoing (See Section 7).
- Obtain Written Authorization from the DOE Contracting Officer and NEPA to proceed with Subtask 2.2, 2.3, and 2.4

Table 1. Summary of Milestone Status

Milestone	Task	Sub-task	Title/Description	Planned Completion Date	Actual Completion Date	Verification Method	Comments
A	1	1	Project Management & Planning	3/31/2021	Ongoing	Report	None
	2 - Phase 1: Re-Fracturing Evaluation	2.1	Evaluation of Existing Data and Design of Observation Wells	9/30/2018	Ongoing	Report	None
B		2.2	Drill, Complete, & Instrument Horizontal Observation Well	9/30/2018	Not Started	Report	None
		2.3	Drill, Complete, & Instrument Vertical Observation Well	9/30/2018	Not Started	Report	None
		2.4	Recomplete Well to be Re-Fractured	9/30/2018	Not Started	Report	None
C		2.5	Monitoring of Re-Fracturing	12/31/2018	Not Started	Report	None
		2.6	Analysis of Re-Fracturing Monitoring	12/31/2019	Not Started	Report	None
D		2.7	DTS/DAS/DSS & Seismic Monitoring During Production	12/31/2019	Not Started	Report	None
		2.8	Laboratory Evaluation of EOR Potential	6/30/2020	Not Started	Report	None
E		2.9	Coupled Modeling for Design, Prediction, Calibration & Code Validation	9/31/2020	Not Started	Report	None
	3 - Phase 2: Fracturing Evaluation	3.1	Drill, Complete & Instrument Two New Producing Wells	6/30/2019	Not Started	Report	None
F		3.2	Drilling Optimization	6/30/2020	Not Started	Report	None
		3.3	Monitoring of Fracturing of Two New Producing Wells	12/31/2019	Not Started	Report	None
		3.4	Analysis of Fracturing Monitoring of Two New Producing Wells	12/31/2020	Not Started	Report	None
		3.5	Coupled Modeling for Design, Prediction, Calibration & Code Validation	12/31/2020	Not Started	Report	None
	4 - Phase 3: EOR Pilot Test	4.1	Conduct Huff & Puff EOR Pilot Test	6/30/2020	Not Started	Report	None
		4.2	Monitor Injected Gas Placement with Active & Passive Seismic Monitoring	12/31/2020	Not Started	Report	None
		4.3	Monitor Injected Gas Distribution with DTS/DAS in Pilot Well	12/31/2020	Not Started	Report	None
G		4.4	Modeling of the Huff & Puff EOR Pilot Test	12/31/2020	Not Started	Report	None
	5 - Final Report	5.1	Multi-Purpose Optimization & Lessons Learned	3/31/2021	Not Started	Report	None
		5.2	Products & Reporting	3/31/2021	Not Started	Report	None

3. PRODUCTS
Nothing to Report

4. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

4.1. Joint Industry Project (JIP) Partner Organizations
There is also a joint industry project supporting the Eagle Ford Shale Laboratory, with five companies currently committed to sponsorship.

5. IMPACT
Nothing to Report

6. CHALLENGES/PROBLEMS
Nothing to Report

7. SPECIAL REPORTING REQUIREMENTS

7.1. Environmental Questionnaire
The Environmental Questionnaire (EQ) for the selected EFSL test site has been completed and submitted on 06/22/2018. This EQ will be updated as further specific details pertaining to the field test site location are determined.

8. BUDGETARY INFORMATION
A summary of the budgetary information for the first reporting quarter of the project is provided in **Table 2**. This table shows the original planned costs, the actual incurred costs, and the variance. The costs are split between federal share and non-federal share.

Table 2. Budgetary Information for Budget Period 1, Q1

Baseline Reporting Quarter	Budget Period 1	
	Q1	
	04/01/2018 - 06/30/2018	
	Q1	Cumulative Total
Baseline Cost Plan		
Federal Share	$1,564,127.00	$1,564,127.00
Non-Federal Share	$500,000.00	$500,000.00
Total Planned	$2,064,127.00	$2,064,127.00
Actual Incurred Cost		
Federal Share	$119,579.07	$119,579.07
Non-Federal Share	$0.00	$0.00
Total Incurred Cost	$119,579.07	$119,579.07
Variance		
Federal Share	$1,444,547.93	$1,444,547.93
Non-Federal Share	$500,000.00	$500,000.00
Total Variance	$1,944,547.93	$1,944,547.93

9. PROJECT OUTCOMES

Nothing to Report

10. APPENDIX

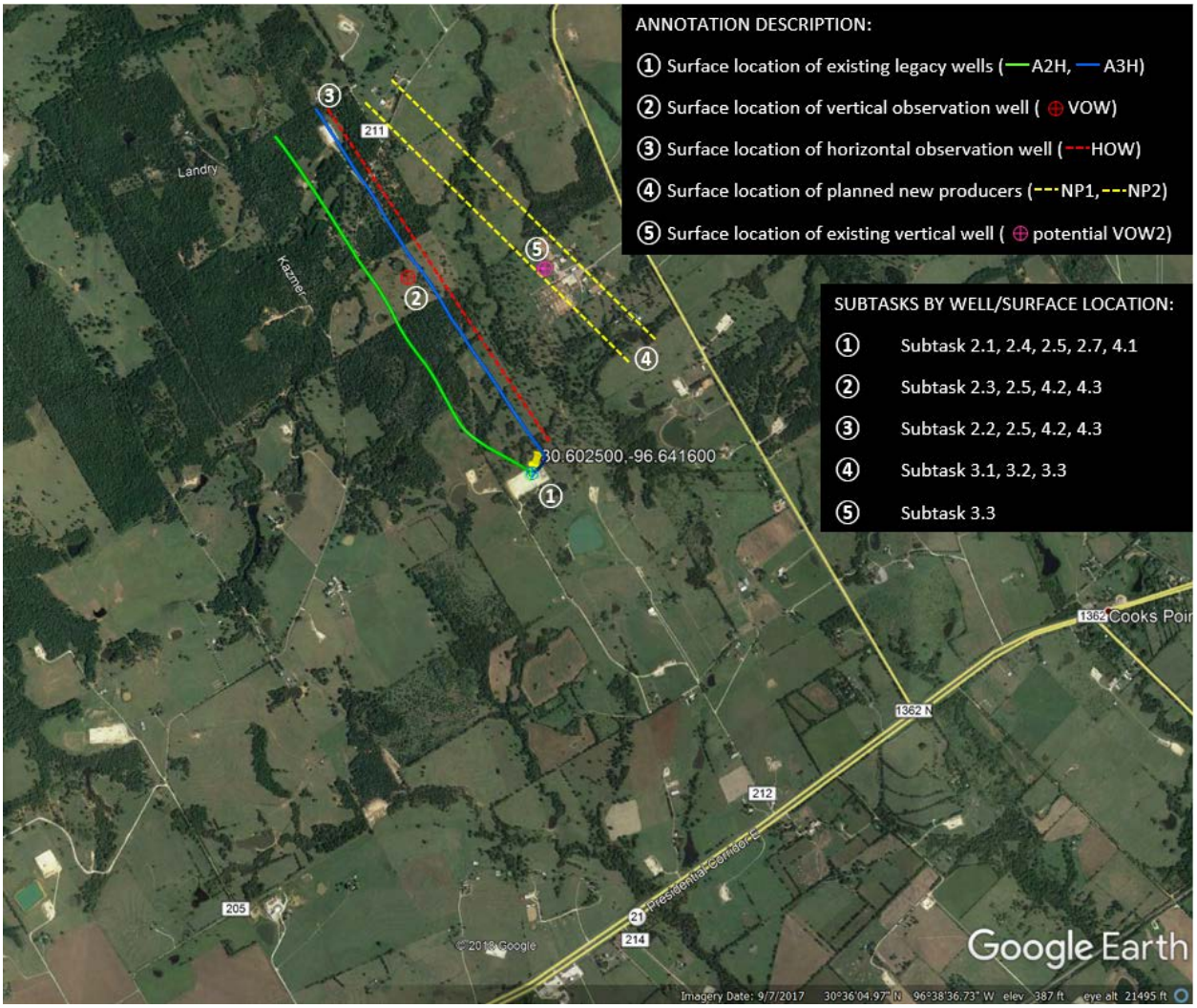

Figure 2: EFSL Test Site Map Showing Subtasks by Proposed Location