Quarterly Research Performance Progress Report

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Prime Recipient Name and Address	Texas A&M Engineering Experiment Station 7607 Eastmark Drive, College Station, TX 77840
Prime Recipient Type	Not for profit organization
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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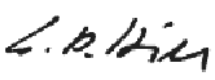
Signature of Principal Investigator:	 Dan Hill

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1. INTRODUCTION

This quarterly research progress report is intended to provide a summary of the work accomplished under this project during the seventh quarter of the first budget period (***October 1st, 2019 – December 31st, 2019***). Summarized herein is a description of the project accomplishments to date, along with the planed work to be conducted in the next quarter.

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 re-fracturing 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 re-fractured well.
- Improve understanding of the flow, transport, mechanical and chemical processes during and after stimulation (both initial and re-fracturing) 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 re-fracturing 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 re-fracturing 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 re-fracturing well. Task 4 will be conducted in the re-fractured 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 re-fracturing, 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

This section summarizes the accomplishments for the current reporting quarter (***October 1, 2019 – December 31, 2019***).

2.2.1. EFSL Project Performers Summit Meeting

A series of meetings and webinars were held between key representatives from all project performer organizations, namely Texas A&M University (TAMU), Lawrence Berkeley National Laboratory (LBNL), Stanford University (Stanford), and the new site operator INPEX Eagle Ford, LLC (INPEX), to develop a detailed project plan for Phase 1 field activities. The sequence of field events has been settled, with drilling of the 3 new producers now planned for second quarter, 2020. The producer nearest the legacy well, designated the 2H well, will be instrumented with fiber optic cables and pressure gauges.

2.2.2. Completion and Stimulation Fractal Design Conducted for Optimization

The completion and stimulation fractal design has been updated for the new project site location and well configurations.

2.2.3. Fracture Conductivity Design of Experiments

A series of experiments have been conducted to measure fracture conductivity of various proppants and concentrations on using Eagle Ford outcrop samples. All procedures for conducting similar tests with the Eagle Ford core have been tested.

2.2.4. Fracture Fluid Tracing

A tracer program for tagging the fracturing fluid has been developed. A source for the gadolinium oxide being planned as a tracer has been identified, and cost estimates received. We have modeled the expected response at the observation well to design the amount of tracer needed.

2.2.5. Fiber Optic Data Analysis Method Developments

A thermal-mechanical model for low frequency DAS measurements has been developed. This model will be used to analyze and interpret low frequency DAS data recorded by the project. We have also tested our models of DTS and high frequency DAS with field data from other sites, including the MSEEL site. A paper, SPE 199723, reporting our analysis of MSEEL fiber optic data, will be presented at the SPE Hydraulic Fracturing Technology Conference in February.

2.2.6. **Numerical Simulation Efforts**

The team has conducted further development of the Fast-Marching-Method (FMM) based on coupled flow and geomechanics simulations, with an extension to a full 3D model. A paper, SPE 197103, presenting a history matching study of 2 Eagle Ford wells similar, was given at the SPE Liquids-Rich Basins Conference

2.2.7. **Geomechanical Measurements and Testing**

Analysis of existing log data for the new test site is underway. Analysis of the new log data will aid in the selection of intervals of interest for downhole core sampling and testing.

2.2.8. **Monitoring System Design**

Design of the active source and passive monitoring integrated arrays were discussed with TAMU and LBNL teams and an array design has been suggested (Subtask 2.1). From previous simulations for transmission imaging (done in 2018), we concluded that a source count of 6 to 8 sources would provide good geometry constraints while larger source counts improves velocity magnitude estimates. Currently, we are working on additional simulations for analyzing the impact of source count for reflection imaging.

Additionally, we continue to process and analyze the data acquired during the previous experiments at Chesapeake in April 2019. We acquired a series of sweeps with the SOV system, with the objective of testing different sweep designs as well as the slewing bearing performance. The slewing bearing was coupled to the SOV to allow for 360-degree rotation of the source. The vertical seismic profile data (VSP) was acquired with a single-mode fiber connected to a DAS system. The VSP data was stacked using 20 repeated sweeps. After stacking, the P wavefield was obtained by summing the sweeps recorded in clockwise (CW) direction to the sweeps recorded in the counter-clockwise (CCW) direction (CW – CCW), and the S wavefield was obtained by subtracting CW with CCW.

Figure 1 show the P wave response of the recorded VSP data. Note that clear P reflection is seen along the well length, including along the lateral. Between ~2700 m to 3300 m MD, the direct P amplitude decreases significantly. This happens due to the angle sensitivity pattern of the DAS measurement, which decays as cosine squared of the angle of incidence.

Figure 2 shows the S wave response after subtracting CW and CCW. Direct S wave and upgoing reflections are clearly seen on the record. However, the sensitivity of the S wave decreases after ~ 1400 m MD. Figure 3 shows the S wave response after rotating the source azimuth in 135 degrees. Note that the response of the S wave improves, especially along the lateral. This happens due to an improved alignment of the polarization of the S wave with the fiber cable axis after rotation of the source.

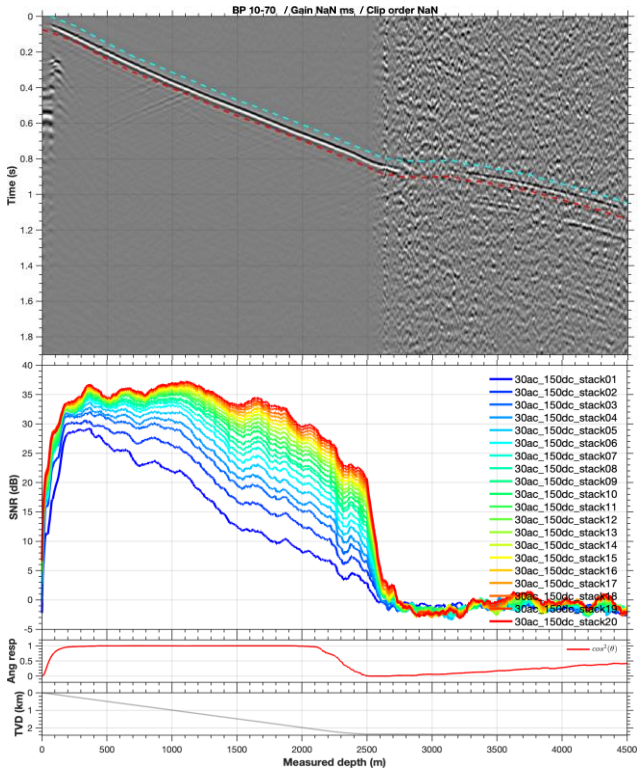

Figure 1: P wavefield component of the vertical seismic profile data acquired with single-mode fiber behind casing after stacking 20 different sweeps.

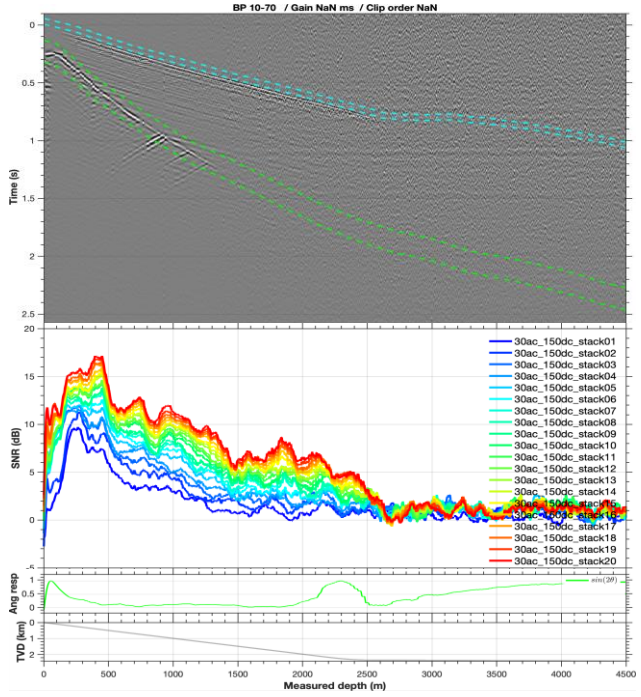

Figure 2: S wavefield component of the vertical seismic profile data acquired with single-mode fiber behind casing after stacking 20 different sweeps.

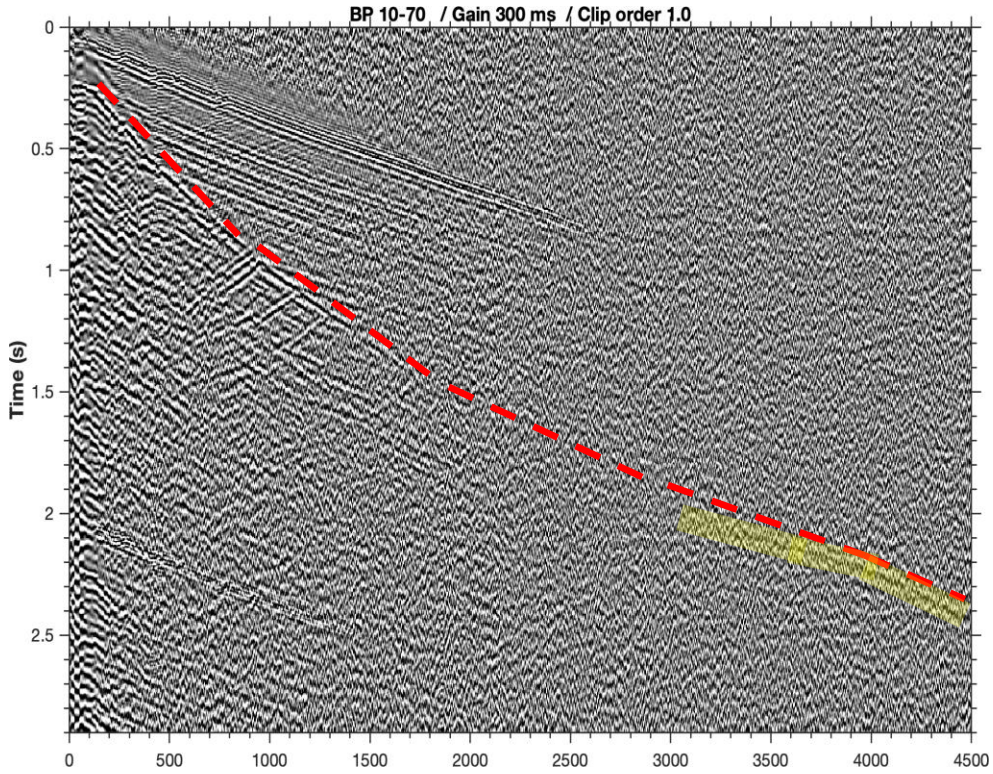

Figure 3: S wavefield of the vertical seismic profile data acquired with single-mode fiber behind casing after stacking 5 different sweeps. SOV source was rotated in 135-degree azimuth.

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 Quarters (BP1-Q8: January 1st – March 31st, and BP2-Q9: April 1st – June 30, 2020)

Given the change of test site operator and related field test site location (See **Section 4**), the project schedule has been updated accordingly (see **Section 2.7**), with the primary change being the rescheduling of Subtask 2.2: Drill, Complete and Instrument Horizontal Observation Well, which is scheduled within next two quarters.

2.6. Summary of Tasks for Next Quarter (BP1-Q8: January 1st – March 31st, and BP2-Q9: April 1st – June 30, 2020)

The following provides a summary of the tasks, subtasks, and activities planned in BP1-Q8 and BP2-Q9:

- Task 1 – Project Management and Planning
- Task 2 – Phase 1: Evaluation of Re-fracturing
  - ✓ Subtask 2.2 – Drill, Complete, & Instrument Horizontal Observation Well
    - *Activity 2.2.1 Drill Pilot Hole*

- *Activity 2.2.2 Drill Horizontal Well Parallel to Refrac Well*
- *Activity 2.2.3 Log Horizontal Observation Well (Open-hole logs)*
- *Activity 2.2.4 Installation of Fiber Optic Cable, Pressure Gauges, and Seismic Source*

2.7. Summary of Milestone Status

The following table provides a summary of milestones and updated planned completion dates:

Table 1. Summary of Milestone Status

Milestone	Task	Sub-task	Title/Description	Planned Completion Date	Actual Completion Date	Comments
A	1	1.1	Project Management & Planning	3/31/2022	-	*Ongoing*
	2 - Phase 1: Re-Fracturing Evaluation	2.1	Evaluation of Existing Data and Design of Observation Wells	9/30/2018	8/1/2019	*Complete*
B		2.2	Drill, Complete, & Instrument Horizontal Observation Well	6/30/2020	-	-
		2.3	Drill, Complete, & Instrument Vertical Observation Well*	6/30/2020	-	**Vertical section of a horizontal well will be instrumented in place of a standalone vertical observation well.*
		2.4	Recomplete Well to be Re-Fractured	6/30/2020	-	-
C		2.5	Monitoring of Re-Fracturing	7/31/2020	-	-
		2.6	Analysis of Re-Fracturing	6/30/2021	-	-
D		2.7	DTS/DAS/DSS & Seismic Monitoring During Production	6/30/2021	-	-
		2.8	Laboratory Evaluation of EOR Potential	6/30/2021	-	-
E		2.9	Coupled Modeling for Design, Prediction, Calibration & Code Validation	6/30/2021	-	-
	3 - Phase 2: Fracturing Evaluation	3.1	Drill & Complete Two New Producing Wells	6/30/2020	-	-
F		3.2	Drilling Optimization	12/31/2020	-	-
		3.3	Monitoring of Fracturing of Two New Producing Wells	7/31/2020	-	-
		3.4	Analysis of Fracturing Monitoring of Two New Producing Wells	6/30/2021	-	-
		3.5	Coupled Modeling for Design, Prediction, Calibration & Code Validation	6/30/2021	-	-
	4 - Phase 3: EOR Pilot Test	4.1	Conduct Huff & Puff EOR Pilot Test	1/30/2022	-	-
		4.2	Monitor Injected Gas Placement with Active & Passive Seismic Monitoring	1/30/2022	-	-
		4.3	Monitor Injected Gas Distribution with DTS/DAS in Pilot Well	1/30/2022	-	-
G		4.4	Modeling of the Huff & Puff EOR Pilot Test	3/31/2022	-	-
	5 - Final Report	5.1	Multi-Purpose Optimization & Lessons Learned	6/30/2022	-	-
		5.2	Products & Reporting	6/30/2022	-	-

3. PRODUCTS

Nothing to Report.

4. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

4.1. Change of Field Test Site Operator

INPEX Eagle Ford, LLC is now a project partner and has fully committed to participate in the project. A new field test site location for the project has been selected in La Salle County, TX within an area leased by INPEX Eagle Ford, LLC.

5. IMPACT

Nothing to Report.

6. CHALLENGES/PROBLEMS

Nothing to Report.

7. SPECIAL REPORTING REQUIREMENTS

7.1. No Cost Time Extension for Budget Period 1 (NCTE - BP1)

A no cost time extension (NCTE) has been submitted to extend Budget Period 1 to a current end date of March 31st, 2020. Under this requested NCTE, the current budget period start and end dates are as follows:

- BP1: 04/01/2018 - 03/31/2020
- BP1: 04/01/2020 - 03/31/2021
- BP1: 04/01/2020 - 03/31/2022

8. BUDGETARY INFORMATION

A summary of the budgetary information for Q1-Q6 of BP1 for the project is provided in **Table 3**. 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- Q6

Baseline Reporting Quarter	EFSL Budget Period 1 (04/01/2018 - 12/31/2019)							
	Q1		Q2		Q3		Q4	
	04/01/2018 - 06/30/2018		07/01/2018 - 09/30/2018		10/01/2018 - 12/31/2018		01/01/2019 - 03/31/2019	
	Federal Share	Non-Federal Share	Federal Share	Non-Federal Share	Federal Share	Non-Federal Share	Federal Share	Non-Federal Share
Baseline Cost Plan								
TAMU	$182,669.50	$0.00	$182,669.50	$0.00	$182,669.50	$0.00	$182,669.50	$0.00
INPEX Egle Ford, LLC	$850,000.00	$500,000.00	$850,000.00	$500,000.00	$850,000.00	$500,000.00	$850,000.00	$500,000.00
LBNL	$166,750.00	$0.00	$166,750.00	$0.00	$166,750.00	$0.00	$166,750.00	$0.00
Stanford	$31,456.25	$0.00	$31,456.25	$0.00	$31,456.25	$0.00	$31,456.25	$0.00
Total Planned	**$1,230,875.75**	**$500,000.00**	**$1,230,875.75**	**$500,000.00**	**$1,230,875.75**	**$500,000.00**	**$1,230,875.75**	**$500,000.00**
Actual Incurred Cost*								
TAMU	$119,579.07	$0.00	$152,177.46	$0.00	$108,898.29	$0.00	$110,749.32	$0.00
INPEX Egle Ford, LLC	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
LBNL	$57,679.00	$0.00	$104,547.00	$0.00	$168,294.00	$0.00	$303,022.00	$0.00
Stanford	$29,084.28	$0.00	$4,847.38	$0.00	$16,552.39	$0.00	$34,658.84	$0.00
Total Incurred Cost	**$206,342.35**	**$0.00**	**$261,571.84**	**$0.00**	**$293,744.68**	**$0.00**	**$448,430.16**	**$0.00**
Variance								
TAMU	$63,090.43	$0.00	$30,492.04	$0.00	$73,771.21	$0.00	$71,920.18	$0.00
INPEX Egle Ford, LLC	$850,000.00	$500,000.00	$850,000.00	$500,000.00	$850,000.00	$500,000.00	$850,000.00	$500,000.00
LBNL	$109,071.00	$0.00	$62,203.00	$0.00	($1,544.00)	$0.00	($136,272.00)	$0.00
Stanford	$2,371.97	$0.00	$26,608.87	$0.00	$14,903.86	$0.00	($3,202.59)	$0.00
Total Variance	**$1,024,533.40**	**$500,000.00**	**$969,303.91**	**$500,000.00**	**$937,131.07**	**$500,000.00**	**$782,445.59**	**$500,000.00**

*Actual incurred costs represent total expenditures (direct costs & indirect costs).

EFSL Budget Period 1 (04/01/2018 - 12/31/2019)							
Q5 - NCTE 1		Q6		Q7		Total (After Modification 5)	
04/01/2019 - 06/30/2019		07/01/2019 - 09/30/2019		10/01/2019 - 12/31/2019		04/01/2018 - 12/31/2019	
Federal Share	Non-Federal Share	Federal Share	Non-Federal Share	Federal Share	Non-Federal Share	Federal Share	Non-Federal Share
$0.00	$0.00	$435,200.50	$0.00	$435,200.50	$0.00	$1,601,079.00	$0.00
$0.00	$0.00	$362,500.00	$0.00	$362,500.00	$0.00	$4,125,000.00	$2,000,000.00
$0.00	$0.00	$333,166.50	$0.00	$333,166.50	$0.00	$1,333,333.00	$0.00
$0.00	$0.00	$59,798.00	$0.00	$59,798.00	$0.00	$245,421.00	$0.00
$0.00	**$0.00**	**$1,190,665.00**	**$0.00**	**$1,190,665.00**	**$0.00**	**$7,304,833.00**	**$2,000,000.00**
$207,650.59	$0.00	$7,195.98	$0.00	$157,809.13	$0.00	$864,059.84	$0.00
$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
$9,811.00	$0.00	($1,329.00)	$0.00	$0.00	$0.00	$642,024.00	$0.00
$31,992.78	$0.00	$31,899.24	$0.00	$0.00	$0.00	$149,034.91	$0.00
$249,454.37	**$0.00**	**$37,766.22**	**$0.00**	**$157,809.13**	**$0.00**	**$1,655,118.75**	**$0.00**
($207,650.59)	$0.00	$428,004.52	$0.00	$277,391.37	$0.00	$737,019.16	$0.00
$0.00	$0.00	$362,500.00	$0.00	$362,500.00	$0.00	$4,125,000.00	$2,000,000.00
($9,811.00)	$0.00	$334,495.50	$0.00	$333,166.50	$0.00	$691,309.00	$0.00
($31,992.78)	$0.00	$27,898.76	$0.00	$59,798.00	$0.00	$96,386.09	$0.00
($249,454.37)	**$0.00**	**$1,152,898.78**	**$0.00**	**$1,032,855.87**	**$0.00**	**$5,649,714.25**	**$2,000,000.00**

*Actual incurred costs represent total expenditures (direct costs & indirect costs).

9. PROJECT OUTCOMES

Nothing to Report