Oil & Natural Gas Technology

DOE Award No.: DE-FE0024297

Quarterly Research Performance Progress Report

(Period ending: 12/31/2015)

Marcellus Shale Energy and Environment Laboratory (MSEEL)

Project Period: October 1, 2014 – December 31, 2019

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Prepared for:
United States Department of Energy
National Energy Technology Laboratory

Office of Fossil Energy

Quarterly Progress Report

October 1 – December 31, 2015

Executive Summary

The objective of the Marcellus Shale Energy and Environment Laboratory (MSEEL) is to provide a long-term field site to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development.

This quarter has been a very active quarter for the project, with the production and science wells reaching completion (drilled, stimulated, completed), and with a large amount of data collected (geologic samples – cores, cuttings, water samples, geophysical logs, etc).

All three MSEEL wells (MIP 3H, MIP 5H and MIP SW) were drilled and logged by the beginning of October. Fiber optic cable for monitoring of sound and temperature during stimulation and production was installed in the MIP 5H. Fracture stimulation on both the MIP 3h and MIP 5H started on 26 October and was completed on 15 November and individual stages were monitored with the fiber optic cable. The MIP SW well was used for microseismic monitoring during stimulation. All operations were successfully completed and production started on 10 December, and is being monitored. Fluids and gas samples are being recovered on a regular basis by several researchers.

Quarterly Progress Report

October 1 – December 31, 2015

Project Performance

This report summarizes the activities of Cooperative Agreement DE-FE0024297 (Marcellus Shale Energy and Environment Laboratory – MSEEL) with the West Virginia University Research Corporation (WVURC) during the first quarter of the FY2016 (October 1 through December 31, 2015).

This report outlines the approach taken, including specific actions by subtopic. If there was no identified activity during the reporting period, the appropriate section is included but without additional information.

Topic 1 – Project Management and Planning

Subtopic 1.1. – Project Management

Approach

The project management team works to generate timely and accurate reporting, and to maintain project operations, including contracting, reporting, meeting organization, and general oversight.

Results and Discussion

This quarter has been a very active quarter for the project, with the production and science wells reaching completion (drilled, stimulated, completed), and with a large amount of data collected (geologic samples – cores, cuttings, water samples, geophysical logs, etc.). The project team is currently working to update the Project Management Plan (PMP) to reflect current progress, as well updating subawards to reflect changes made to the Statement of Project Objectives at the end of the fiscal year.

Subtopic 1.2. – Database Development

Approach

We will use CKAN, open source data portal software (www.ckan.org). This platform is used by NETL-EDX and Data.gov among other organizations and agencies. We will use this platform to store, manage, publish and find datasets.

Results and Discussion

CKAN is up and running and is used to share data among numerous researchers from the existing wells and presentations among research personnel (Task 1.2). There is now a very large amount of data on the MSEEL portal measuring in the 100's of gigabytes covering all aspects of drilling and completion of the wells. It is expected that the last of the raw data from the wells will be loaded in the next quarter. Additional data will be generated by various laboratory analyses. The MSEEL web site has been enhanced with MSEEL News articles, a time line and with images. We have generated static and dynamic 3D images of the surface and subsurface at the MSEEL site (Figure 1.1)

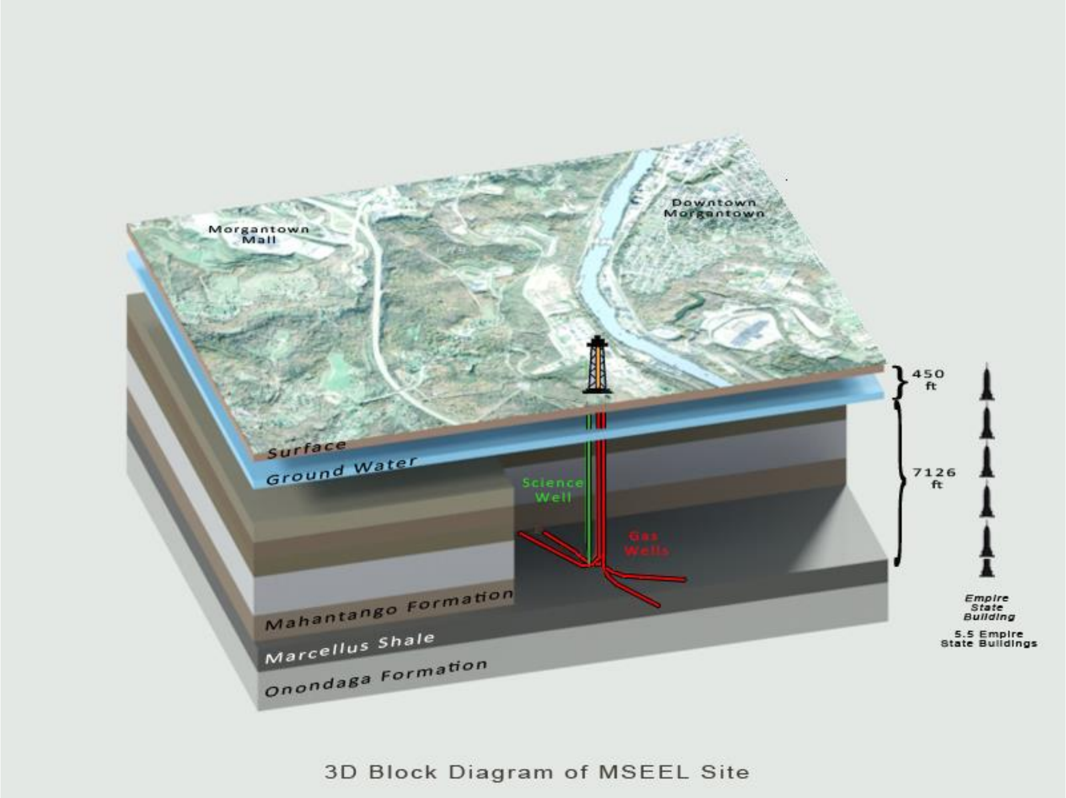

Figure 1.1: Static 3D image of the MSEEL sit showing the existing production wells and the two new production wells along with the science/observation well.

Plan for Next Quarter

Upload 3D static and dynamic images to online site and federate MSEEL portal with EDX.

Topic 2 – Geologic Engineering

Approach

The geologic engineering team will work to generate to improve the effectiveness of fracture stage design. Evaluating innovative stage spacing and cluster density practices to optimize recovery efficiency. The team will use a data driven approach to integrate geophysical, fluid flow and mechanical properties logs, microseismic and core data to better to characterize subsurface rock properties, faults and fracture systems to model and identify the best practices for field implementation, and assess potential methods that could enhance shale gas recovery through experimental and numerical studies integrated with the results of the production wells at the MSEEL site.

Drilling at MSEEL site began on 26 August, 2015 and ended in the present quarter on 04 October, 2015. Completion and stimulation on the MIP5H with 30 stages began 28 October and was completed on 6 November 2015. Completion and stimulation on the MIP3H with 28 engineered stages of variable cluster design began 7 November and was completed on 15 November 2015. Final completion with drilling out of plugs was 10 December and production began on December 12, 2015. All three MSEEL wells (MIP 3H, MIP 5H and MIP SW) were drilled and logged 03 October. Fiber optic cable for monitoring of sound and temperature during stimulation and production was installed in the MIP 3H and shows changes during stimulation and production. Fracture stimulation of individual stages in the individual stages was monitored with the fiber optic cable (Figure 2.1 and 2.2). Production continues to be monitored with the fiber-optic cable via temperature (Figure 2.3). The MIP SW well was used for microseismic monitoring during stimulation. Preliminary microseismic data appear very robust and final data is to be delivered before the end of January (Figure 2.4). All operations were successfully completed and production started on 10 December and is being monitored for temperature. This data will be finalized during the coming quarter.

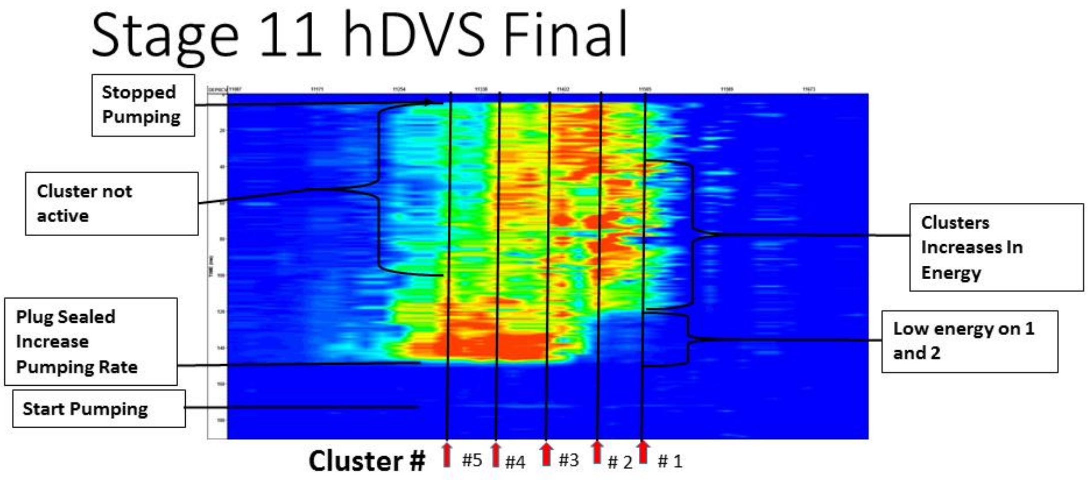

Figure 2.1: Example of sonic response during stage 11 of the MIP3H as measured by the fiber-optic cable. Data was collected for each of the 28 stages.

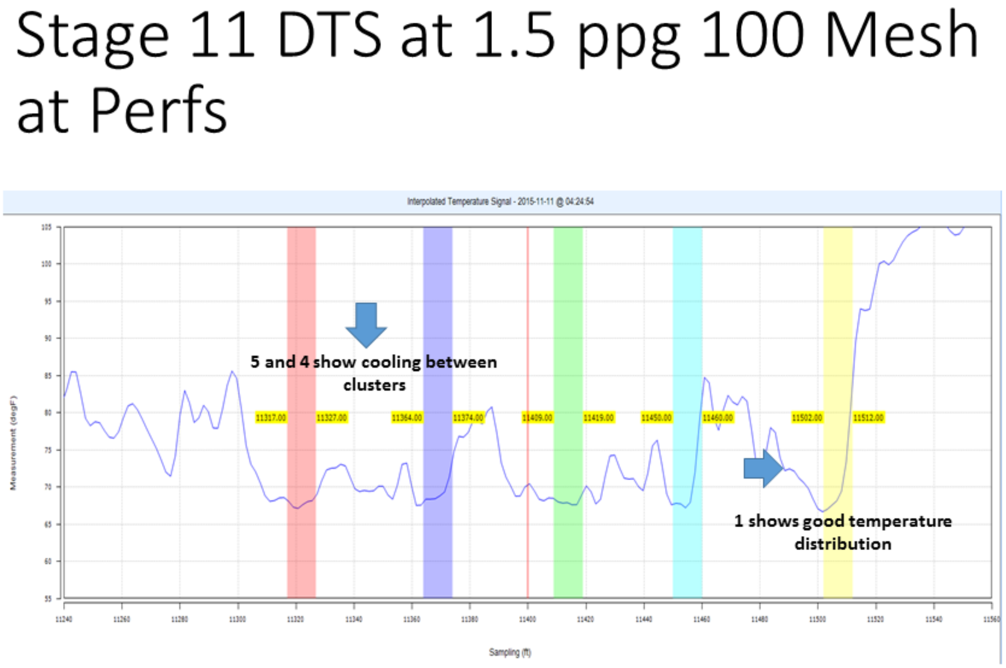

Figure 2.2: Example of temperature response during stage 11 of the MIP3H as measured by the fiber-optic cable during stage 11 of the MIP3H. Data was collected for each of the 28 stages.

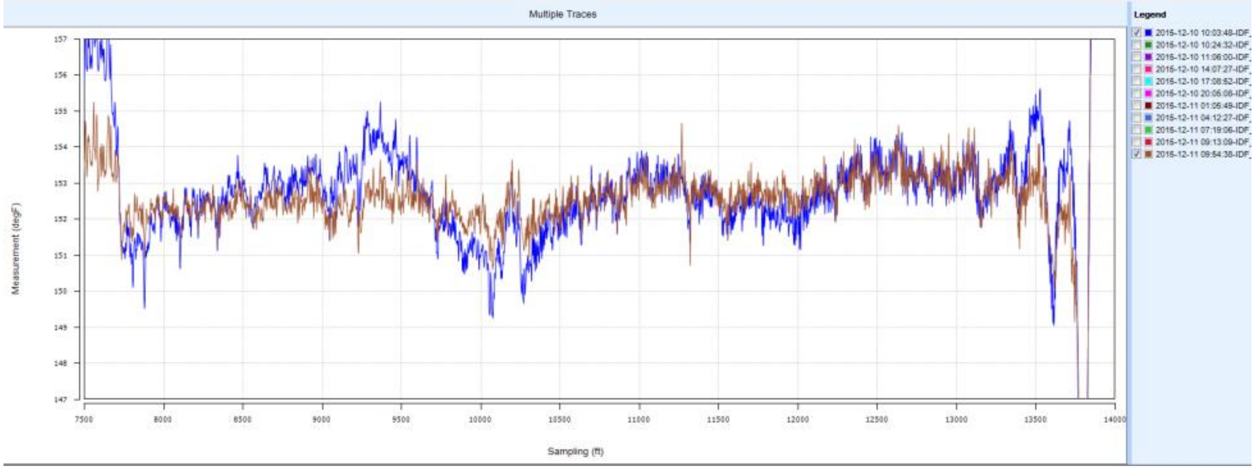

Figure 2.3: Example of change in temperature along the entire lateral MIP3H as measured by fiber-optic cable during the first 24 hours of production beginning 10 December at 10:03 am (blue) through 9:54am on 11 December (rust). Increased cooling indicates areas of relatively higher production from the various stages.

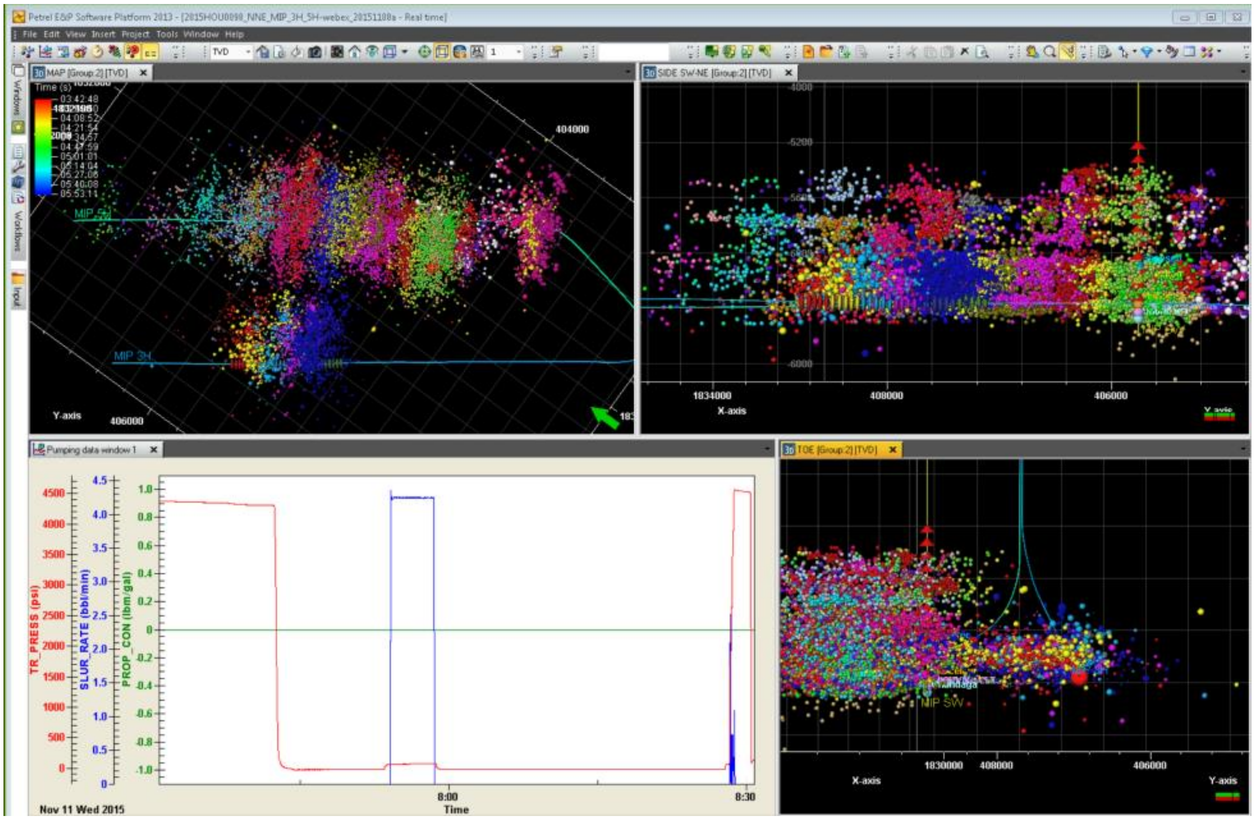

Figure 2.4: Example of preliminary real-time microseismic monitoring with pump schedule shows good results in terms of resolution and performance. Final microseismic results will be delivered during Quarter 2.

Results and Discussion

Core plug samples from the science well have been obtained. The established protocols for sample analysis have been implemented to characterize the core plugs. The base set of experiments using Helium for measurement of porosity, permeability, and compressibility are under way.

The analysis of the production and stimulation data from the existing horizontal wells at the MIP site as well as other horizontal Marcellus shale wells in the region is nearly complete.

In addition, the analysis of the data generated during drilling wells MIP-3H and MIP-5H at NNE site is in progress. The determining formation characteristics from wireline and thermal logs is also in progress.

Plan for Next Quarter

The measurement on the core plug samples will continue to obtain a complete set of characteristics. In addition, experiments with Carbon Dioxide or Methane will be initiated to evaluate the adsorption characteristic of the core plugs.

Topic 3 – Deep Subsurface Rock, Fluids, and Gas

Approach

The “Deep Subsurface Rock, Fluids & Gas” team is responsible for high resolution temporal and/or spatial characterization of the core, produced fluids, and produced gases. The team will use whole and sidewall core and geophysical logs from the science well to conduct various petrophysical analyses to analyze physical rock properties. Data generated by all team members will be integrated to answer following key research questions: 1) geological controls on microbial distribution, diversity and function and how it can effect gas productivity, potential for fracture and pore clogging, well infrastructure and souring 2) major controls on distribution/source/type of organic matter that has implications for oil vs gas production, frackability, restimulation and porosity/permeability effects 3) what are spatiotemporal variations in elemental, isotopic, mineralogical and petrological properties that control presence, geological migration, and modern flow of fluids, water, gases and microorganisms and also effect long-term production behavior of reservoir 4) what are possible water-rock-microbial interactions as a result of injection of fracturing fluids, and 5) does hydraulic fracturing create new pathways for fluid/gas migration

Plan is to develop specific methodology for testing during the next quarter, so that all scientific objectives can be achieved.

Results and Discussion

The main focus of this quarter was to collect core, fluid and gas samples from the MSEEL site. Members of Sharma’s lab group (Dr. Warrier and Mr. Wilson) and Daly from Wrighton’s Ohio State lab group coordinated and supervised all sample collection. Samples were also distributed to research team at OSU and NETL for analysis under different sub-tasks. Several talks and presentations were given at local and regional conferences /universities. Two proposals are currently underworks to support MSEEL research. Dr. Wrighton (Wrighton et al. 2015) presented initial results at the annual AGU meeting in December (http://phys.org/news/2015-12-gas-hydraulic-fracturing-source.html#jCp)

Goal 1: Sample collection and Processing

Sidewall and Vertical Core

Significant effort from all groups occurred during and after sidewall core collection from well 3H and vertical Science well at MSEEL site. To identify sections of sidewall cores which have come in contact with coring fluids fluorescent microspheres (0.5 mm diameter) were added to drilling fluids at target concentration. All the side wall cores were received by our group as soon as they hit ground and preserved per the required protocols to avoid microbial contamination. The cores were photographed, inventoried, labeled and transported to the laboratory in cold and sterile environment. The cores were examined microscopically and sections of the core contaminated by the fluorescent microspheres were scraped off by fine steel wool at Wrighton's lab. The cores are processed by triple cleaning using a salt-water wash, with tracers enumerated prior to and post-cleaning using microscopy. A few cleaned core samples have been ground/split and distributed to research groups (Cole, Darrah, Mouser, Wilkins, Wrighton, Sharma) for analysis. Isotope analysis, Elemental analysis, Porosity/pore structure, and noble gas analysis of cores are underway. The remaining intact cores will be archived in Sharma's Lab at WVU and Mouser lab at OSU for future analysis.

Produced Fluid and Gas

Produced water samples were collected in 5 gallon carboys just after the seperartor. The samples were the tranported, filtered and processed in Sharma Laboratory at WVU. All water samples were collected in different containers using different methods/ preservatives etc. specified for different kinds of analysis. All PI's at OSU and NETL and provided their detailed sampling instructions. Dr. Warrier, Wilson from WVU and Daly from OSU were primarirly in charge of sample collection and distribution among different PI's at WVU, OSU and NETL. The collected fluids are curretly being processsed for biomass, reactive chemistry, organic acids, and noble gas and stable isotope analysis at different institutes.

The produced gas samples were collected from well heads of the two production wells and transported to Sharma Lab at WVU and analyzed for molecular composition and C/H isotope composition of methane, ethane and CO_2. The gas samples were then sent to Darrah's lab at OSU for noble gas analysis. Currently isotope and noble gas analysis is underway.

Goal 2: Test methods biomarker extraction, identification and quantification

Out of the 44 sidewall cores collected from the well 3H 8 cores were selected for analysis. Biomarkers were extracted in Dr. Sharma's lab at WVU. Biomarker identification and quantification is currently under way. In addition, graduate students Ryan Texler from Mouser lab and Rawlings Akondi from Sharma Lab will be travelling to University of Tennessee, Knoxville (UTK) to work on extraction, identification and quantification of Phospholipid Fatty Acids (PLFA's) and diglyceride fatty acids (DGFA's) from a few selected samples. The results from all these analysis will help us better understand the controls on organic matter distribution and preservation and microbial diversity in different parts of core.

Goal 3: Microbial cultivation

Samples collected from pristine side wall cores collected from different lithologies from a vertically resolved depth profile from the two wells are being incubated under a range of conditions (variable pressure, carbon source, electron acceptor) to enrich for indigenous microbial populations and isolates.

1. Training/Professional Development?

- Sharma, Warrier, Wilson from Sharma Lab and Rebecca Daly from Wrighton Lab, trained in sidewall core sample collection
- Multiple staff and students from the Sharma, Mouser, Wrighton, Wilkins, Darrah, and Cole lab were involved in tours over the past quarter, and visited MSEEL during drilling and well completion activities.
- Sharma, Wilson, Akondi and Agarwal gave oral and poster presentations at the 2015 Geological Society of America Annual meeting in Baltimore, MD in November (see abstracts below).
- Mouser and Trexler travelled to the 2015 Geological Society of America Annual meeting in Baltimore, MD in November and presented in shale related sessions (see abstracts below)
- Wrighton traveled to and presented in shale related sessions at the 2015 American Geophysical Union Annual meeting in San Francisco, CA during December (see abstracts below).
- Booker is a second-year student in OSU's Microbiology graduate program working with Dr. Mike Wilkins. Anne has had the opportunity to travel to EMSL/PNNL in Washington State to perform NMR analyses in collaboration with staff scientists.

2. Data Dissemination?

   Sharma, Mouser, Wrighton & Wilkins gave several presentations highlighting the importance of MSEEL research in future discoveries. Some popular media articles are listed below:

   - Preston County Journal: http://www.theet.com/news/local/wvu-project-setting-the-standard-for-researching-oil-and-gas/article_25e0c7d0-279d-59c1-9f13-4cbe055a1415.html
   - The statesman: http://www.thestatesman.com/news/science/fracking-messiah-or-menace/81925.html
   - Nova Next article: http://www.pbs.org/wgbh/nova/next/earth/deep-life/
   - NPR interview: http://www.wksu.org/news/story/43880
   - Midwest Energy News : http://midwestenergynews.com/2015/11/17/researchers-study-microbes-living-in-shale-and-how-they-can-impact-drilling/
   - McClatchyDC News: *"Could deep earth microbes help us frack for oil?"* S. Cockerham http://www.mcclatchydc.com/news/nation-world/national/article29115688.html

Publications (Abstracts)

Agrawal V, Sharma S , Chen R, Warrier A, Soeder D, Akondi R. 2015. Use of biomarker and pyrolysis proxies to assess organic matter sources, thermal maturity, and paleoredox conditions during deposition of Marcellus Shale. Annual Geological Society of America Meeting, Baltimore, MD, November 1-4.

Akondi R, Sharma S, Pfiffner SM, Mouser PJ, Trexler R, Warrier A. 2015. Comparison of phospholipid and diglyceride fatty acid biomarker profiles in Marcellus Shale cores of different maturities. Annual Geological Society of America Meeting, Baltimore, MD, November 1-4.

Mouser, PJ, Daly, RA, Wolfe, R. and Wrighton, KC (2015). Microbes living in unconventional shale during energy extraction have diverse hydrocarbon degradation pathways. Oral presentation presented at 2015 Geological Society of America Annual Conf. Baltimore, MD, Nov 1-4.

Sharma S and Wilson T. 2015. Isotopic evidence of microbe-water-rock interaction in Shale gas produced waters. Annual Geological Society of America Meeting, Baltimore, MD, November 1-4.

Sharma S, Chen R, Agrawal V. 2015 Biogeochemical evidences of oscillating redox conditions during deposition of organic-rich intervals in the middle Devonian Marcellus Shale. Annual Geological Society of America Meeting, Baltimore, MD, November 1-4.

Trexler RV, Pfiffner SM, Akondi R, Sharma S, Mouser PJ.(2015) Optimizing Methods for Extracting Lipids from Organic-Rich Subsurface Shale to Estimate Microbial Biomass and Diversity. Poster session presented at: 2015 Geological Society of America Annual Meeting. 2015 Nov 1-4; Baltimore, MD.

Wrighton, KC; Daly, R; Hoyt, D; Trexler, R; MacRae, J; Wilkins, M; Mouser, PJ (2015), Oral presentation at the American Geophysical Union Annual Meeting. Something new from something old? Fracking stimulated microbial processes. Presentation# B13K-08. San Francisco, CA, Dec 14-18, 2015.

Plan for Next Quarter

- Complete processing/cleaning of pristine cores. Submit DNA from sample washes for sequencing in order to identify contaminant DNA and lipid signatures.
- Sharma lab will be working on processing and analyzing samples for C/N/S isotopes and biomarkers
- Wrighton lab will be working on extracting DNA from shale core.
- Mouser group will continue processing fluid samples from MSEEL wells. Circulate preliminary chemistry data to identify samples for future metagenomics/lipid analysis.
- Students from Mouser and Sharma labs will travel to UTK for lipid extraction of sidewall cores.
- Students and staff from the Cole and Darrah lab will be continuing pore, elemental, and noble gas analysis of shale core and fluids.

Topic 4 – Geophysical and Geomechanical

Approach

Team is conducting microseismic analyses during the fracture stimulation of the production wells and tie that data back to the geophysical logs obtained from the science well, providing a clearer picture of proppant placement through the establishment of a detailed rock velocity model. Some inferences toward fracture quantity and patterns will also be vetted.

Plan is to identify specific methodology to obtain the data that will provide most understanding of subsurface rock model.

Results and Discussion

Task 4a - Geophysics:

This past quarter: 1) Detailed analysis of the Quanta Geo fracture data was undertaken; 2) Developed a model fracture network based on Quanta Geo observations at a specific location along a test well; 3) perforations were located in regions of similar stress and pump parameters from Schedule D were used to develop a stimulation case; 4) Several simulations were tested including two with orientations of S_{Hmax}: one obtained from the average induced fracture trend and the other from the average breakout trend. Effort 0.65 FTE months.

Fracture data from the Schlumberger Quanta Geo image logs was provided by NNE this quarter. The fracture intensity data reveals considerable variability in fracture intensity along the length of the lateral (Figure 4.1). Twenty-one fracture intensity intervals were identified (Figure 4.1.1).

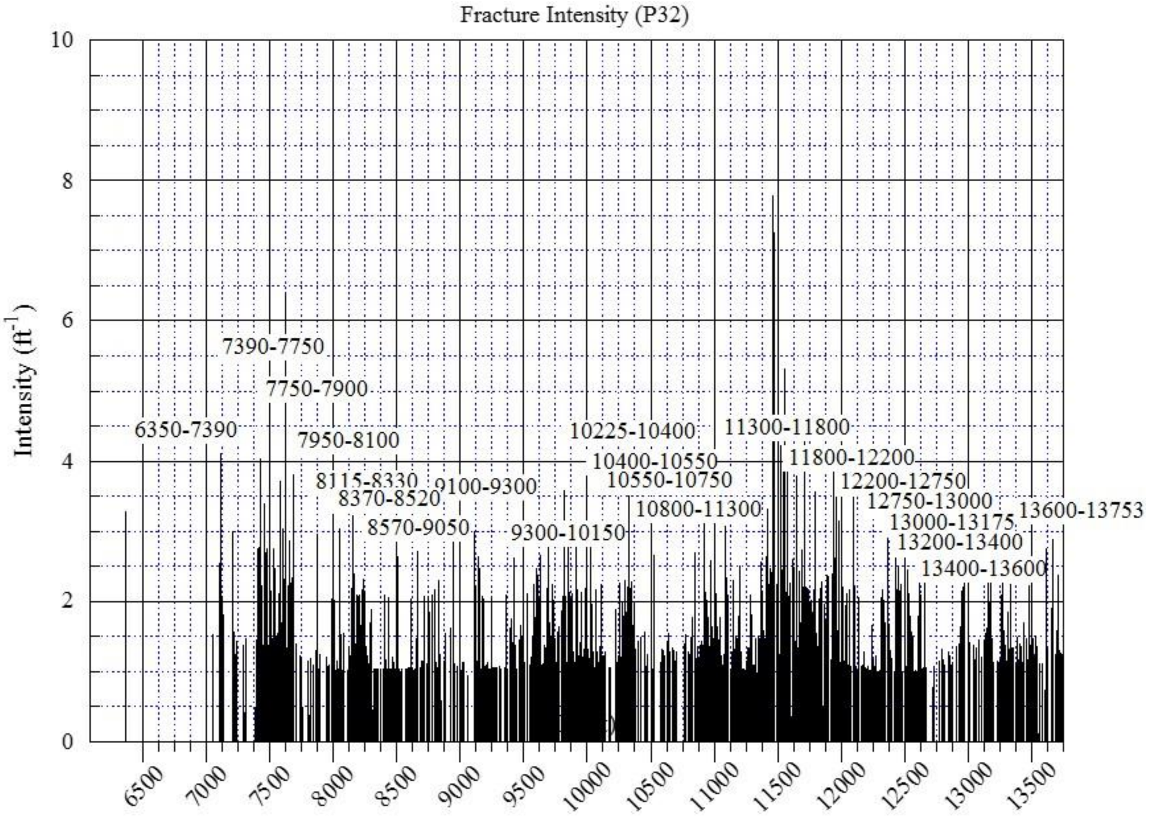

Figure 4.1.1: Fracture intensity observed in the Quanta Geo image log from the MIP3H lateral.

Fracture orientations in each of these intervals were plotted in rose diagram form (Figure 4.1.2) to illustrate variations on natural fracture trend along the length of the lateral.

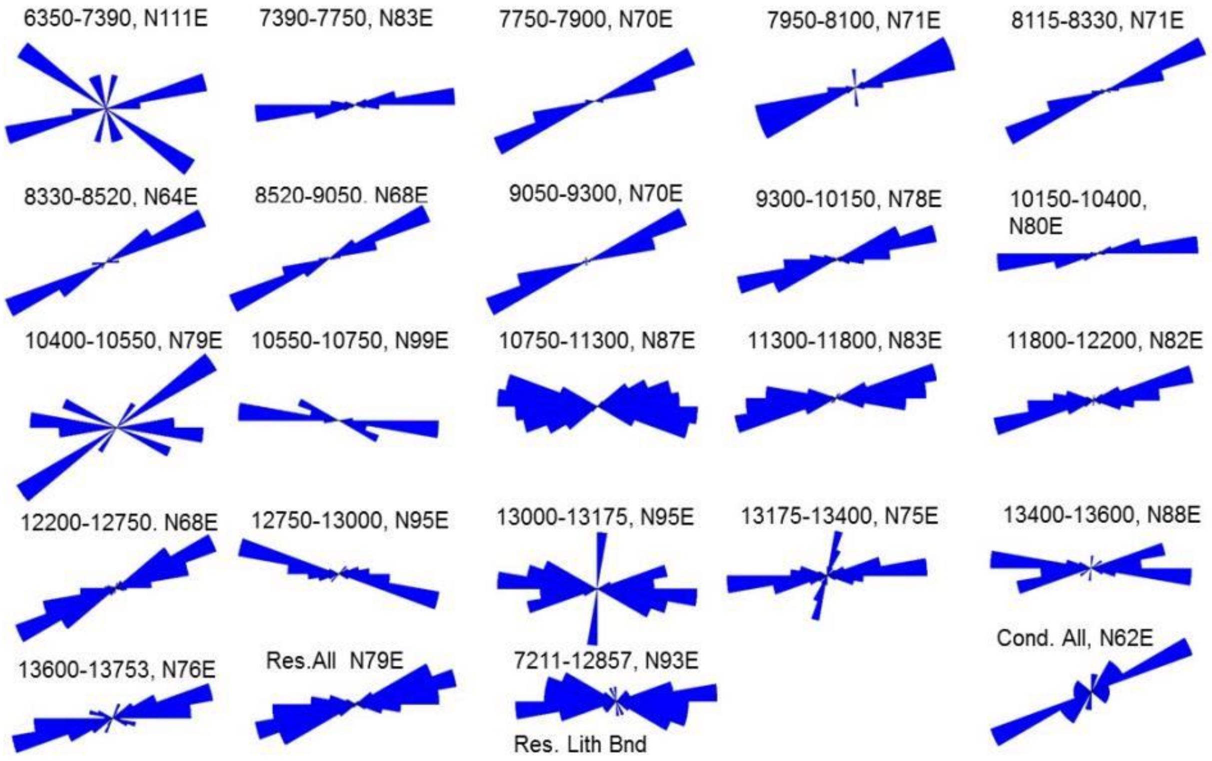

Figure 4.1.2: Rose diagrams of resistive fractures from zones of similar fracture intensity in the MIP 3H lateral.

The average trend in each region is noted in Figure 4.1.2 and presented in histogram form in Figure 4.1.3. Average fracture trend is concentrated between N70-85E.

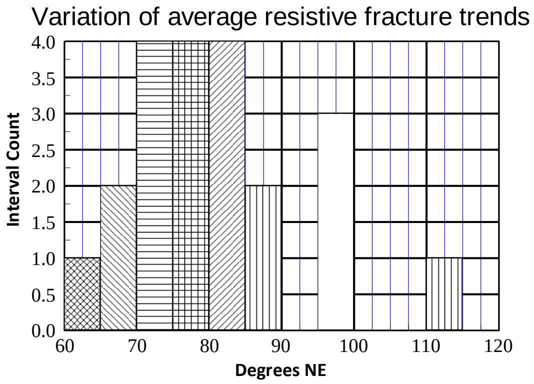

Figure 4.1.3: Histogram of average trends noted in Figure 4.1.2.

Fracture orientations observed between approximately 11,000 and 12,000 feet along the lateral were used to develop a local 2D fracture model (Figure 4.1.4).

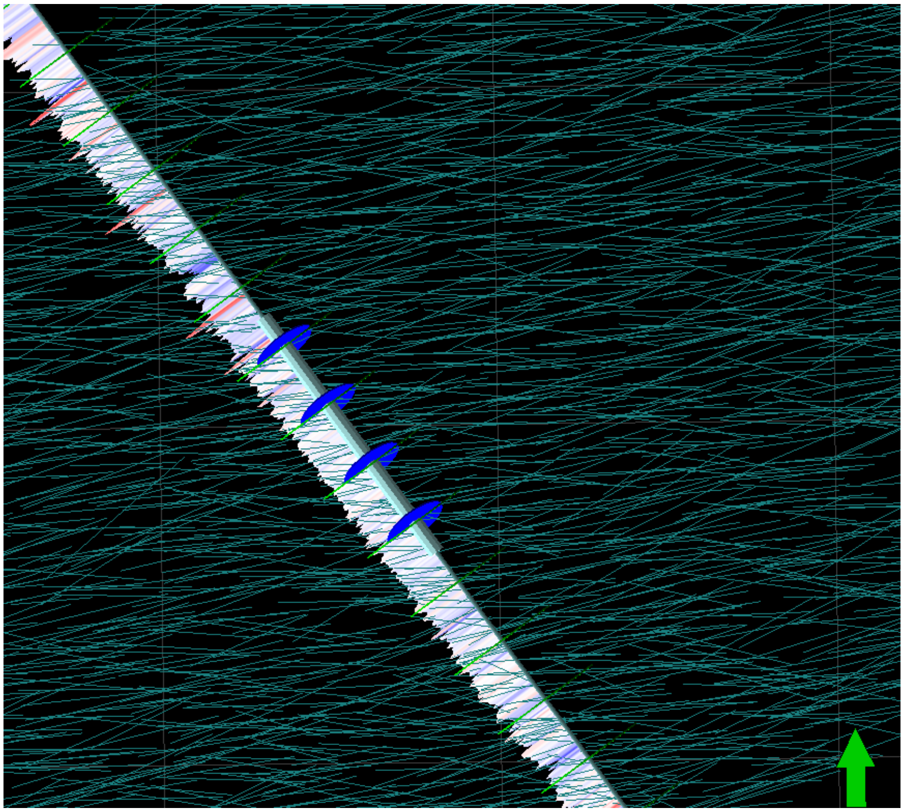

Figure 4.1.4: Fractures with average trend of N83E and standard deviation of 10ºare shown along the lateral. The minimum stress gradient log is plotted along the length of the lateral. Four perf clusters are shown for this test stimulation case.

The locations of the perforation clusters in this test case were located in an area of similar stress. The pump parameters from Schedule D were used to develop the test stimulation case. In this test, structure along the length of the candidate well was eliminated. The results (Figure 4.1.5) reveal potential interactions of the hydraulic fracture stimulation with the local natural fracture network. The orientation of S_{Hmax} was set to approximately N60E as inferred from the induced fractures and breakouts.

A stress gradient or stress shadow was also incorporated into some of the models to evaluate the potential influence of stress perturbations that might be related to earlier stimulation of an adjacent well (Figure 4.1.6). Stimulated fractures extend farther to the northeast into areas of reduced stress. Microseismicity associated with treatment in the 3H well was often concentrated northeast toward the MIP 5H well which was stimulated a few days earlier.

The initial tests used a flat structural model. A structural model based on local structure inferred from the well paths and nearby vertical well will be developed. Structure based solely on the well paths and vertical well control points (Figure 4.1.7A) reveals a local northwest strike.

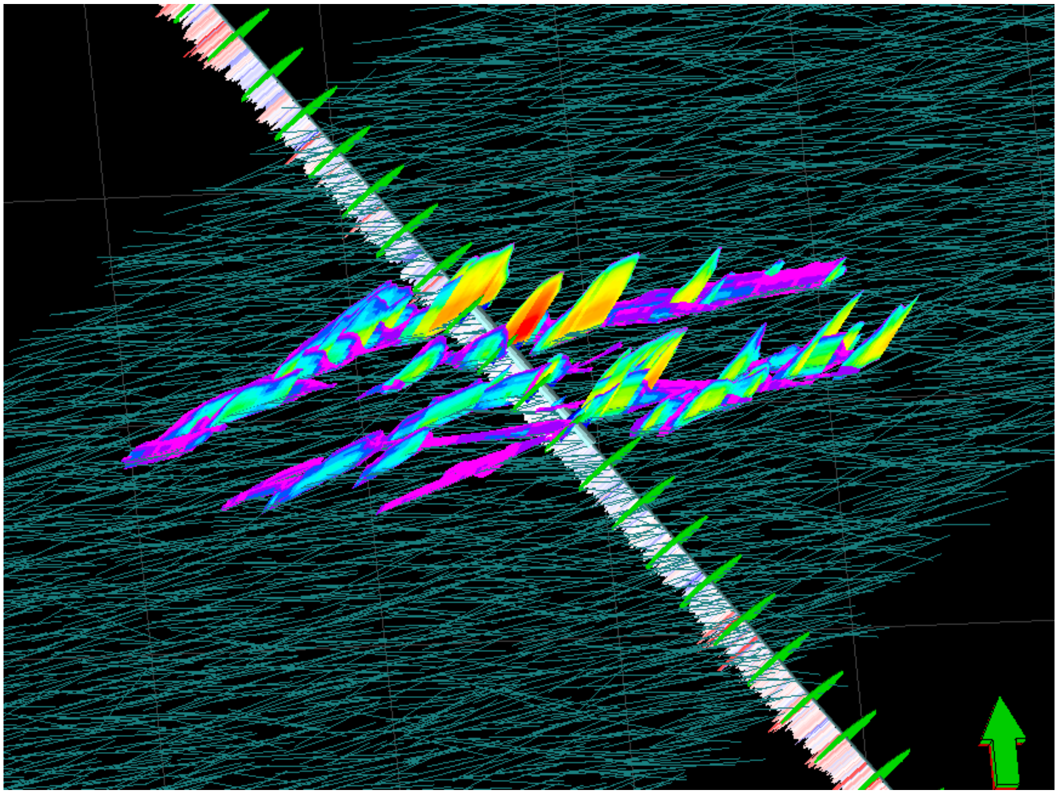

Figure 4.1.5: Interaction of the hydraulic fracture stimulation with the natural fracture network observed in the Quanta Geo image logs.

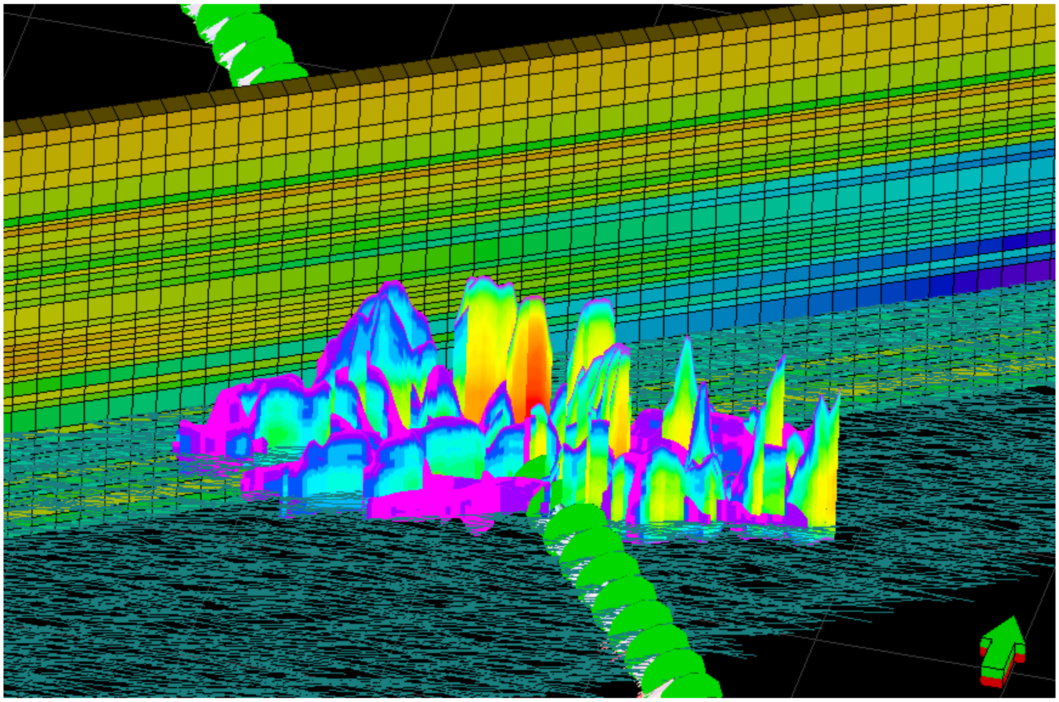

Figure 4.1.6: Stress gradient in the zone set extends to the northeast. Stimulated natural fractures are show in the foreground over the projected natural fracture network.

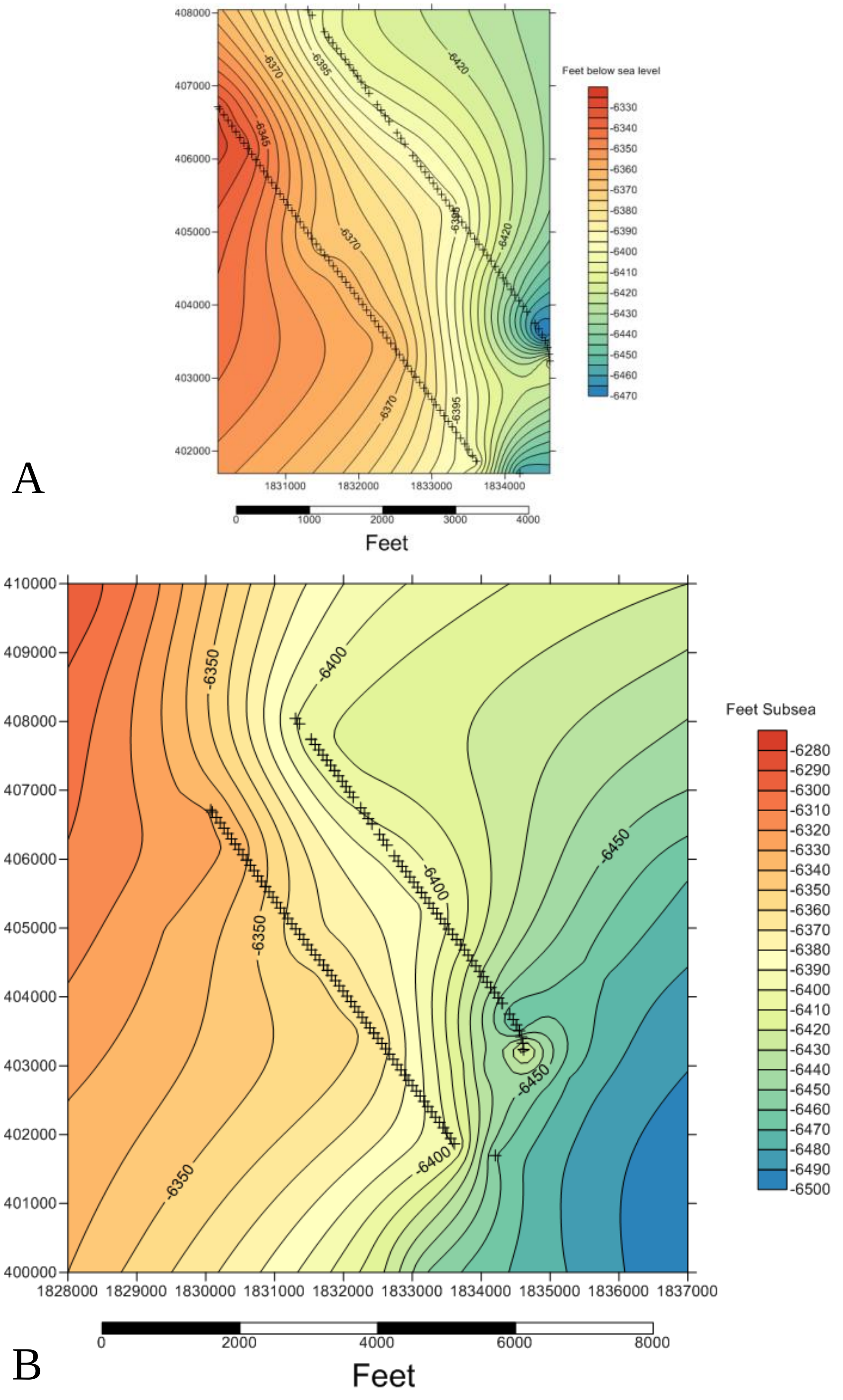

Figure 4.1.7: A) Local structure inferred from the MIP3H and 5H well paths; B) additional control points were added to produce a reasonable extension of the structure along local strike of ~N30E.

Additional points were added to the well control points to extend the model out ~2000 feet and more from the laterals (Figure 4.1.7B). This structure will be used to develop another zone set that will incorporate the estimate of local structure into the model grid.

Task 4b - Geomechanical:

Review of available data for the MSEEL site was continued. Modeling parameters for the anticipated hydraulic fracturing operation were identified and requested from NNE. Following specific items were performed.

(a) Parameters of the actual hydraulic fracturing operations were requested from NNE. These parameters are given below.

DATA NEEDED:

(1) Complete Treatment Schedule for each stage: (a) slurry rate (bpm) variation, (b) liquid volume variation, (c) fluid type, (d) proppant type(s), (e) proppant concentration (lbm/bbl), (f) details of each stage of injection, (g) bottom hole treatment pressures, (h) Fluid rheology and friction data (if available)

(2) Details of perforations: (a) Number of perforation clusters per stage, (b) Number of perforations in each cluster, (c) perf diameter

(3) Pay zone information: (a) TVD top and bottom for each stage, (b) permeability, if known

(4) Casing or Tubing Details: (a) measured depth, (b) outside and inside diameters, (c) weight (lbf/ft)

(5) Wellbore information: (a) inclination angle as a function of depth

(b) Preliminary modeling work was performed to determine potential fracture geometry based on assumed treatment schedule (fluid volume, proppant mass, and injection rate) and geomechanical properties. The following treatment parameters were assumed:

(1) Injection fluid volume = 300,000 US Gallons
(2) Proppant mass = 400,000 lbm
(3) Proppant type: 40/70 sand
(4) Maximum injection rate = 90 bpm

During this quarterly period, numerical modeling studies were performed to determine the influence of depth and injection layer thickness on hydraulic fracture length and height. As site-specific hydraulic fracturing data is not yet available to the research team, parameters were assumed in this study. A treatment schedule using a maximum injection pressure of 90 BPM, slickwater, and 40/70 proppant was utilized. Four hydraulically induced fractures were assumed to propagate from each stage. A base case was developed using an assumed depth to the Marcellus shale of 8,200 feet, and an assumed Marcellus thickness of 100 feet. The width profiles and contours from numerical simulation of the base case are shown in Figure 4.2.1. Both the depth to the Marcellus shale and the thickness of the Marcellus shale were varied in a parametric study. The depth of the Marcellus shale was varied from 7,900 feet to 8,500 feet. The width profiles and contours from numerical simulation of the 7,900 foot depth and 8,500 foot depth cases are shown in Figure 4.2.2 and Figure 4.2.3, respectively. The impacts of Marcellus shale depth on maximum fracture length and maximum fracture height are shown in Figure 4.2.4 and Figure 4.2.5, respectively. The thickness of the Marcellus shale was varied from 80 feet to 120 feet. The width profiles and contours from numerical simulation of the 80 foot Marcellus thickness and 120 foot Marcellus thickness cases are shown in Figure 4.2.6 and Figure 4.2.7, respectively. The impacts of Marcellus shale thickness on maximum fracture length and maximum fracture height are shown in Figure 4.2.8 and Figure 4.2.9, respectively. For this particular situation the following conclusions can be made:

- An increase in Marcellus shale depth resulted in an increase in hydraulic fracture length and a decrease in hydraulic fracture height.
- An increase in Marcellus shale thickness resulted in a decrease in hydraulic fracture length and an increase in hydraulic fracture height.

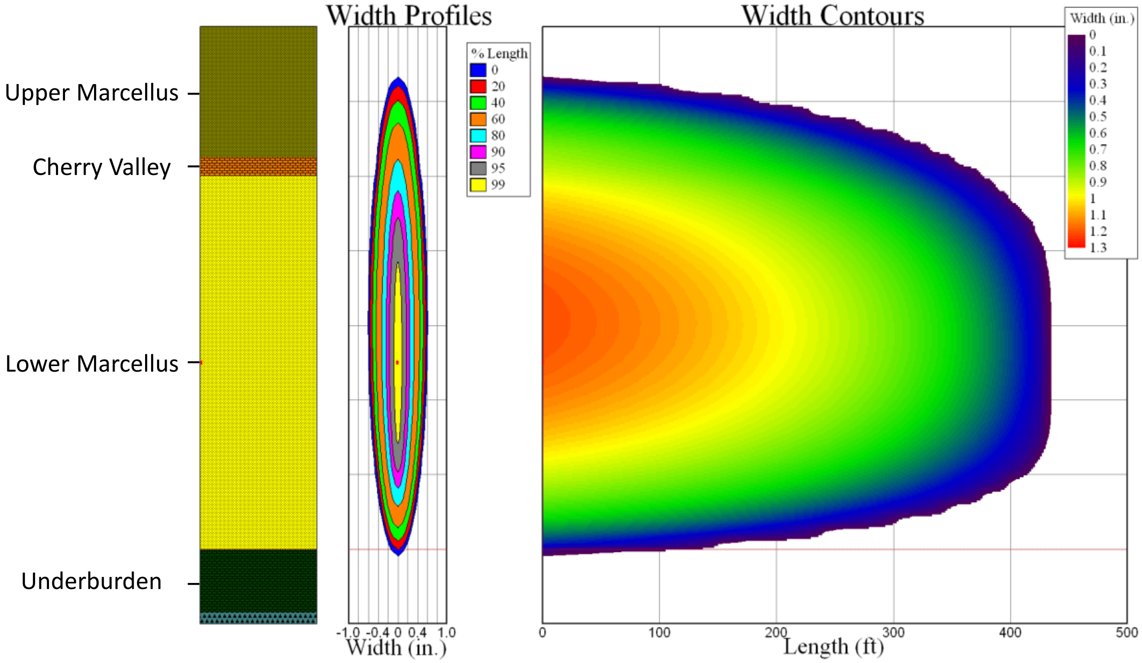

Figure 4.2.1: Width Profiles and Contours for the Base Case

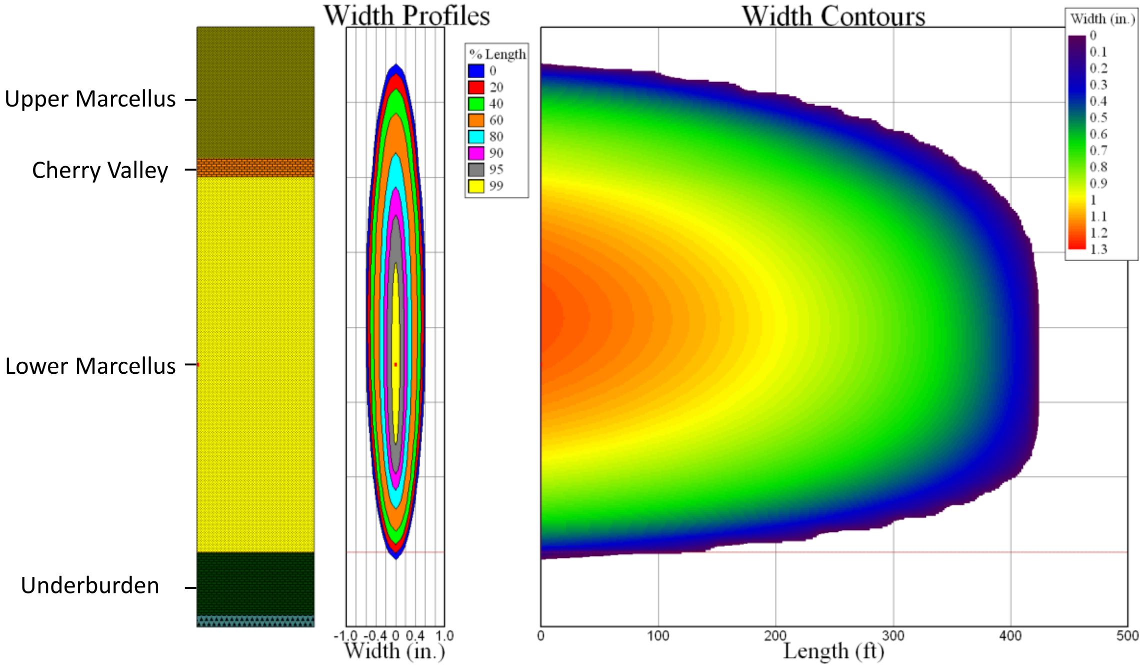

Figure 4.2.2: Width Profiles and Contours for the 7900 foot Marcellus Depth Case

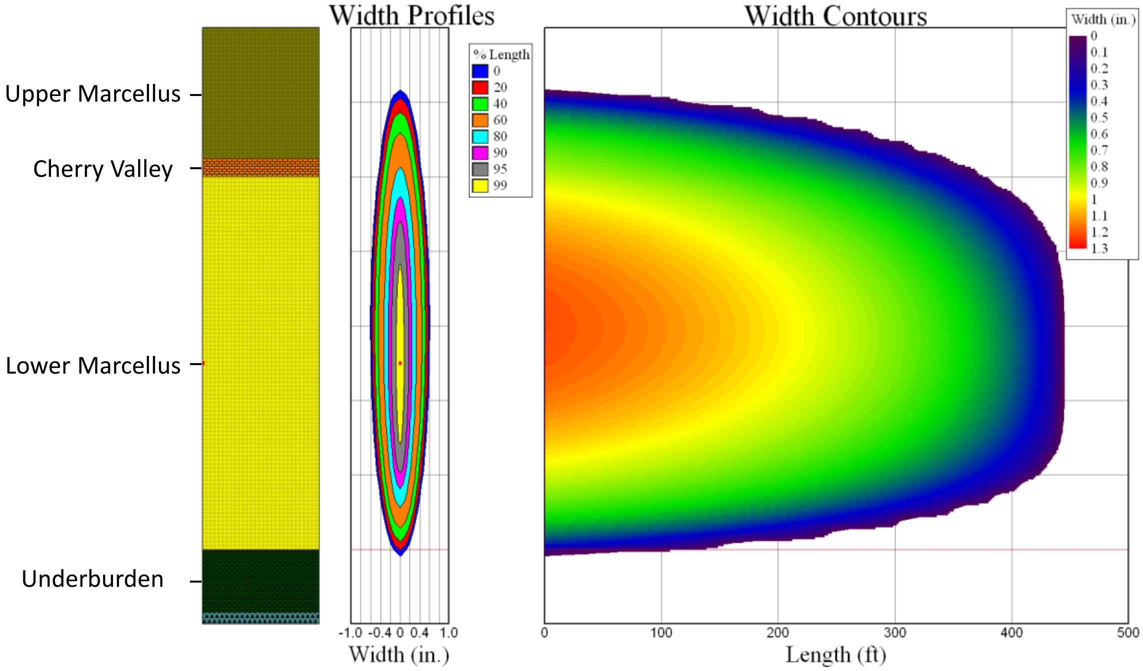

Figure 4.2.3: Width Profiles and Contours for the 8500 foot Marcellus Depth Case

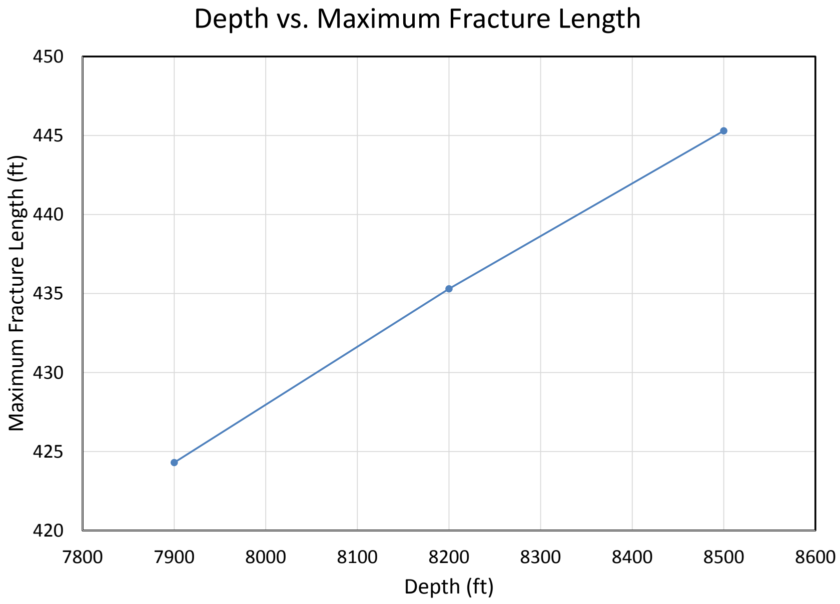

Figure 4.2.4: Marcellus Shale Depth vs. Maximum Fracture Length

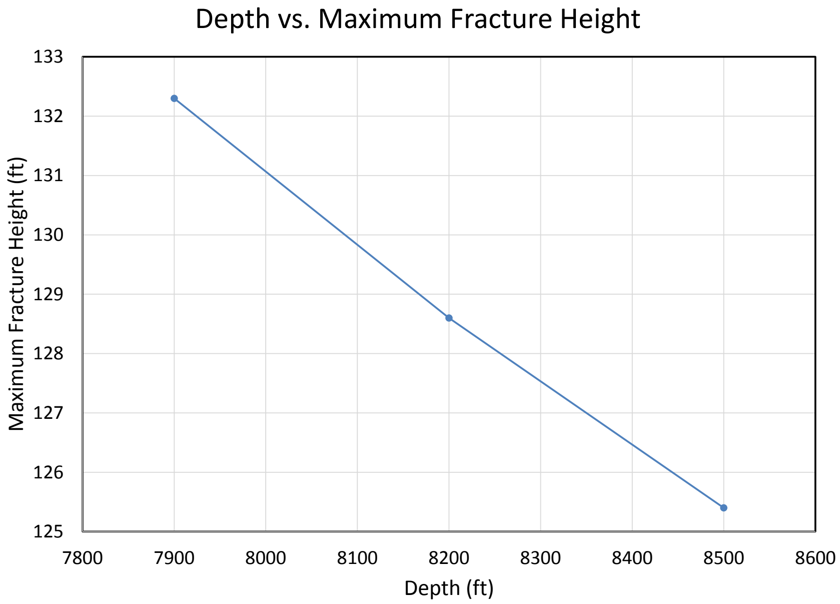

Figure 4.2.5: Marcellus Shale Depth vs. Maximum Fracture Height

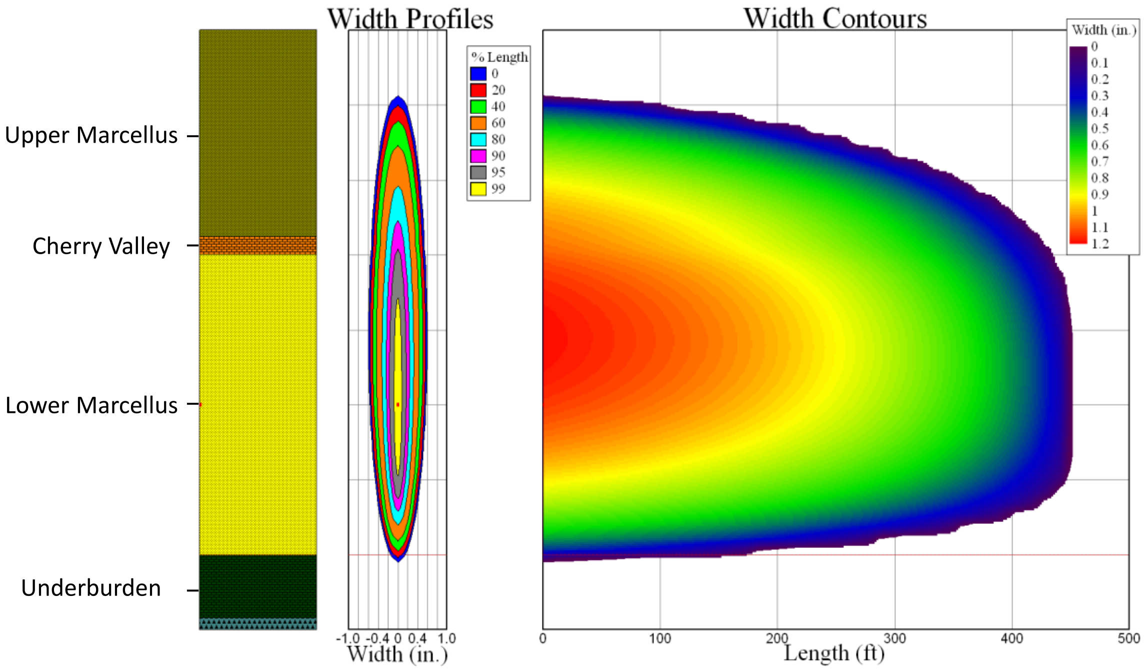

Figure 4.2.6: Width Profiles and Contours for the 80 foot Marcellus Thickness Case

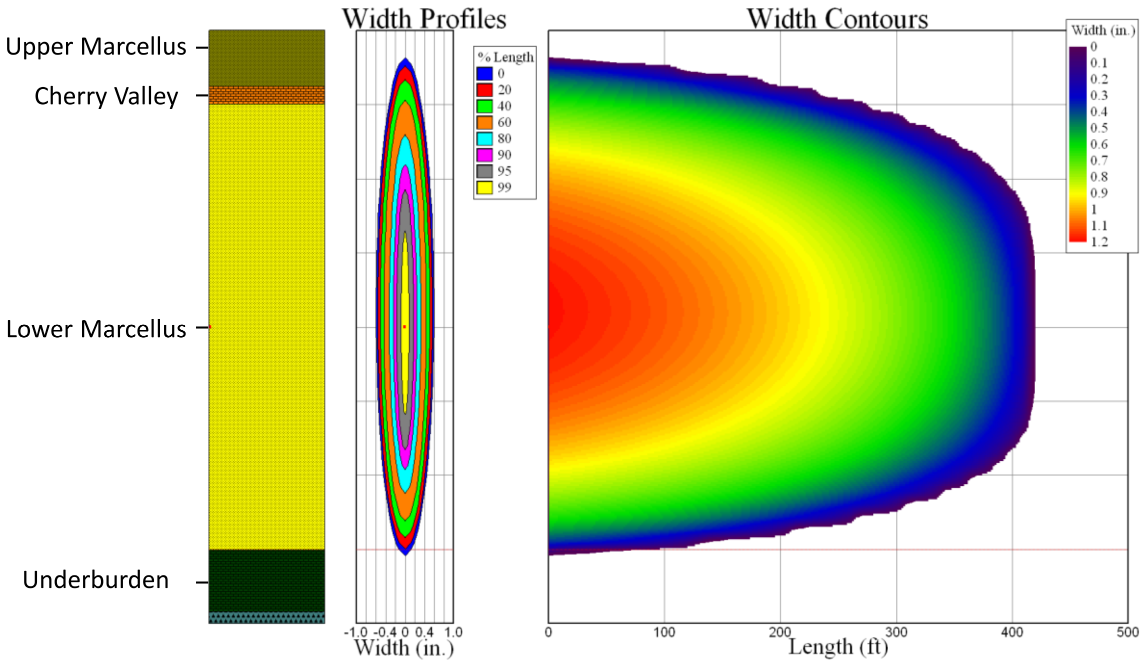

Figure 4.2.7: Width Profiles and Contours for the 120 foot Marcellus Thickness Case

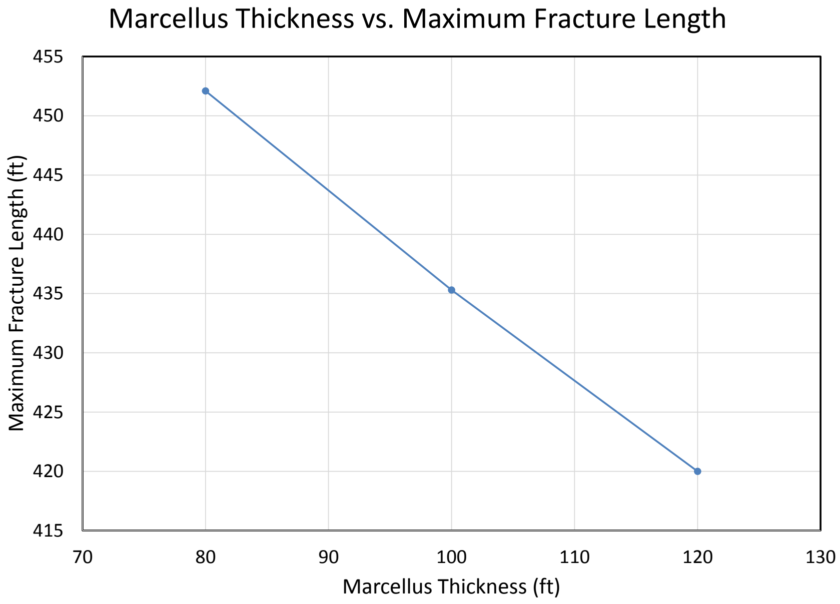

Figure 4.2.8: Marcellus Shale Thickness vs. Maximum Fracture Length

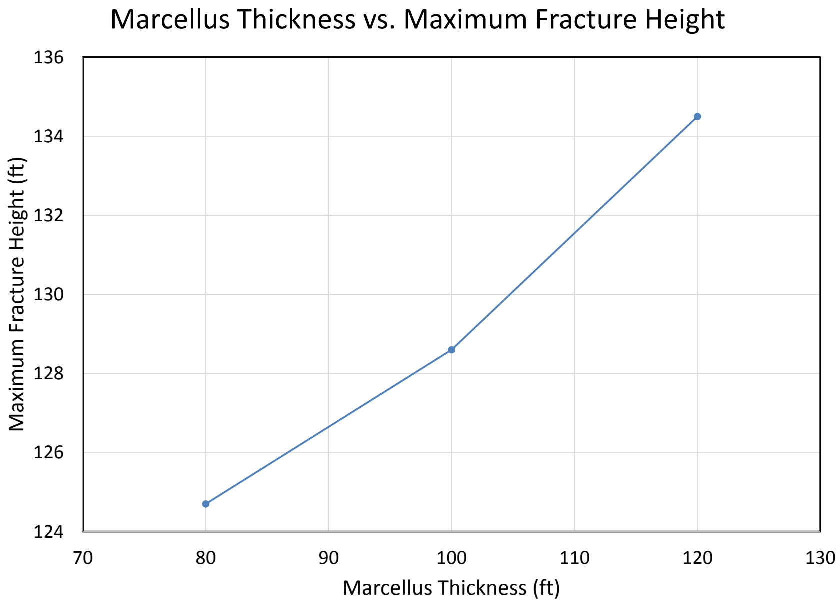

Figure 4.2.9: Marcellus Shale Thickness vs. Maximum Fracture Height

Plan for Next Quarter

Task 4a – Geophysical:

Microseismic data was monitored during acquisition. Work with this data awaits transfer of the final product to MSEEL. The final microseismic data will be available in the next quarter and will be integrated into the modeling.

Efforts to develop a more realistic structural model initiated this quarter will be carried forward in the next quarter.

Task 4b - Geomechanical:

Information on the hydraulic fracturing field parameters (fluid volumes, pumping rate, and proppant schedule) will be sought from NNE for the field operations. The modeling work will be performed on the basis of available data.

Topic 5 – Surface Environmental

Task 5a – Surface Environmental – Water

Approach

Surface water baseline sampling was conducted since June at the three points selected along the Monongahela River. Based on the timeline for gas well development being shortened and activities moved up, two separate sampling events were conducted. Figure 5.1.1 shows the locations of sampling points MR-1, MR-2, and MR-3 in red with the Northeast Energy site indicated in purple.

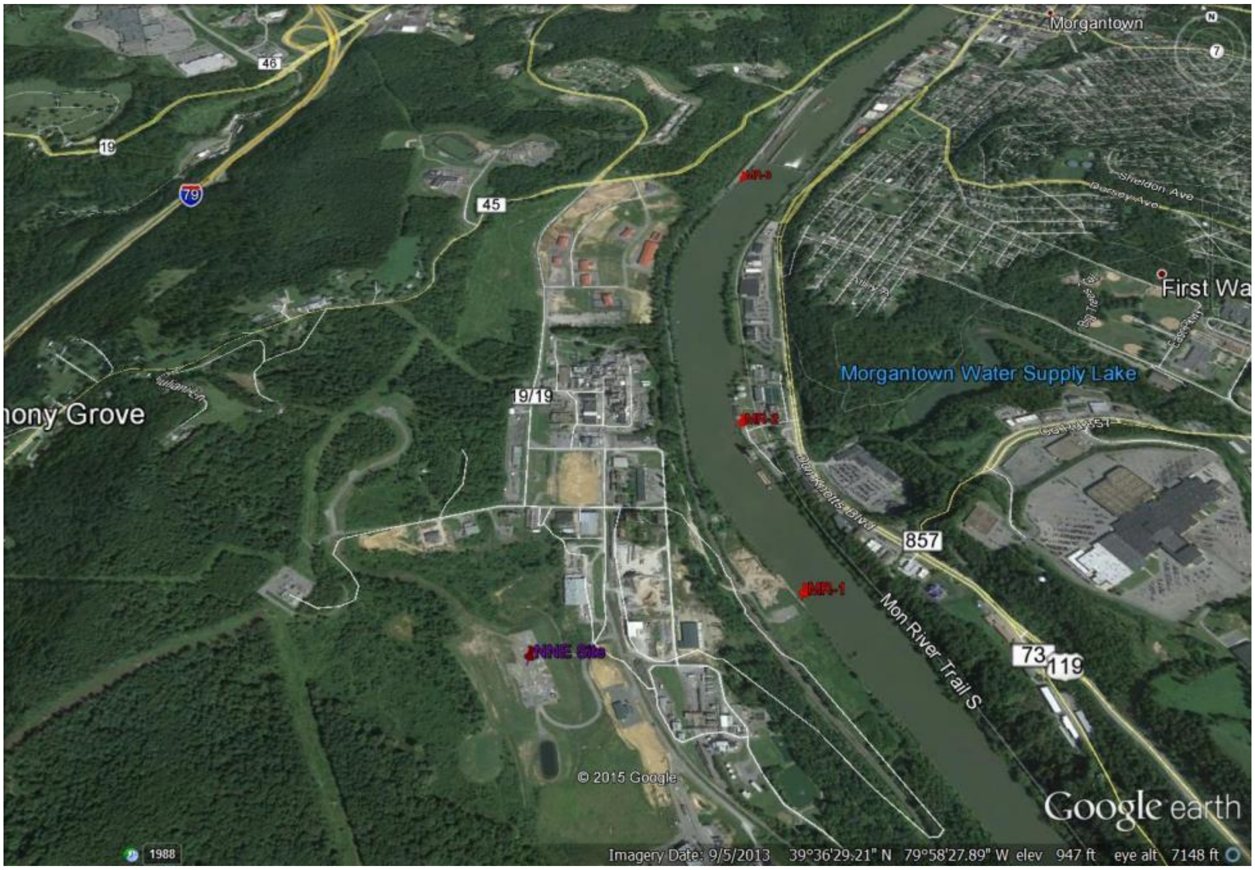

Figure 5.1.1: MSEEL surface water sampling locations

The sampling schedule for surface water and gas well development water/waste streams is detailed in Table 5.1.1.

Table 5.1.1: MSEEL sampling schedule

		Freshwater		Aqueous/Solids: drilling/completion/production									
		Mon River	ground water	HF fluid makeup	HF fluids	flowback/ produced	drilling fluids	drilling muds*	drilling cuttings	total aqueous	total solids	Sampling Dates	Notes
	Sampling Stations	3	0	2	2	2	2	2	2				
Subtask 1.4.1 Test surface sampling plan													
	ID and review existing GW/SW data	**Completed-flow path identification, otherwise no other value**											
	Finalize project surface sampling plan	**Completed-see below**											
Subtask 1.4.3 Develop water qualiity baseline													
	Groundwater baseline prior to drilling	**Access denied-groundwater will not be sampled**											
	Surface water baseline prior to drilling	3								3		6/12/2015	
		4								4		6/25/2015	Field duplicate taken
Subtask 2.1.1 Environmental monitoring-Drilling													
	Vertical drilling	3								3		7/8/2015	surface water only
									1		1		
									1		1		
	Horizontal drilling	3					1	1	1	5	2		liquids & solids fraction of muds
							1	1	1	2	2		liquids & solids fraction of muds
Subtask 2.2.1 Environmental monitoring-Completion													
	Hydraulic fracturing	3		2	2					7			
	flowback Initial	3				2				5			
	Flowback 1 week	3				2				5			
	Flowback 2 weeks	3				2				5			
	Flowback 4 weeks	3				2				5			
	Flowback 8 weeks	3				2				5			
Subtask 2.3.1 Environmental monitoring-Production													
	Production 3 stations x 3/yr x 4 yrs	36				24				60			

Surface water samples are being analyzed for the following parameters, see Table 5.1.2.

Table 5.1.2: Analytical parameters

Aqueous chemistry parameters					
Inorganics				Organics	Radionuclides
	Anions	Cations			
pH	Alkalinity	Ag	Mg	Benzene	α
TDS	Br	Al	Mn	Toluene	β
TSS	Cl	As	Na	Ethylbenzene	^{40}K
Conductance	SO_4	Ba	Ni	Xylene	^{226}Ra
		Ca	Pb	MBAS	^{228}Ra
		Cr	Se		
		Fe	Sr		
		K	Zn		

Results and Discussion

Preliminary water sampling results are presented in Appendix A. The results are still undergoing QA checking with the analytical and should not be distributed or quoted.

- A1. Produced water, 2011 MIP well completions.
- A2. Hydraulic Fracturing (HF) and Makeup Water (MU)-2015 Completions
- A3. Surface Water Monitoring Results-Inorganics, total

- A4. Surface Water Monitoring Results-Inorganics, dissolved
- A5. Surface Water Monitoring Results-Field readings
- A6. Surface Water Monitoring Results-Organics, Lab EC, TDS, TSS
- A7. Surface Water Monitoring Results-Radiochemistry
- A8. Drill cuttings MIP 5H-vertical section
- A9. Drill cuttings MIP 5H-horizontal section
- A10. Drill cuttings MIP 3H-horizontal section
- A11. TCLP Results-inorganics
- A12. TCLP Results-semi-volatile organics
- A13. TCLP Results-volatile organics

Appendix summarizes the chemistry of the two currently producing wells on the MIP pad. These are late stage produced waters from wells that were completed in 2011. Appendix A2 summarizes the organic, inorganic and radiochemistry of makeup (MU) and hydraulic fracturing (HF) fluid used in the MIP 3H and 5H wells which were completed in fall 2015. This was a green completion well and analysis of the HF fluid reflects that. The composition of the HF fluids in both wells is similar to the makeup water which was drawn from the Monongahela River. Its chemistry is typical of Monongahela River water. This is true of inorganics, organics and radiologicals. Organic surrogate recoveries were in the range of 90 to 104% indicating good quality control at the analytical laboratory.

Appendices A3-7 summarize water chemistry at our three River monitoring points (Figure 5.1.1). None of the dissolved values exceeded finished primary or secondary drinking water standards.

With regard to radioactivity, the maximum isotopic activity was recorded for 40 K which was 28.32 pCi/g. Gross alpha accounted the highest reading at 60 pCi/g. Neither of these levels are considered hazardous.

Appendices 8-10 summarize the chemistry of solid wastes from the MIP 3H and 5H wells. The 5H data include both vertical and horizontal (Marcellus) sections. Appendices 11-13 are the results of inorganic and organic TCLP (SW 1311) testing. Under the Resources Conservation and Recovery Act (RCRA) the TCLP is specified to determine hazardous solid wastes which, in turn would be subject to disposal under Subtitle C. None of the samples violated a TCLP limit. Mindful that EPACT 2005 excludes drilling wastes from RCRA, these tests indicate that these drill cuttings would not be considered hazardous.

These results, particularly for the organics are unlike previous studies in the same formation. The one significance that may account for the benign nature of the solid wastes is the use of green completion fluids. If that is the determining factor, then it is an important result of the MSEEL facility.

Plan for Next Quarter

Activities in the next quarter will follow the schedule provided in Table 5.1.1 above. We expect to begin detailed analysis of the data including trend development and comparison of these results with other liquid and solid wastes in the WRI data set. In addition we will continue developing trends in the river and trends related to flowback/produced water as the wells enter production.

Task 5b – Surface Environmental – Air and Vehicular

5.1 Particulate Monitoring - Preliminary Baseline Results

Four air sampling sites were designated for fixed location sampling. This isolated drill site is located directly on the boundary of an urban area that has a population of 120,000 permanent residents (Figure 5.1.1). The location of the well provides a novel opportunity for delineating three very separate exposure zones. *As part of the unique* <u>*approach*</u> *of this study, there is no other drilling occurring for at least ten miles in all directions*. Fixed site samplers at the well pad and in each of the three study zones will allow us to assess associations between ambient levels and the UNGD activities. Station 1 isolates the area where the plume from the drilling platform likely will impact the surrounding populated area as it lies within the 100 meter deep river valley which is known to be subject to inversions and is where the drilling platform will be located. In this zone, winds follow the valley which runs approximately north to south. To the north and east of the platform is the city of Morgantown, WV proper. The urban area of Morgantown is listed as containing about 70,000 people and the metropolitan area as containing 120,000 residents. The majority of heavy diesel traffic going to the drill site comes from Interstate 79, to the west of Morgantown, and approaching the east through a parallel valley. This route was dictated by the drilling company and crossed over the separating hill just before entering the industrial park in which the pad was located. Station 2 was located at a slightly raised elevation just north of Station 1 and approximately 50 meters up the hillside. Station 3, although still within the river valley is the control area and lies north of and outside the main valley area where the first two zones are located. This area, called "Suncrest," is northeast of the other two zones and a distance of 10 or 12 kilometers away from either of the other two zones. Site 4 was located south of the drill site and approximately 100 meters higher, completely outside of the valley.

Researchers visited each of the site sampling stations at least once per week. Water-proof sampling boxes with good ventilation were used to prevent the air sampling instruments (except HI-Vol Sampler) from being exposed to outside weather. Inlets of the HI-Vol were approximately 2 meters high. The field team members checked each fixed site sampler on a daily basis to ensure filter changes and proper running of the samplers. The instruments and sampling schemes were as follows:

Dust Track (*direct-reading, continuous $PM_{2.5}$ associated measurement*, *TSI, Shoreview, MN*): One instrument per zone was used to collect $PM_{2.5}$ measurements continuously during the sampling period in each of the four zones and on the drill pad. Dust Tracks provide information on the variability of particulate concentrations, but cannot be used for absolute values of mass since their measurement varies depending on dust density. **CPC** (*condensation particle counter,P-Trak Model 8525 Ultrafine Particle Counter,TSI, Shoreview, MN*): was used for monitoring $PM_{0.1}$ number concentration. **PM2.5 filter and PUF:** One custom-made monitoring box was used in each zone with an accurate flow rate control (spanning from 0.5 to 4.0 LPM) and elapsed-time monitor will be run for 1 wk and used for gas and particulate phase pollutants collected on a Teflon filter and polyurethane foam (PUF) downstream from a cyclone (model SCC 1.062, BGI, Inc.) at the same flow rate (1.5 L/min for one week). The collected filters, after post-weight to determine airborne $PM_{2.5}$, mass levels can be used for metal analyses using x-ray fluorescence spectroscopy and black carbon using a non-destructive optical approach. After analyses, the Teflon filter will be extracted together with PUF (using a strong solvent) to estimate semi-volatile and nonvolatile PAHs[25] **. HI-Vol** (high flow (40 cubic feet/min) $PM_{2.5}$ samplers, Tisch Industries, Cleves, OH): One per zone was used to collect samples on filters that will be used to provide material for subsequent animal testing for a measure of relative toxicity as well as metals analysis.

Results

Figure 5.1.2 shows the mass particulate concentration fluctuations during hydraulic fracturing operation for the on-pad sampling site and the 4 off-pad sampling sites. There are substantially higher peak mass concentrations seen on-pad than off-pad. The off-pad sites are relatively similar appearing to follow the same pattern among themselves and showing a smaller range of concentrations than at the on-pad site. It appears that the dust being generated on-pad has substantially diminished even at the closest sampling location less a kilometer away (Station 1) and is not significantly different for most of the time from the background stations (Stations 3 and 4, Figure 5.1.3).

Organics, metals and toxicity measurements are still awaiting complete analysis to determine if there are differences based on measurements other than mass.

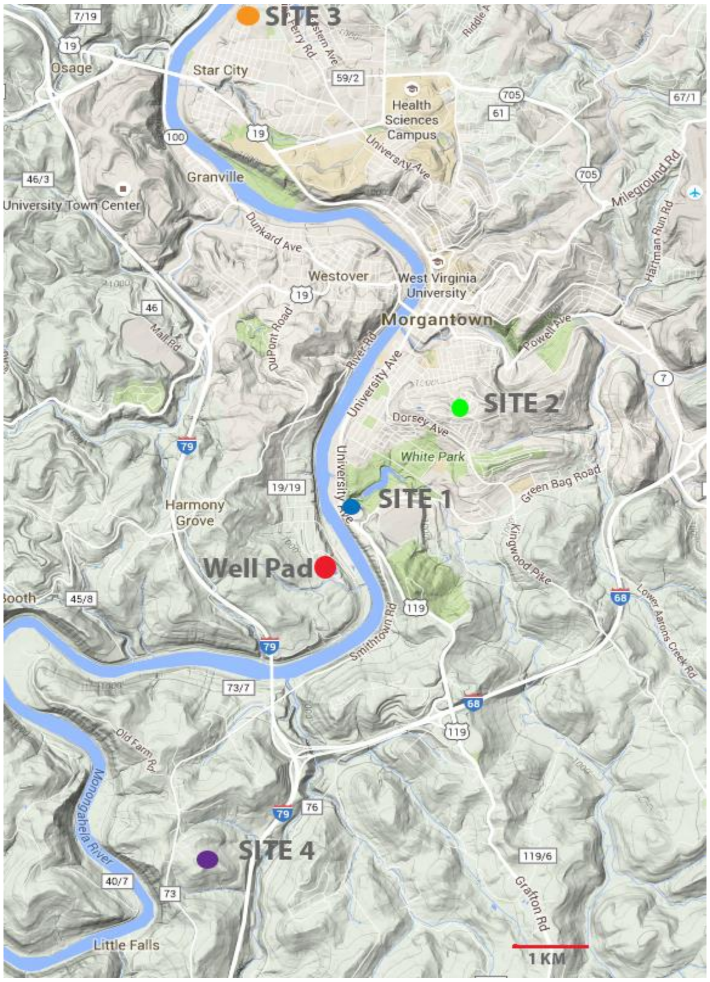

Figure 5.1.1: Topographic features of the sample site locations.

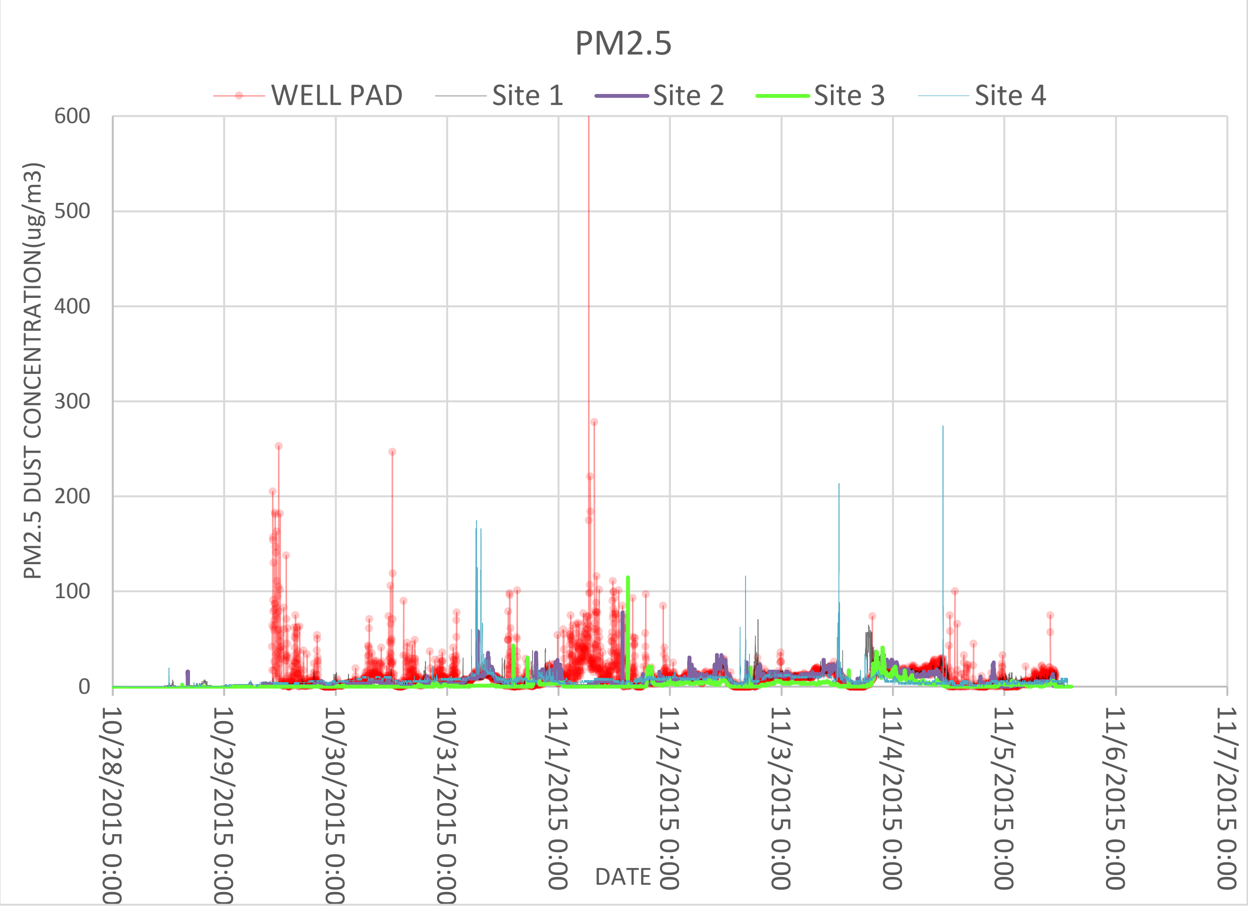

Figure 5.1.2: Dust Track Measurements (once per minute) of PM2.5 mass concentrations at all five sampling sites for the period when hydraulic fracturing occurred (Oct 29 – Nov 2).

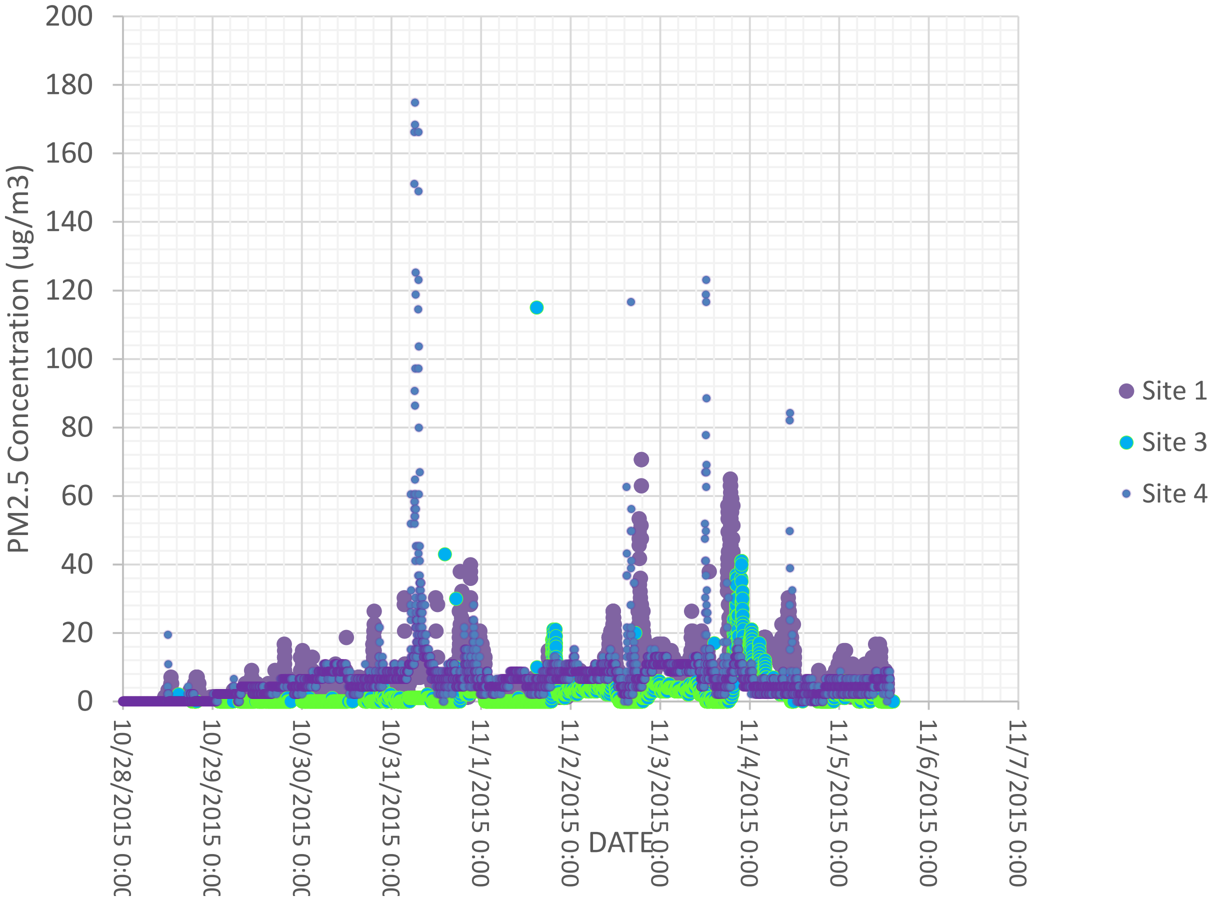

Figure 5.1.3: Close-up of data from Sites 3 and 4 (background samples) showing similar results compared to the Site 1, the closest sampling location to the well pad during the same period as Figure 2.

A Presentation was made to the Environmentally Friendly Drilling Conference on 11/15/2015 by Sunil Moon and Michael McCawley, Diesel Traffic Volume Correlates with Ultrafine Particle Concentrations but not PM2.5.

The Suncrest baseline site was used to evaluate the effect of diesel engines used for a number of tasks at drill sites and have been considered a major source of particulate with a size range that may encompass both fine (PM2.5) and ultrafine (UFP <0.1µm) particles. Moon and McCawley conducted a baseline study prior to MSEEL drilling to characterize diesel exhaust impacts on near-road air quality to determine the best methods to monitor and, in turn, mitigate particulate concentrations. Concentrations of PM2.5 and UFP were monitored along with a concurrent recording of traffic volume. In addition, environmental parameters, including wind speed and precipitation were recorded. Multivariate regression analysis was done to find the correlation between concentrations (PM2.5 and UFP), traffic count and environmental parameters. UFP concentrations were highly significant (p<0.01%) with the wind speed and truck count indicating UFP concentrations were due to diesel emissions. Concentrations of PM2.5, however, were not correlated with diesel engine emissions.

5.2 Direct Emissions Measurements

Researchers at West Virginia University’s (WVU) Center for Alternative Fuels, Engines, and Emissions (CAFEE) completed two measurement campaigns at the Marcellus Shale Energy and Environment Laboratory (MSEEL) during year one of the program. Horizontal well drilling and hydraulic stimulation equipment were outfitted with CAFEE transportable emissions equipment for measurement of both regulated and unregulated exhaust and crankcase emissions. Campaigns were conducted on engines equipped with Caterpillar Dynamic Gas Blending (DGB) Kits. These dual fuel technologies allowed engines to operate on diesel fuel only or in dual fuel mode which included both diesel and natural gas as fuel. In both cases, natural gas was processed with a portable processing skid from on-site wells that were drilled previously. Exhaust and crankcase emissions were analyzed in four configurations: pre-catalyst diesel fuel only, pre-catalyst dual fuel, post-catalyst diesel fuel only, and post-catalyst duel fuel. Dual fuel technologies often lead to higher carbon monoxide emissions, which require the use of a diesel oxidation catalyst (DOC). Even when operating in diesel fuel mode only, the implementation of DOCs reduce emissions from these operations. Natural gas replaced diesel fuel consumption at a rate of 19-64% for drilling engines and 53% for fracturing engines. Drilling and fracturing engines that used DOCs showed reductions in CO emissions in both diesel and dual fuel modes. The use of dual fuel for drilling engines showed reductions in oxides of nitrogen (NOx) of up to 20% at high load, while they were found to be 12% higher for stimulation engines. Carbon dioxide (CO2), total hydrocarbons (THC), methane (CH4), and particulate matter (PM) emissions were also measured during these efforts. Additional results are found below. Particulate matter data are still under analysis.

Results and Discussion

Data Collection

Onsite Measurements

Emissions and fuel rates from the drilling engine were measured in a series of 16 tests. Diesel only emissions were measured during the drilling of the first horizontal well onsite and dual fuel emissions were measured during the drilling of the second horizontal on site. Table 5.2.3 shows information on the tests performed.

Table 5.2.1: Emissions Data Collection Test Information

Sample Position	Fueling Type	Test	Date	Start Time	End Time	Total Length
(Pre/Post-Catalyst)	(Diesel/Dual)	#	MM/DD/YYYY	0:00 - 23:59	0:00 - 23:59	HH:MM
Pre	Diesel	1	9/9/2015	14:58	17:58	3:00
Pre	Diesel	2	9/10/2015	7:15	10:15	3:00
Pre	Diesel	3	9/10/2015	11:03	14:03	3:00
Pre	Diesel	4	9/10/2015	14:26	17:26	3:00
Pre	Dual	1	9/19/2015	9:41	12:41	3:00
Pre	Dual	2	9/19/2015	13:15	16:15	3:00
Pre	Dual	3	9/19/2015	18:21	21:21	3:00
Pre	Dual	4	9/20/2015	8:15	11:15	3:00
Post	Diesel	1	9/10/2015	18:02	21:02	3:00
Post	Diesel	2	9/10/2015-9/11/2015	21:15	0:15	3:00
Post	Diesel	3	9/11/2015	8:15	11:15	3:00
Post	Diesel	4	9/11/2015	11:40	14:40	3:00
Post	Dual	1	9/18/2015	6:13	9:15	3:02
Post	Dual	2	9/18/2015	9:35	12:35	3:00
Post	Dual	3	9/18/2015	12:52	15:52	3:00
Post	Dual	4	9/18/2015	16:30	19:30	3:00

Emissions and fuel rates from a fracturing engine were measured in a series of 12 tests. It also should be noted that different stages required different amounts of pressure and because of this required different engine loads. Table 5.2.2 shows information on the tests performed.

Table 5.2.2: Emissions Data Collection Test Information

Position	Fuel	Test	Date	Start Time	End Time
Pre	Diesel	1	11/9/2015	1:02	3:38
Pre	Diesel	2	11/9/2015	8:14	10:10
Pre	Diesel	3	11/9/2015	15:50	17:40
Pre	Dual	1	11/5/2015	10:27	13:08
Pre	Dual	2	11/6/2015	23:48	3:21
Pre	Dual	3	11/8/2015	16:39	18:50
Post	Diesel	1	11/9/2015	21:10	22:40
Post	Diesel	2	11/12/2015	7:46	9:32
Post	Diesel	3	11/12/2015	21:11	23:34
Post	Dual	1	11/11/2015	4:00	5:28
Post	Dual	2	11/11/2015	8:20	11:51
Post	Dual	3	11/11/2015	15:08	16:48

Engine Activity

Engine control unit (ECU) data collection was performed using a nine pin deutsch connector, a serial connection to a VIA Model HDV100A1. A laptop utilizing CAFEE’s in house software was used for interpreting the SAE J1939 messages from the engine. Data from the ECU were collected over a period of 311 hours for well drilling. After data processing, 233 hours were deemed valid.

Invalid data was sometimes read from the ECU when the engine broadcasts false messages. Other reasons for data loss included power failure, connection problems, and software conversion issues. The engine was a constant speed engine, so the most important parameter that was recorded was engine percent load at the current speed (SAE J1939 SPN 92). Engine fuel rate (SPN 183) was also recorded to verify that the fuel flow meters installed on the engine were accurate. The drilling data was sorted into categories based on percent load at the current speed, so that a profile of engine operation could be developed. The engine percent load was divided into 21 activity "bins." Table 5.2.2 shows the distribution of the engine load collected during drilling operations. The majority of the engine load distribution falls into two major groupings, one centered on 15-20% load and the other centered on 55-60% load. These two categories will be referred to as low and high load. Table 5.2.4 shows the ECU activity for hydraulic fracturing engines.

Table 5.2.3: ECU Data Activity Bins – Drilling

Bin	Range Start	Range End	Time in Bin	Percent of Time
(#)	(<= %load)	(%load <)	(s)	(%)
1	0	0.05	7211	1%
2	0.05	0.1	5330	1%
3	0.1	0.15	87418	10%
4	0.15	0.2	132467	16%
5	0.2	0.25	69864	8%
6	0.25	0.3	19116	2%
7	0.3	0.35	14474	2%
8	0.35	0.4	13905	2%
9	0.4	0.45	20245	2%
10	0.45	0.5	16054	2%
11	0.5	0.55	75660	9%
12	0.55	0.6	159650	19%
13	0.6	0.65	76133	9%
14	0.65	0.7	56234	7%
15	0.7	0.75	61941	7%
16	0.75	0.8	21073	3%
17	0.8	0.85	2049	0%
18	0.85	0.9	505	0%
19	0.9	0.95	301	0%
20	0.95	1	208	0%
Total			839838	100%

Table 5.2.4: Average Values: from ECU Data – Fracturing

Position	Fuel	Test	Stage Length	Average Speed	Average Load	Average Power
(Pre/Post)	(Diesel/Dual)	(#)	(s)	(RPM)	(%)	(kW)
Pre	Diesel	1	6300	1845	66.5	1116
Pre	Diesel	2	5200	1821	73.9	1239
Pre	Diesel	3	5250	1930	90.6	1520
Pre	Dual	1	5000	1850	72	1208
Pre	Dual	2	5300	1850	80	1342
Pre	Dual	3	6250	1602	72.5	1216
Post	Diesel	1	5200	1839	66.3	1113
Post	Diesel	2	4650	1874	57.3	961
Post	Diesel	3	5250	1938	78.8	1321
Post	Dual	1	5000	1867	60.4	1013
Post	Dual	2	5250	1935	79.2	1329
Post	Dual	3	5000	1937	84.8	1422
Average			5300	1857	73.5	1233

Fuel Consumption

Engine fueling rates were measured using WVU's fuel flow meters, which were installed on feed and return line. Diesel fuel flow was measured with meters on the inlet and return line of the engine in order to obtain net fuel consumption of the engine. These fuel rates were measured using KRAL OME20 Volumeters®. These meters are capable of measuring diesel flow rates between 0.03 and 135 gallon/minute. The natural gas meter was installed on the gas line feeding the engine examined. A KURZ MFT-B flowmeter was used which a range of 0-252 SCFM. The diesel gallon equivalent (DGE) of natural gas is the diesel equivalent of the amount of natural gas used which makes for a better comparison of the two fuels. One DGE of natural gas is equivalent to 143.94 standard cubic feet (SCF). Tables 5 and 6 show the fuel consumption results for drilling and fracturing operations, respectively

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Table 5.2.5: Loading and Fueling Averages during Drilling

Fueling		Diesel	Diesel	Dual	Dual
Catalyst Position		Pre	Post	Pre	Post
		High Load Averages			
Percent Load	%	55.7	54.62	61.13	54.68
Diesel Flow	gal/hr	40.11	39.63	15.79	14.71
CNG Flow	DGE/hr	0	0	43.73	39.43
		Low Load Averages			
Percent Load	%	24.29	24.52	24.11	22.2
Diesel Flow	gal/hr	19.61	19.72	15.12	14.92
CNG Flow	DGE/hr	0	0	10.89	8.67

Table 5.2.6: Loading and Fueling Averages during Hydraulic Fracturing

Fueling		Diesel	Diesel	Dual	Dual
Catalyst Positio		Pre	Post	Pre	Post
		Averages			
Load	%	77	67.5	74.8	74.8
Diesel	Gal/hr	95.1	84.1	39.7	50.7
CNG	DGE/hr	0	0	88.8	84.4

Emissions

The emissions recorded included exhaust carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NOx), total hydrocarbons (THC), and methane (CH_4), as well as crankcase CO_2 and CH_4. The exhaust emissions were sampled through 50 feet of heated line and a heated filter before being passed to a MKS Multigas™ 2030 FTIR Continuous Gas Analyzer for concentration measurement. The crankcase emissions were sampled using WVU's Full Flow Sampling System (FFS) and a Los Gatos Research Greenhouse Gas Analyzer. Both types of emissions were recorded and processed using WVU CAFEE software. Figures 1-10 present drilling emissions results for the engine exhaust. Figures 11-15 present fracturing emissions results for the engine exhaust.

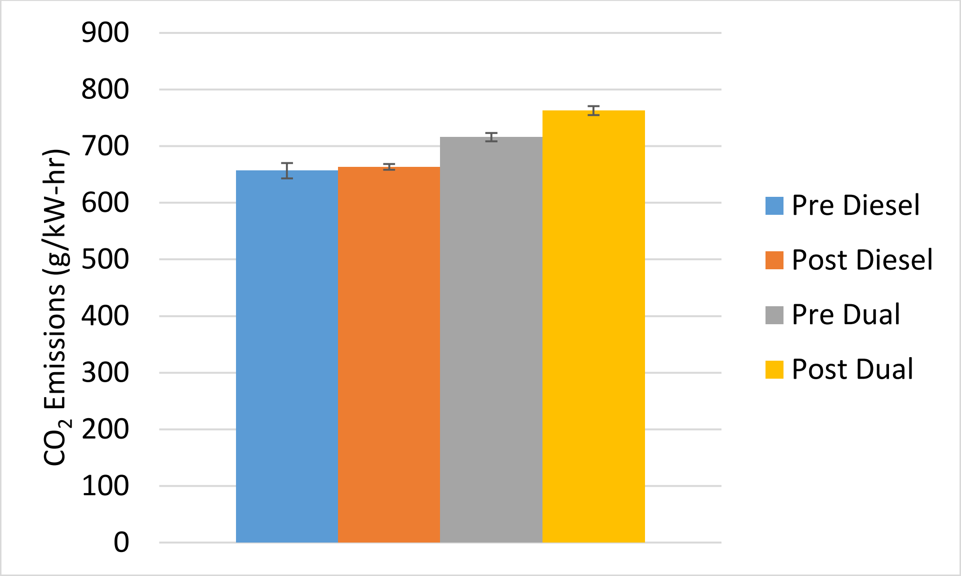

Figure 5.2.1: High Load Drilling Brake Specific CO$_2$ Emissions

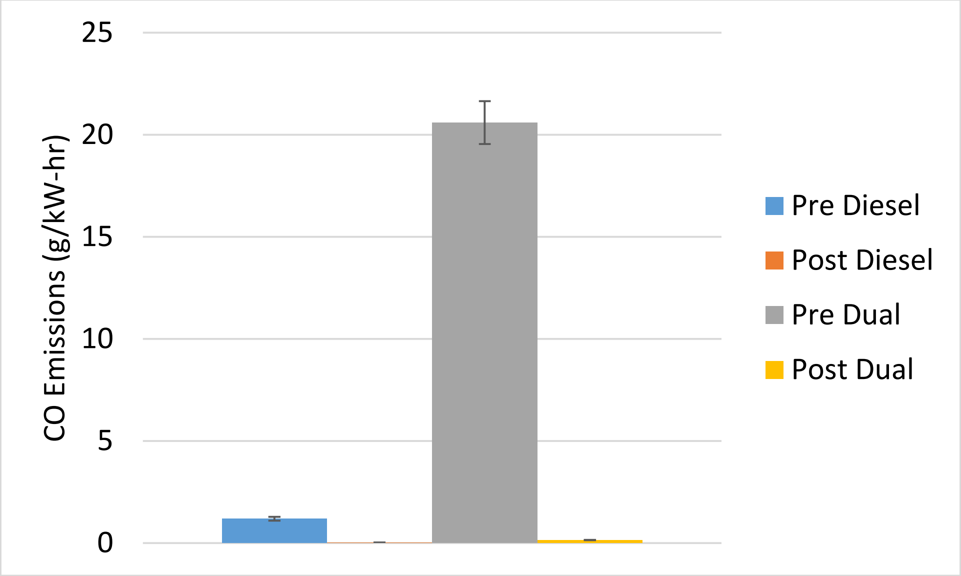

Figure 5.2.2: High Load Drilling Brake Specific CO Emissions

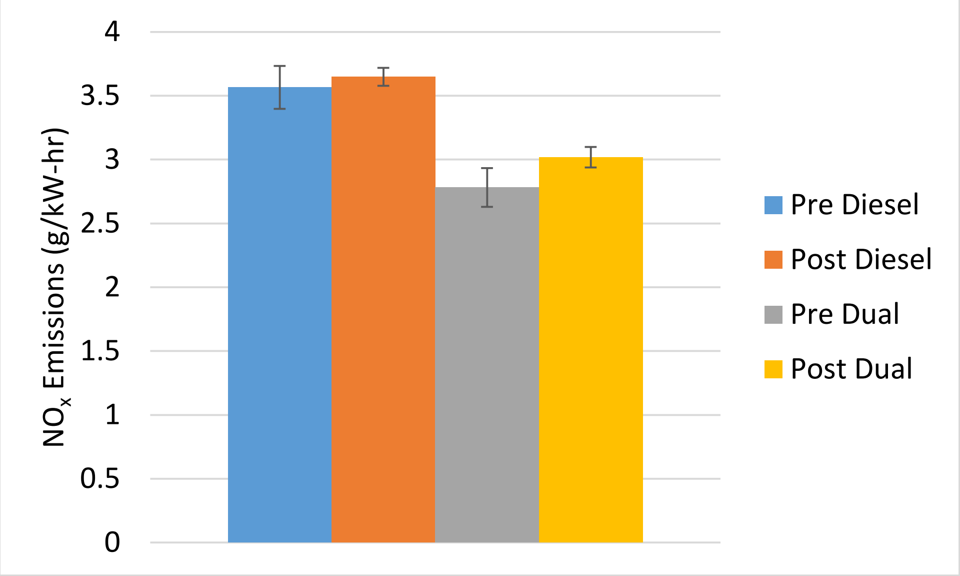

Figure 5.2.3: High Load Drilling Brake Specific NOx Emissions

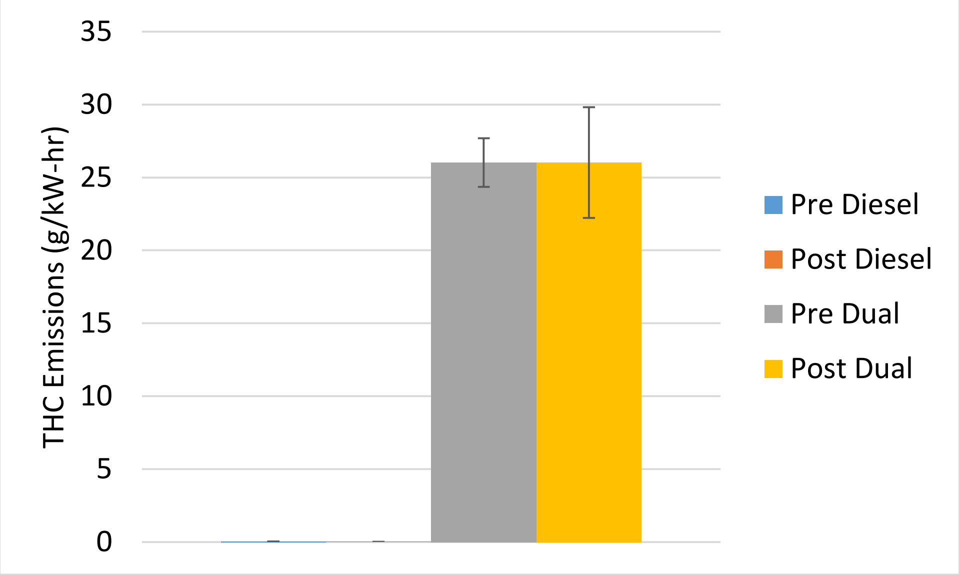

Figure 5.2.4: High Load Drilling Brake Specific THC Emissions

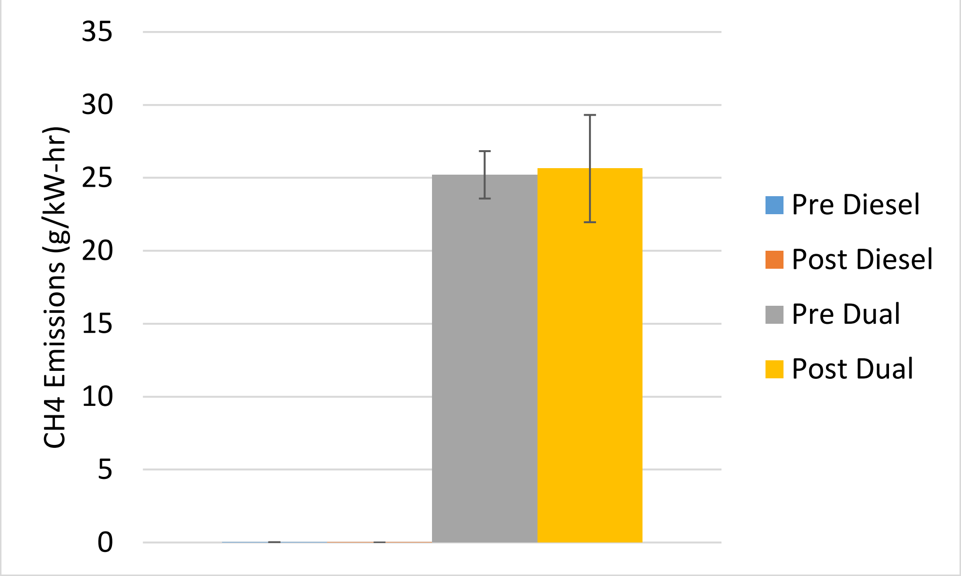

Figure 5.2.5: High Load Drilling Brake Specific CH_4 Emissions

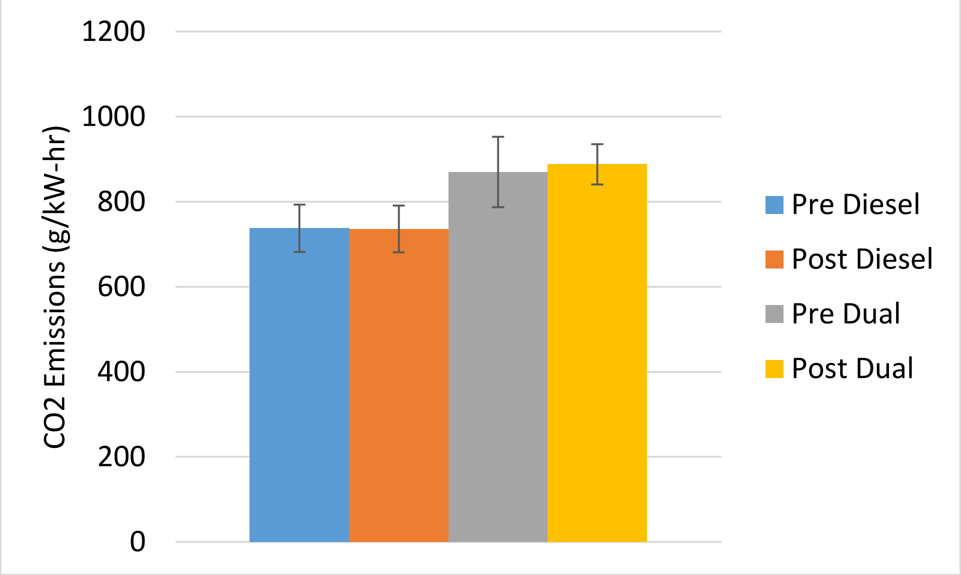

Figure 5.2.6: Pipe Connection Brake Specific CO_2 Emissions

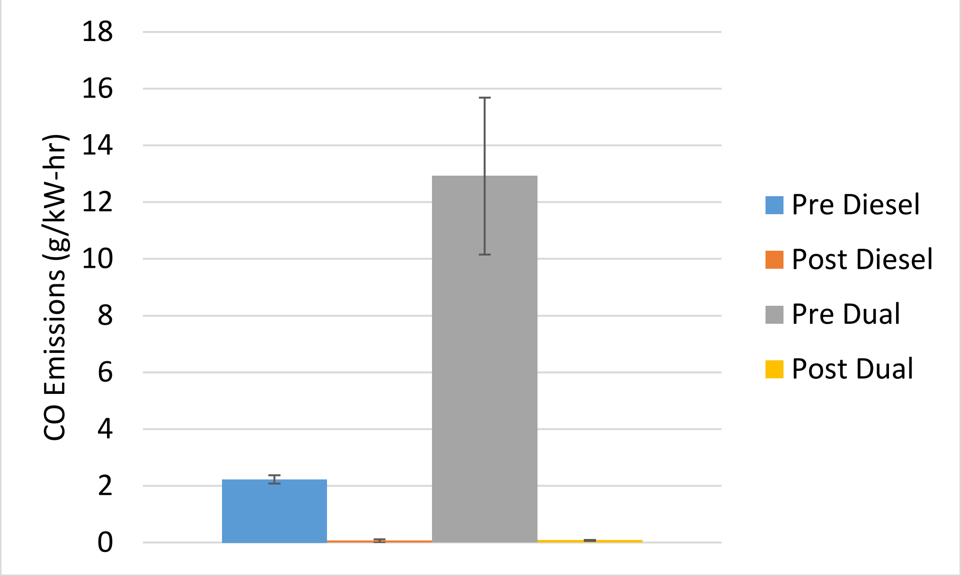

Figure 5.2.7: Pipe Connection Brake Specific CO Emissions

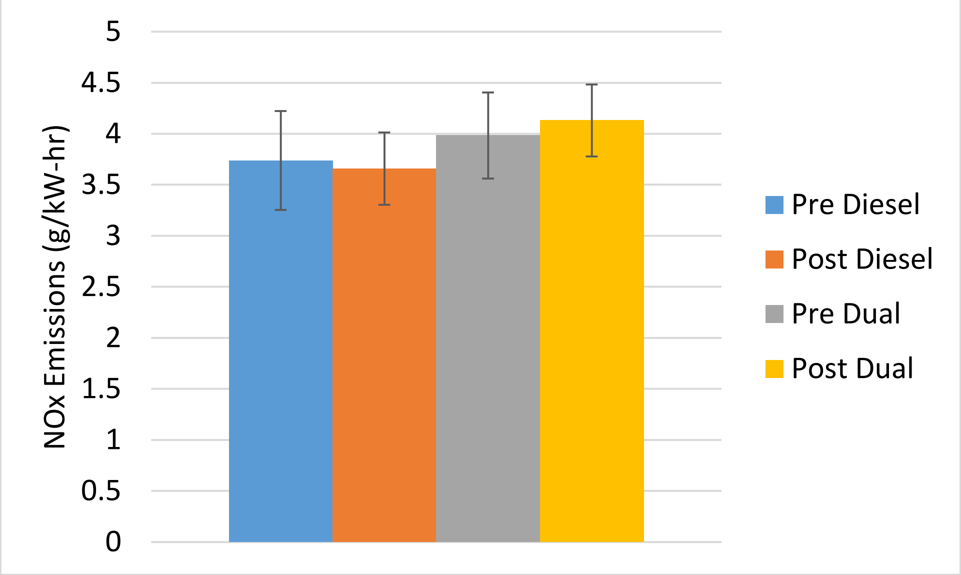

Figure 5.2.8: Pipe Connection Brake Specific NOx Emissions

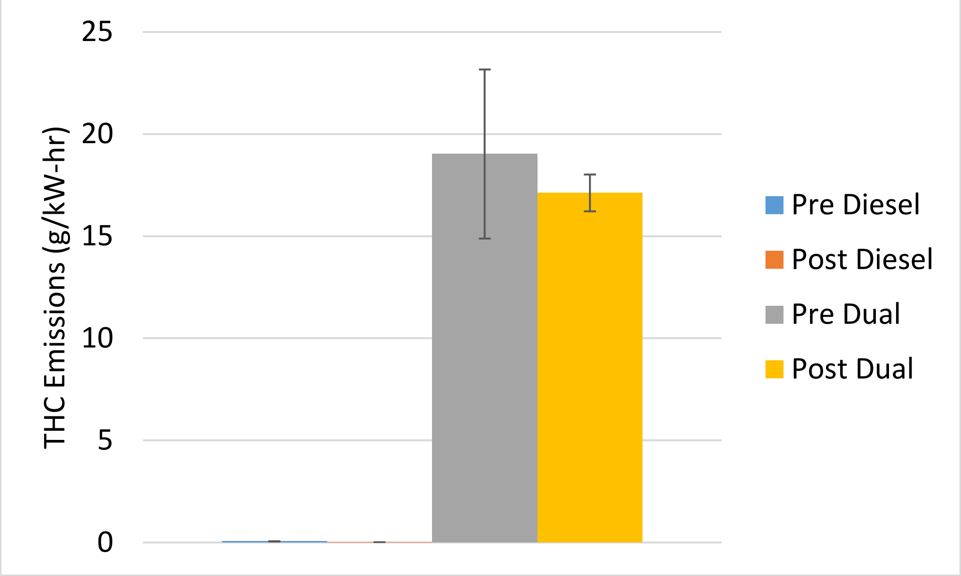

Figure 5.2.9: Pipe Connection Brake Specific THC Emissions

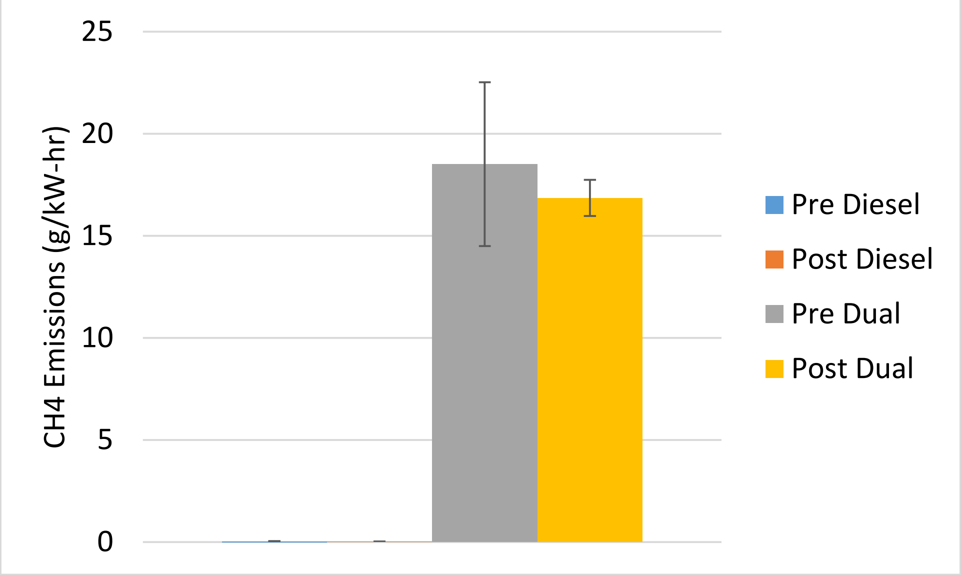

Figure 5.2.10: Pipe Connection Brake Specific CH_4 Emissions

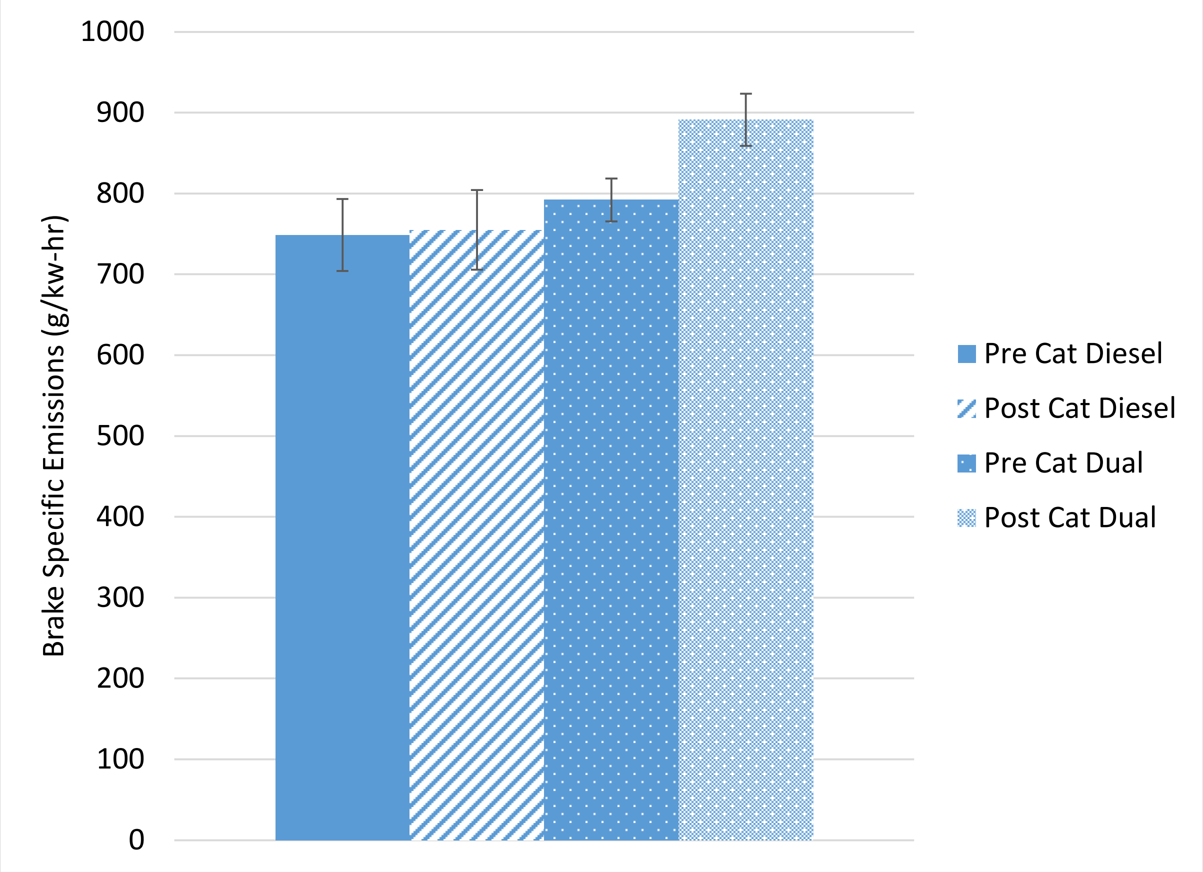

Figure 5.2.11: Brake Specific CO_2 Emissions during Fracturing

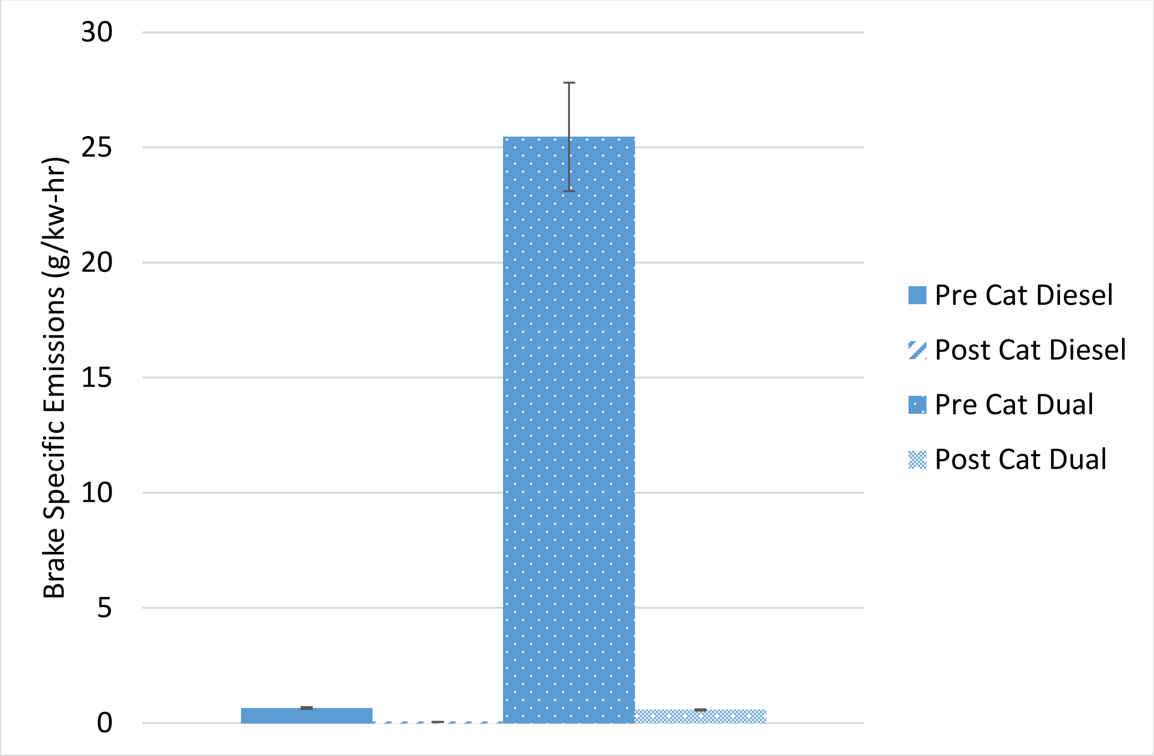

Figure 5.2.12: Brake Specific CO Emissions during Fracturing

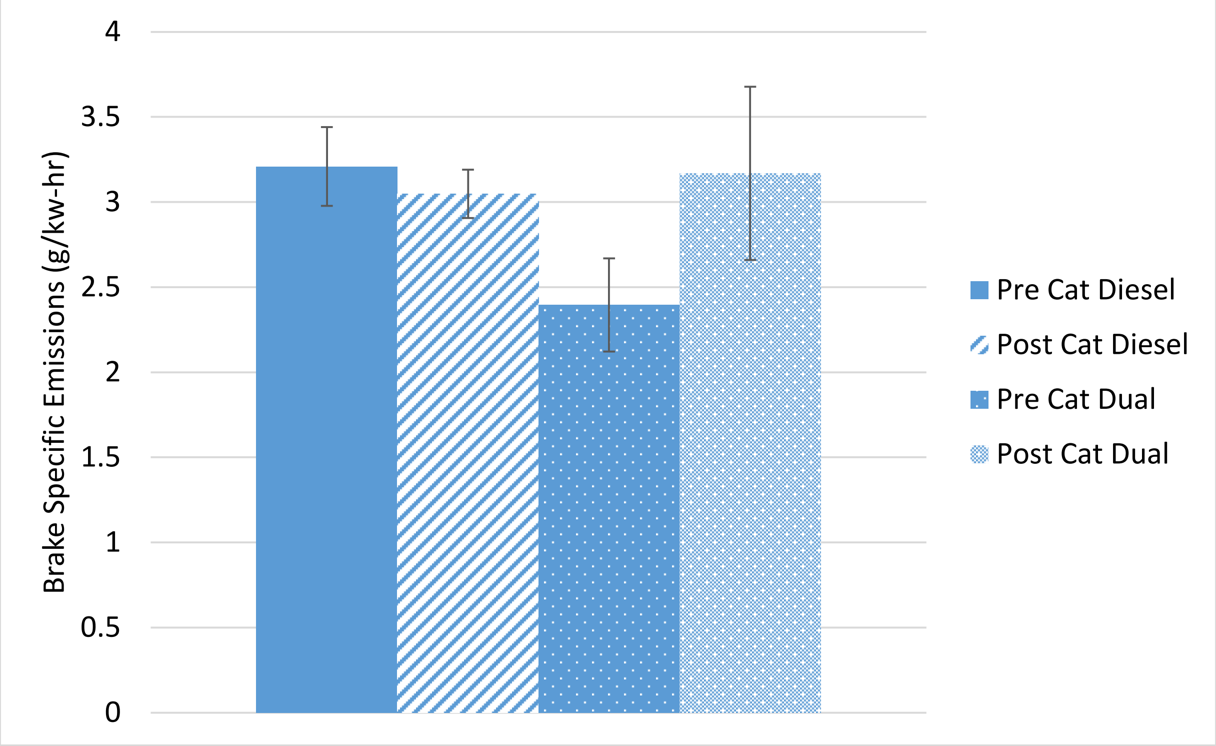

Figure 5.2.13: Brake Specific NO_x Emissions during Fracturing

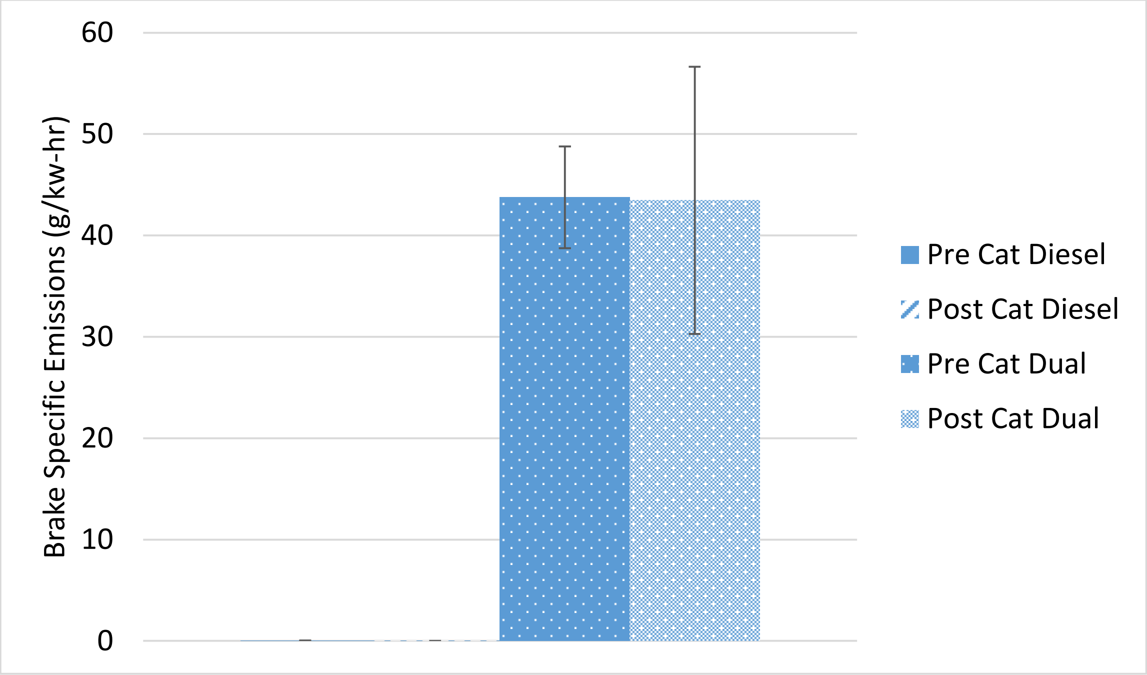

Figure 5.2.14: Brake Specific THC Emissions during Fracturing

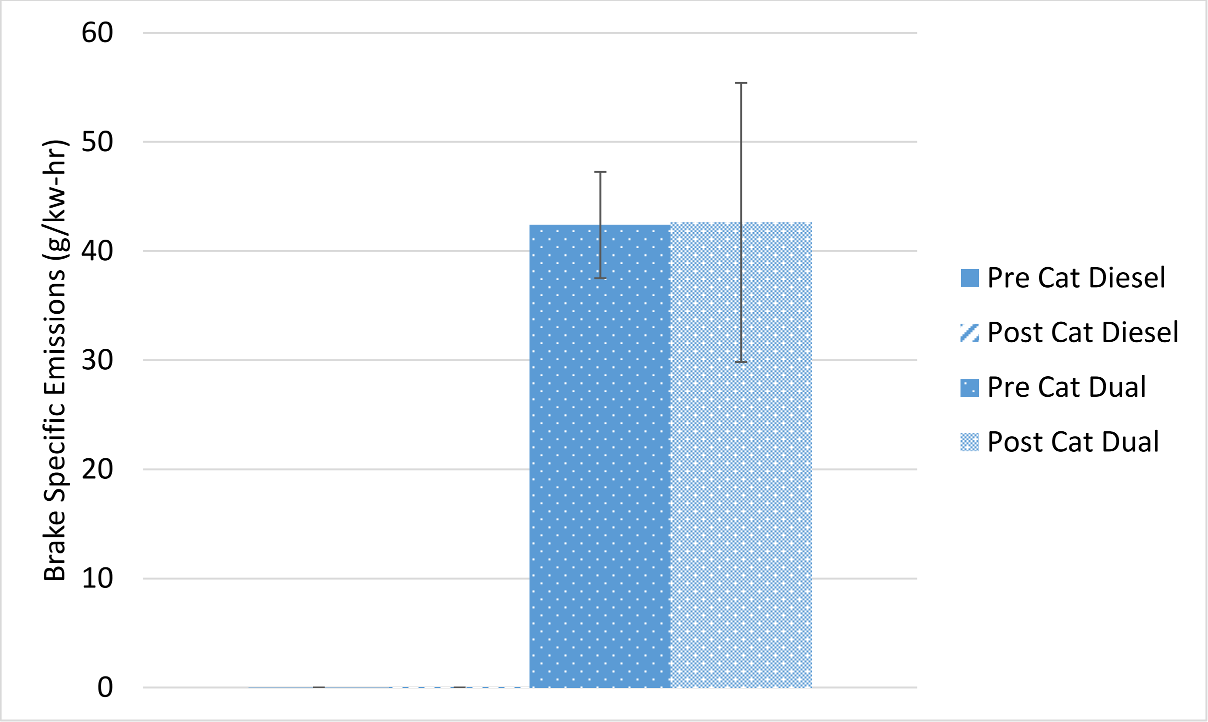

Figure 5.2.15: Brake Specific CH_4 Emissions

Conclusions

Drilling

Emissions testing was performed on a drilling rig that used Caterpillar 3512C generator sets outfitted with a Bi-fuel DGB kit. Emissions were recorded in four different fueling/sampling configurations (pre-catalyst diesel, pre-catalyst dual fuel, post-catalyst diesel, and post-catalyst dual fuel). The operating data were binned into two distinct modes of operation, high load drilling and pipe connection operation. The average natural gas substitution ratio for both cases was 63.5% and 19.3% respectively for each other modes of operation. Slight increases in CO_2 emissions were observed due to a decrease in fuel conversion efficiency. Pre-catalyst CO emissions increased by 5-20 times as expected during dual fuel operation. However, the DOC reduced CO emissions to below diesel only pre-catalyst emissions for both post-catalyst diesel only and dual fuel operations. NOx emissions were not statistically different for any configuration during low load operation. During high load dual fuel operation, NOx emission were decreased by over 20% when compared to diesel only operation.

Fracturing

Testing of emissions was performed on a hydraulic fracturing engine that used a Caterpillar 3512B-HD engine outfitted with a Caterpillar DGB kit. Emissions were recorded in four different fueling/sampling configurations (pre-catalyst diesel, pre-catalyst dual fuel, post-catalyst diesel, and post-catalyst dual fuel). Three stages of hydraulic fracturing were recorded at each configuration. The average natural gas substitution ratio was 53% when dual fuel mode was utilized. Increases in CO_2 equivalent emissions were observed due to a decrease in fuel conversion efficiency. CO emissions were over 40 times lower in dual fuel mode when measured after the catalyst compared to before and were lower than diesel pre catalyst levels. The DOC also reduced CO emissions during diesel only operation, showing levels 14 times lower than pre-catalyst values. NOx emissions on were 12% higher during dual fuel operation compared to diesel only and were measured slightly higher post catalyst. This is most likely due to the difference in loading between the tests, although there is little difference when compared with a standard deviation applied. The average substitution rate during dual fuel operation was 53%.

Topic 6 – Economic and Societal

Approach

The lead on the political and societal project will work to identify and evaluate the factors shaping the policymaking response of local political actors. Included in this assessment will be an accounting, past and present, of the actions of public and private individuals and groups acting in favor of or opposed to shale gas drilling at the MSEEL site.

First year activity includes developing, distributing, collecting and compiling the responses from a worker survey and a vendor survey. The worker survey will address job characteristics and offsite expenditures. The vendor survey will help to identify per-well cost structures.

Results and Discussion

Project team continued to distribute and collect surveys from on-site workers. Approximately 100 surveys have been completed to date. This data will be used to develop an estimate of worker consumption expenditures by type, which will be used to estimate the local economic impacts. Other data collected will be drilling expenditures by type. Data collection is expected to continue into 2QCY2016, with analysis to being shortly after.

Hydrocarbon production was collected from West Virginia, Pennsylvania and Ohio. Unconventional oil and gas production has increased significantly in all states over the last decade. An example is West Virginia where unconventional gas production in 2014 represents 85% of total annual gas production from only 4% of the wells (Figure 6.1). In terms of liquids production (condensate and natural gas liquids), unconventional production represents 87% of total annual gas production from only 9% of the wells (Figure 6.2). Production is concentrated in a small number of counties in northern West Virginia and amongst a small number of companies (Figures 6.3 & 6.4). This change concentration in production in a small number of wells operated by a small number of companies in a small number of counties will have an impact on regional economics.

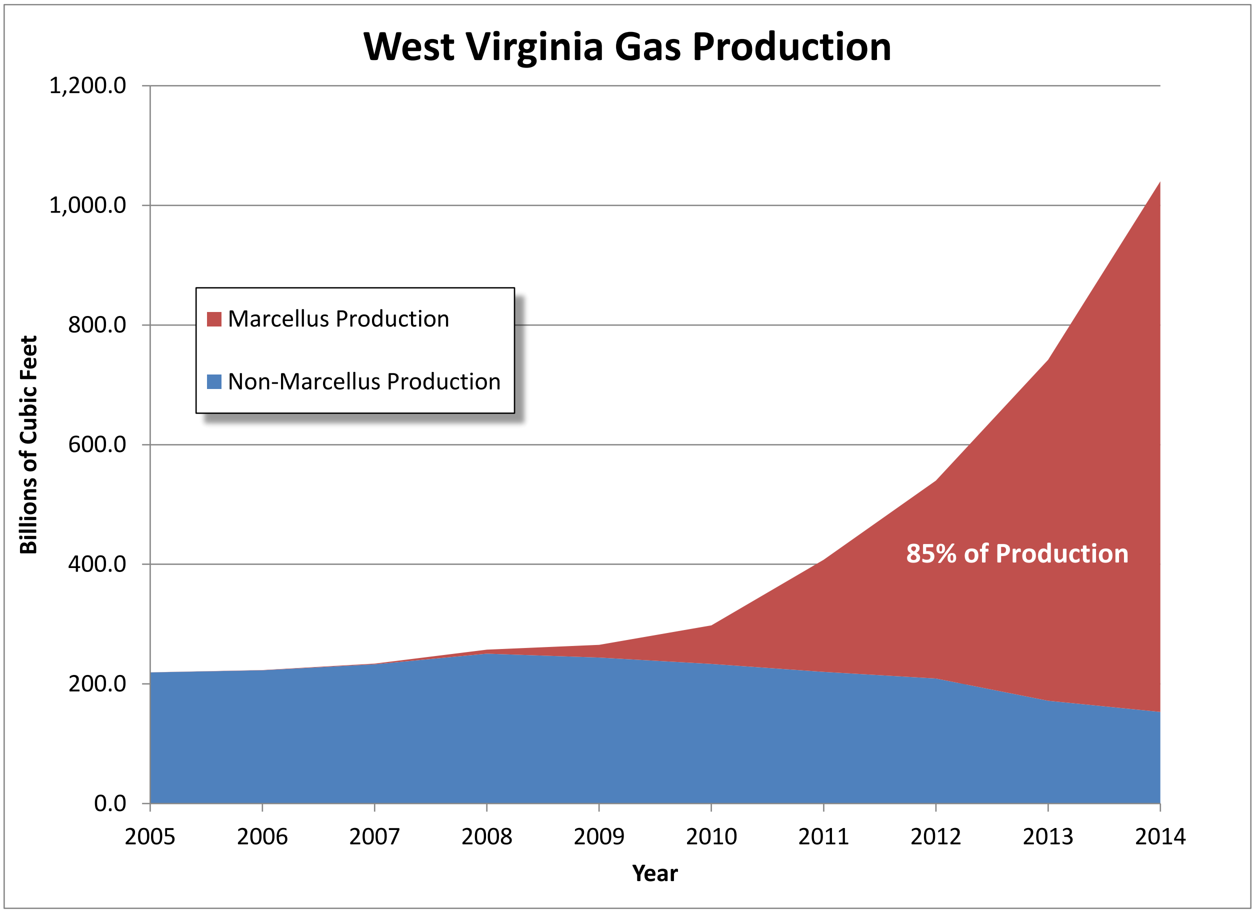

Figure 6.1: Annual gas production from West Virginia from 2005 to 2014 divided by Marcellus and conventional production.

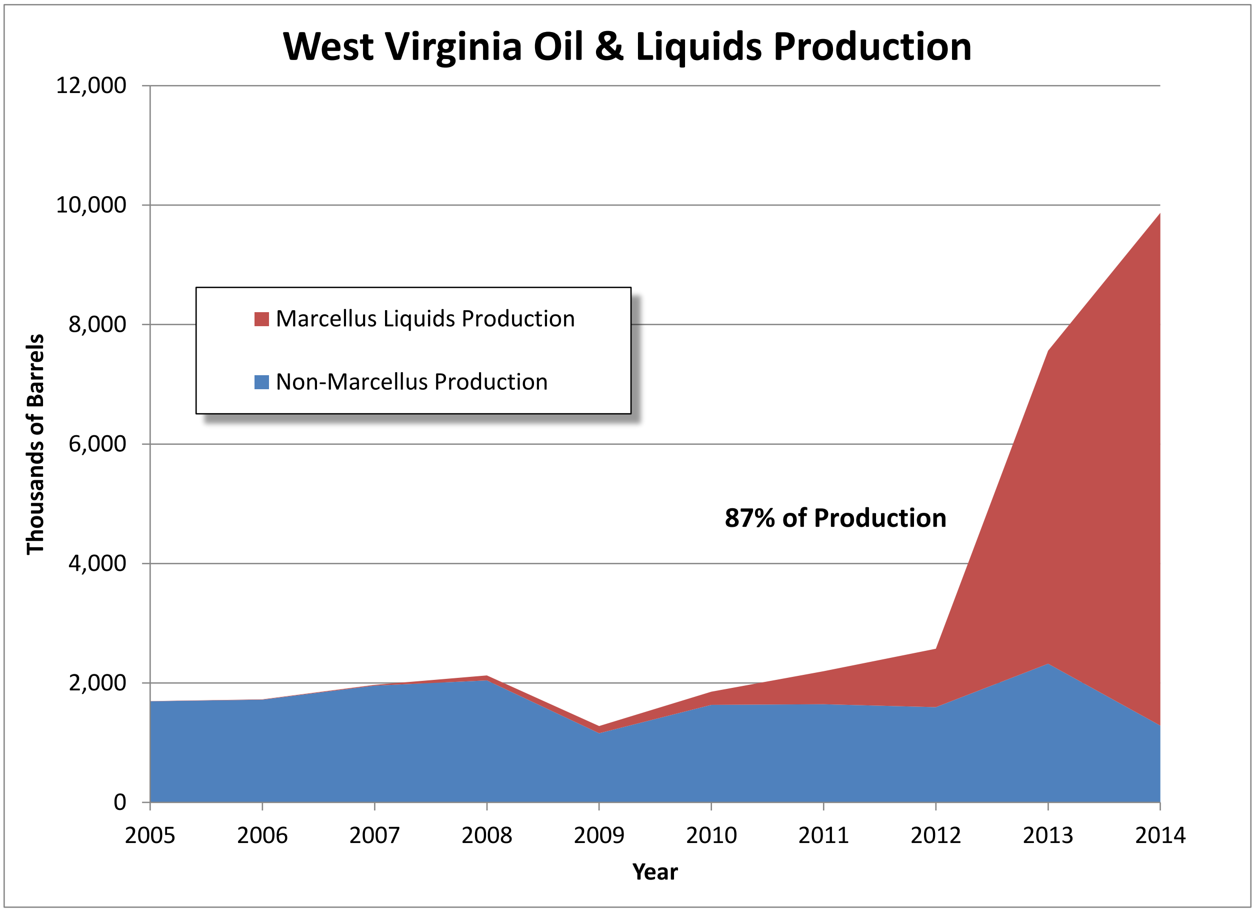

Figure 6.2: Annual liquids production (condensate and natural gas liquids) from West Virginia from 2005 to 2014 divided by Marcellus and conventional production.

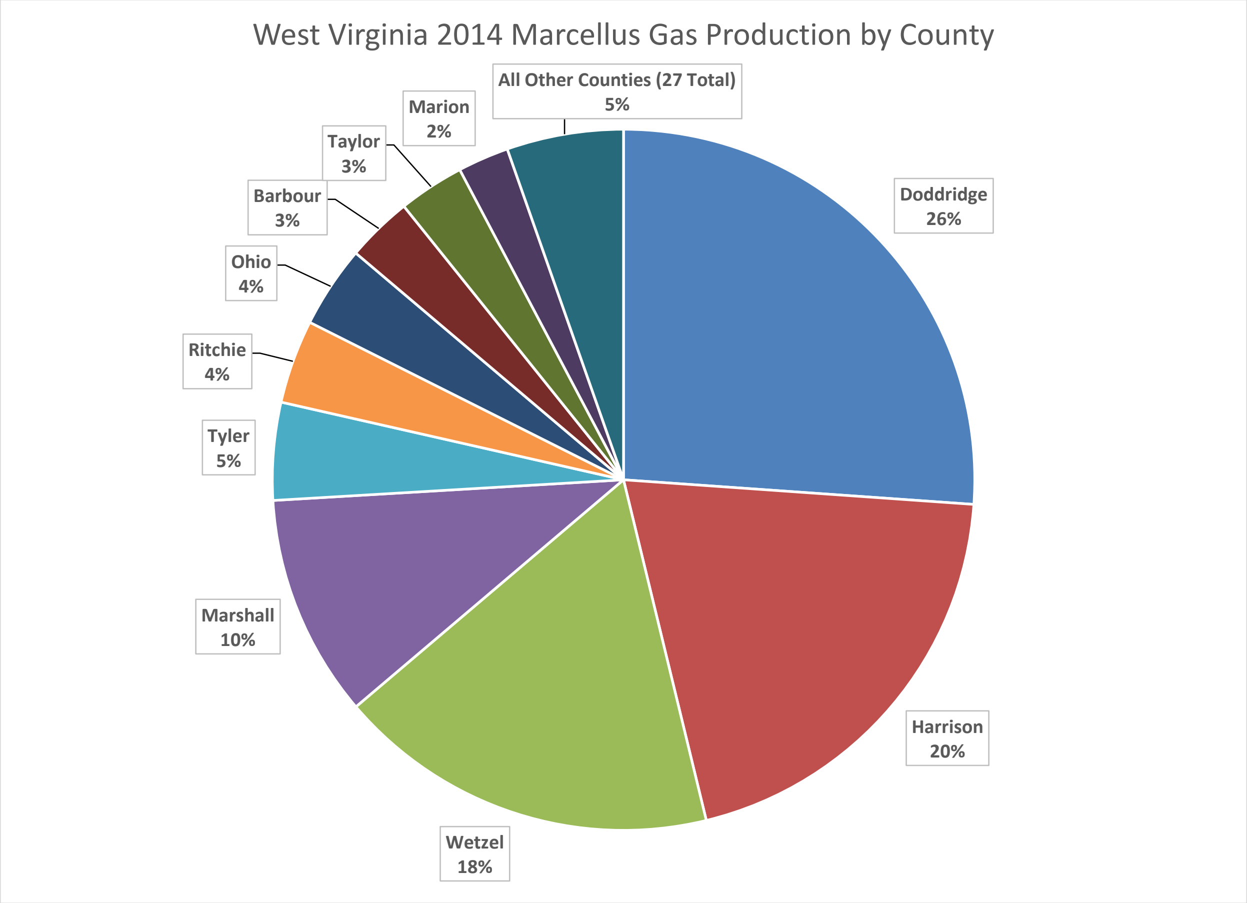

Figure 6.3: Annual unconventional gas production from West Virginia by county.

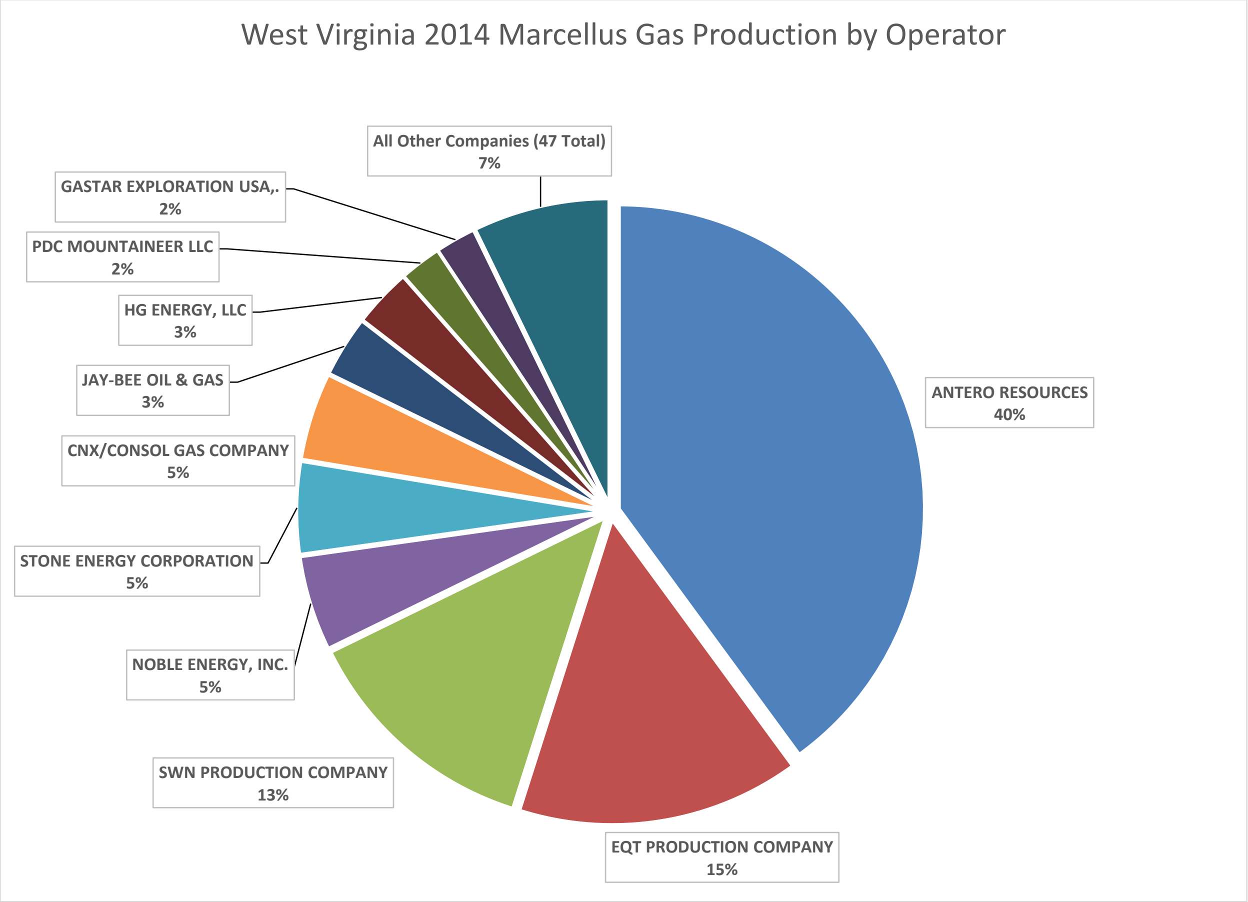

Figure 6.4: Annual unconventional gas production from West Virginia by company.

Plan for Next Quarter

Continue collection of worker and well cost data. Develop methodology for data reduction and begin development of model.

Appendix A

Topic 5. Water and solid waste results

Abbreviations:

- MIP-Morgantown industrial park
- PQL-probable quantitation limit
- MDL-method detection limit
- BDL-below method detection limit
- t-total extractable
- d-dissolved
- TDS_g-Total dissolved solids by gravimetric
- TDS_{sdc}-Total dissolved solids by sum of dissolved constituents
- EC-Electrical conductivity
- TSS-Total suspended solids

Radiolochemistry:

- Act-activity
- Unc-uncertainty
- MDC-minimum detectable concentration

A1. Produced water, 2011 MIP well completions

Method	Parameter	Units	PQL	MIP 4-H 4/14/2015	MIP 6-H 4/14/2015
EPA 120.1	EC	uS/cm	1.0	143000	99300
EPA 300.0	Br	mg/L	125	643	416
	Cl	mg/L	500	59300	34700
	SO4	mg/L	125	63	63
SM 2320B	Alk	mg/L	10	124	180
EPA 6010B	Al d	mg/L	0.05	0.93	0.49
	Ba d	mg/L	1	4970	3040
	Ca d	mg/L	100	9480	5550
	Fe d	mg/L	0	93	155
	K d	mg/L	50	146	93
	Li d	mg/L	0	93	53
	Mg d	mg/L	0	809	571
	Mn d	mg/L	0	3	4
	Na d	mg/L	100	23700	15000
	Sr d	mg/L	5	1970	1310
	Al t	mg/L	0.05	0.45	0.30
	Ba t	mg/L	1	4850	3050
	Ca t	mg/L	100	9060	5460
	Fe t	mg/L	0	97	161
	K t	mg/L	50	122	81
	Li t	mg/L	0	90	52
	Mg t	mg/L	0	803	567
	Mn t	mg/L	0	2	4
	Na t	mg/L	100	23000	14600
	Sr t	mg/L	5	1930	1270
SM 2540C	TDS $_g$	mg/L	20	104000	65100
SM 2540D	TSS	mg/L	4	75	99
EC x 0.7	TDS	mg/L		100100	69510
SDC	TDS $_{sdc}$	mg/L		101394	61135
cation meq				1709727	1068803
anion meq				1681805	986924
anion/cation				0.98	0.92

d=dissolved, t=total extractable

A2. Hydraulic Fracturing (HF) and Makeup Water (MU)-2015 Completions

BDL=below detection level					Sampling date			
				Date	6-Nov-15		10-Nov-15	
Method	MDL	units	Details	Sample ID	MIP 5H HF	MIP 5H MU	MIP 3H HF	MIP 3H MU
SW6020A	0.0011	mg/L	Cations ICP (Total)	Al	-	0.021	0.800	0.037
	0.0007			As	-	BDL	0.002	0.001
	0.0002			Ba	-	0.048	0.026	0.054
	0.4			Ca	-	34.000	35.000	36.000
	0.0001			Cr	-	BDL	0.007	0.000
	0.01			Fe	-	BDL	3.900	0.092
	0.0001			Pb	-	BDL	0.008	BDL
	0.019			Mg	-	8.000	9.700	9.700
	0.0002			Mn	-	0.001	0.170	0.046
	0.0004			Ni	-	0.002	0.009	0.002
	0.03			K	-	2.500	4.300	2.500
	0.001			Se	-	BDL	BDL	BDL
	0.0001			Ag	-	BDL	BDL	BDL
	0.1			Na	-	30.000	62.000	31.000
	0.0003			Sr	-	0.270	0.320	0.350
	0.02			Zn	-	0.037	0.140	0.007
SW8260	0.25	µg/L		Benzene	BDL	BDL	BDL	BDL
	0.22			Ethylbenze	BDL	BDL	BDL	BDL
	0.4			m,p-Xylene	BDL	BDL	BDL	BDL
	0.21			o-Xylene	BDL	BDL	BDL	BDL
	0.2			Toluene	BDL	BDL	0.840	BDL
	0.62			Total-Xylene	BDL	BDL	BDL	BDL
A4500-CO2D	4.3	mg/L	Anions IC	Alk	69	59.000	80.000	60.000
E300.0	1.90			Br	BDL	BDL	BDL	0.110
	0.29			Cl	55	14.000	48.000	15.000
	3			SO4	140	140.000	120.000	130.000
A5540C	0.005	mg/L		MBAS	BDL	BDL	BDL	BDL
A2510 B-97	2.4	µS/cm		EC	550	420.000	500.000	380.000
A2540 C-97	7.6	mg/L		TDS	860	270.000	420.000	260.000
A2540 D-97	1.8			TSS	140	2.000	150.000	9.500
A4500-H B-11		pH		pH	6.6	7.800	6.740	6.810
900.0		pCi/L	Act	alpha	1.61	-0.672	2.870	1.840
			Unc		1.54	0.692	1.800	1.420
			MDC		2.93	2.500	2.890	2.590
			Act	beta	1.7	1.780	5.140	2.020
			Unc		0.861	0.999	1.640	1.010
			MDC		1.46	1.750	2.120	1.720
903.1			Act	^{226}Ra	1.52	0.000	1.440	0.318
			Unc		1.02	0.291	1.910	0.292
			MDC		1.09	0.630	0.974	0.172
904.0			Act	^{228}Ra	2.51	0.869	1.230	0.608
			Unc		1.49	0.433	1.480	0.367
			MDC		2.72	0.751	3.120	0.685
901.1			Act	^{40}K	0	43.766	16.565	0.000
			Unc		42.366	49.865	77.176	21.878
			MDC		112.5	63.590	88.450	99.780
A4500-NO2 B-11	0.02	mg/L		NO2	0.01	0.016	0.200	0.023
A4500-NO3 B/E-11	0.012			NO3	0.68	0.340	BDL	0.160
E1664A	1.4			O&G	8.1	-	BDL	1.400
E365.1 R2.0	0.04			P t	3.8	0.041	3.500	0.041
SW9030B	0.44			S^-	BDL	BDL	BDL	BDL

A3. Surface Water Monitoring Results-Inorganics, total

	Method	SW6020A															
	MDL	0.0011	0.0007	0.0002	0.4	0.0001	0.01	0.0001	0.019	0.0002	0.0004	0.03	0.001	0.0001	0.1	0.0003	0.02
	units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
samp. Stn	Date	Al t	As t	Ba t	Ca t	Cr t	Fe t	Pb t	Mg t	Mn t	Ni t	K t	Se t	Ag t	Na t	Sr t	Zn t
MR-1	12-Jun-15	0.41	0.00074	0.06	57.00	0.00057	0.81	0.00065	16.00	0.17	0.0027	2.80	BDL	BDL	39.00	0.49	0.03
MR-1	25-Jun-15	0.36	BDL	0.04	18.00	0.00035	0.56	0.00066	3.90	0.12	0.0017	1.30	BDL	BDL	6.90	0.08	0.03
MR-1	8-Jul-15	0.41	0.00097	0.04	25.00	0.00047	0.73	0.00073	6.00	0.11	0.0021	1.80	BDL	BDL	14.00	0.16	0.02
MR-1	25-Sep-15	0.11	BDL	0.05	43.00	0.00016	0.22	0.00031	12.00	0.07	0.0033	2.90	BDL	BDL	40.00	0.44	0.01
MR-1	14-Oct-15	0.01	BDL	0.04	41.00	0.00005	0.02	0.00005	11.00	0.01	0.0016	3.00	BDL	BDL	28.00	0.33	0.00
MR-1	19-Nov-15	0.11	BDL	0.06	49.00	0.00005	0.24	0.00023	13.00	0.14	0.0025	3.20	BDL	BDL	39.00	0.42	0.01
MR-2	12-Jun-15	0.14	BDL	0.06	56.00	0.00016	0.22	0.00017	16.00	0.07	0.0021	2.70	BDL	BDL	39.00	0.49	0.02
MR-2	25-Jun-15	0.78	0.00072	0.04	18.00	0.00087	1.00	0.00084	3.90	0.10	0.0022	1.50	BDL	BDL	6.90	0.08	0.02
MR-2	8-Jul-15	0.67	BDL	0.04	27.00	0.00064	0.74	0.00065	6.70	0.08	0.0021	1.90	BDL	BDL	15.00	0.17	0.02
MR-2	25-Sep-15	0.06	BDL	0.05	44.00	0.00013	0.09	0.00017	13.00	0.04	0.0032	3.00	BDL	BDL	42.00	0.45	0.05
MR-2	14-Oct-15	0.01	BDL	0.04	42.00	0.00005	0.02	0.00005	11.00	0.01	0.0015	3.20	BDL	BDL	29.00	0.35	0.00
MR-2	19-Nov-15	0.06	BDL	0.05	48.00	0.00011	0.12	0.00033	13.00	0.10	0.0023	3.20	BDL	BDL	39.00	0.41	0.00
			BDL														
MR-3	12-Jun-15	0.09	BDL	0.05	55.00	0.00013	0.14	0.00250	16.00	0.06	0.0017	2.60	BDL	BDL	38.00	0.48	0.02
MR-3	25-Jun-15	0.38	0.00077	0.04	18.00	0.00040	0.56	0.00061	3.90	0.09	0.0025	1.40	BDL	BDL	6.60	0.08	0.04
MR-3	8-Jul-15	0.85	BDL	0.04	28.00	0.00072	0.80	0.00072	6.70	0.09	0.0022	2.00	BDL	BDL	14.00	0.17	0.02
MR-3	25-Sep-15	0.06	BDL	0.05	44.00	0.00013	0.09	0.00012	12.00	0.05	0.0034	3.00	BDL	BDL	42.00	0.42	0.02
MR-3	14-Oct-15	0.13	BDL	0.05	44.00	0.00005	0.02	0.00005	12.00	0.01	0.0016	3.20	BDL	BDL	30.00	0.37	0.01
MR-3	19-Nov-15	0.06	BDL	0.06	48.00	0.00012	0.14	0.00015	13.00	0.11	0.0023	3.10	BDL	BDL	41.00	0.41	0.00

BDL=below method detection limit

A4. Surface Water Monitoring Results-Inorganics, dissolved

	Method	SW6020A																A4500-CO2D	E300.0		
	MDL	0.001	0.0007	0.0002	0.4	0.0001	0.01	0.0001	0.2	0.0002	0.0004	0.034	0.001	0.0001	0.1	0.0003	0.002	4.3	0.19	0.29	3
	units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
samp. Stn	Date	Al d	As d	Ba d	Ca d	Cr d	Fe d	Pb d	Mg d	Mn d	Ni d	K d	Se d	Ag d	Na d	Sr d	Zn d	Alk	Br*	Cl	SO4
MR-1	12-Jun-15	0.02	BDL	0.05	53	0.00013	0.02	BDL	15.00	0.08	0.0017	2.50	BDL	BDL	37.00	0.47	0.03	84.00	BDL	12.00	220
MR-1	25-Jun-15	0.02	BDL	0.03	17	BDL	0.04	BDL	3.70	0.08	0.0006	1.20	BDL	BDL	6.90	0.08	0.04	34.00	BDL	4.60	40
MR-1	8-Jul-15	0.03	BDL	0.03	26	BDL	0.06	BDL	6.20	0.07	0.0018	1.70	BDL	BDL	14.00	0.16	0.04	61.00	BDL	6.90	66
MR-1	25-Sep-15	0.01	BDL	0.05	43	BDL	0.01	BDL	12.00	0.03	0.0016	3.20	BDL	BDL	38.00	0.44	0.01	69.00	BDL	14.00	180
MR-1	14-Oct-15	0.00	BDL	0.04	38	BDL	0.02	BDL	10.25	0.00	0.0015	2.80	BDL	BDL	26.29	0.34	0.00	70.00	BDL	14.00	100
MR-1	19-Nov-15	0.00	BDL	0.05	45	BDL	0.05	BDL	12.00	0.12	0.0022	2.90	BDL	BDL	35.00	0.40	0.01	79.00	0.10	17.00	160
MR-2	12-Jun-15	0.03	BDL	0.05	53	0.00014	0.02	BDL	15.00	0.02	0.0015	2.40	BDL	BDL	36.00	0.47	0.02	85.00	BDL	12.00	210
MR-2	25-Jun-15	0.02	BDL	0.03	16	0.00012	0.03	BDL	3.60	0.04	0.0005	1.20	BDL	BDL	6.40	0.08	0.02	51.00	BDL	4.90	45
MR-2	8-Jul-15	0.03	BDL	0.03	26	BDL	0.04	BDL	6.00	0.02	0.0013	1.70	BDL	BDL	13.00	0.16	0.02	62.00	BDL	6.60	64
MR-2	25-Sep-15	0.01	0.0014	0.05	43	BDL	0.02	BDL	12.00	0.00	0.0013	3.10	BDL	BDL	44.00	0.44	0.00	67.00	BDL	14.00	180
MR-2	14-Oct-15	0.01	BDL	0.04	39	BDL	0.01	BDL	10.69	0.00	0.0014	2.90	BDL	BDL	27.00	0.35	0.00	71.00	BDL	14.00	100
MR-2	19-Nov-15	0.00	BDL	0.05	43	BDL	0.03	BDL	11.00	0.08	0.0021	2.80	BDL	BDL	33.00	0.40	0.00	77.00	0.11	17.00	160
MR-3	12-Jun-15	0.02	BDL	0.05	54	0.00011	0.01	BDL	15.00	0.00	0.0013	2.40	BDL	BDL	37.00	0.48	0.02	85.00	BDL	13.00	220
MR-3	25-Jun-15	0.02	BDL	0.03	16	BDL	0.03	BDL	3.70	0.03	0.0006	1.20	BDL	BDL	6.70	0.08	0.02	52.00	BDL	4.80	45
MR-3	8-Jul-15	0.03	BDL	0.03	26	BDL	0.05	BDL	6.30	0.02	0.0013	1.80	BDL	BDL	14.00	0.16	0.03	47.00	BDL	6.80	64
MR-3	25-Sep-15	0.01	BDL	0.05	41	BDL	0.01	BDL	12.00	0.01	0.0014	3.00	BDL	BDL	45.00	0.41	0.01	65.00	BDL	14.00	170
MR-3	14-Oct-15	0.06	BDL	0.05	41	BDL	0.02	BDL	11.30	0.00	0.0015	2.90	BDL	BDL	28.66	0.38	0.00	72.00	BDL	15.00	110
MR-3	19-Nov-15	0.01	BDL	0.05	44	BDL	0.03	BDL	11.00	0.08	0.0021	2.80	BDL	BDL	35.00	0.39	0.01	76.00	0.07	17.00	150

BDL=below method detection limit

* MDL lowered to 0.02 ug/L on 19 nov 15

A5. Surface Water Monitoring Results-Field readings

	Method MDL units	Field Readings				
		°C	µS/cm	mg/L	pH	mg/L
samp. Stn	Date	Temp.	EC	TDS	pH	DO
MR-1	12-Jun-15	24.44	643	419	8.05	6.47
MR-1	25-Jun-15	20.39	181	131	7.60	8.11
MR-1	8-Jul-15	22.52	256	175	7.88	6.40
MR-1	25-Sep-15	22.57	653	445	7.52	5.86
MR-1	14-Oct-15	18.32	486	362	7.82	8.79
MR-1	19-Nov-15	12.30	400	343	7.49	10.19
MR-2	12-Jun-15	24.21	635	419	8.23	6.02
MR-2	25-Jun-15	20.46	180	128	7.70	7.60
MR-2	8-Jul-15	22.52	254	173	7.97	6.49
MR-2	25-Sep-15	22.60	649	441	7.69	6.95
MR-2	14-Oct-15	18.23	500	373	7.79	7.98
MR-2	19-Nov-15	12.55	402	343	7.71	10.90
MR-3	12-Jun-15	25.85	657	420	8.49	9.73
MR-3	25-Jun-15	20.37	181	129	7.77	8.31
MR-3	8-Jul-15	22.66	256	174	7.99	6.40
MR-3	25-Sep-15	22.69	636	432	7.60	6.44
MR-3	14-Oct-15	18.30	519	387	7.82	8.99
MR-3	19-Nov-15	12.33	407	349	7.48	11.62

A6. Surface Water Monitoring Results-Organics, Lab EC, TDS, TSS

	Method	SW8260						A5540C	A2510 B-97	A2540 C-97	A2540 D-97
	MDL	0.25	0.22	0.4	0.21	0.2	0.62	0.005	2.4	7.6	1.8
	units	µg/L						mg/L	µS/cm	mg/L	
samp. Stn	Date	Benzene	Ethyl benzene	m-p xylene	o-xylene	toluene	total xylene	MBAS	EC	TDS$_{g}$	TSS
MR-1	12-Jun-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	620	410	20
MR-1	25-Jun-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	170	94	21
MR-1	8-Jul-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	260	1850	12
MR-1	25-Sep-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	550	350	7
MR-1	14-Oct-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	440	270	3
MR-1	19-Nov-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	480	300	5
MR-2	12-Jun-15	BDL	BDL	BDL	BDL	0.48	BDL	BDL	610	300	6
MR-2	25-Jun-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	170	96	28
MR-2	8-Jul-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	250	150	12
MR-2	25-Sep-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	540	360	7
MR-2	14-Oct-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	460	280	4
MR-2	19-Nov-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	470	300	0
								BDL			
MR-3	12-Jun-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	610	400	6
MR-3	25-Jun-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	170	96	16
MR-3	8-Jul-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	260	150	14
MR-3	25-Sep-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	530	350	3
MR-3	14-Oct-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	470	280	2
MR-3	19-Nov-15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	460	300	3

BDL=below method detection limit

A7. Surface Water Monitoring Results-Radiochemistry

	Method	900.0						903.1			904.0			901.1		
	units	pCi/L						pCi/L			pCi/L			pCi/L		
		alpha			beta			^{226}Ra			^{228}Ra			^{40}K		
samp. Stn	Date	act	unc	MDC	act	unc	MDC	act	unc	MDC	act	unc	MDC	act	unc	MDC
MR-1	12-Jun-15	BDL	1.60	2.90	5.20	1.80	2.90	BDL	0.10	0.19	BDL	0.32	0.64	BDL	98.00	175.00
MR-1	25-Jun-15	1.67	1.48	2.75	1.70	1.18	2.16	0.19	0.33	0.58	-0.41	0.34	0.88	0.00	18.95	110.80
MR-1	8-Jul-15	-0.83	0.61	2.24	1.60	0.98	1.89	0.13	0.30	0.48	0.06	0.39	0.89	0.00	26.80	116.30
MR-1	25-Sep-15	0.93	1.27	2.66	0.73	0.77	1.57	-0.04	0.46	0.94	0.29	0.37	0.79	0.00	28.94	129.80
MR-1	14-Oct-15	0.83	0.92	1.83	1.81	0.73	1.09	0.30	0.27	1.62	0.49	0.35	0.68	13.68	62.23	81.35
MR-1	19-Nov-15	1.99	1.57	2.91	2.35	1.28	2.34	-0.27	0.33	0.89	0.22	0.31	0.66	9.71	35.61	62.99
MR-2	12-Jun-15	BDL	1.20	3.00	3.20	1.60	2.90	0.23	0.13	0.04	0.75	0.35	0.06	BDL	98.00	178.00
MR-2	25-Jun-15	-0.37	0.89	2.78	0.28	1.07	2.59	0.27	0.38	0.63	0.23	0.39	0.84	3.29	90.86	100.90
MR-2	8-Jul-15	-0.06	0.56	1.62	0.10	0.85	2.00	0.26	0.44	0.77	0.30	0.45	0.96	0.79	88.99	96.53
MR-2	25-Sep-15	1.86	1.52	2.78	1.33	0.89	1.64	-0.06	0.32	0.74	-0.05	0.36	0.86	23.82	39.55	64.06
MR-2	14-Oct-15	-0.22	0.94	2.47	3.01	0.95	1.22	0.33	0.31	0.18	0.48	0.37	0.72	0.00	10.94	104.40
MR-2	19-Nov-15	0.53	1.25	2.91	2.81	1.22	1.94	0.00	0.83	1.33	0.36	0.30	0.61	0.00	30.94	102.40
MR-3	12-Jun-15	BDL	1.30	3.00	BDL	1.50	3.00	0.15	0.12	0.14	BDL	0.27	0.55	BDL	100.00	170.00
MR-3	25-Jun-15	-0.32	0.80	2.64	-0.46	0.97	2.63	0.00	0.35	0.75	-0.06	0.33	0.79	0.00	36.28	100.90
MR-3	8-Jul-15	-0.17	0.65	2.09	0.92	1.10	2.40	1.21	0.68	0.80	0.18	0.38	0.83	0.00	15.47	106.90
MR-3	25-Sep-15	2.08	1.66	2.82	2.60	1.05	1.49	0.53	0.49	0.72	0.37	0.44	0.92	0.00	23.52	110.70
MR-3	14-Oct-15	0.51	1.20	2.83	2.23	1.05	1.74	0.35	0.53	0.90	0.76	0.37	0.64	0.00	10.94	93.65
MR-3	19-Nov-15	2.48	1.73	2.92	2.19	1.02	1.66	1.33	0.46	0.78	0.27	0.32	0.67	0.00	10.94	102.40

BDL=below method detection limit act=activity, unc=uncertainty, MDC=minimum detectable concentration

A8. Drill cuttings MIP 5H-vertical section

			MIP 5H 4400	MIP 5H 5026	MIP 5H 6798
Units	Parameter	MDL	13-Jul-15	13-Jul-15	6-Oct-15
mg/kg-dry	DRO (C10-C28)	1.4	250	85	66000
	ORO (C28-C40)	1.4	65	34	1800
% Rec	Surr: 4-terphenyl-d14	-	90	64	598
µg/kg	GRO C6-C10)	1200	60000	BDL	43000
% Rec	Surr: Toluene-d8	-	96	95	102
µg/kg-dry	Ethylbenzene	1300	58.00	29.00	BDL
	m,p- Xylene	2700	430.00	240.00	BDL
	o- Xylene	1500	130.00	60.00	BDL
	Styrene	1300	BDL	BDL	BDL
	Toluene	1300	370.00	200.00	BDL
	Xylenes total	4200	560.00	300.00	BDL
% Rec	Surr: 1,2- Dichloroethane-d4	-	102.00	108.00	101.00
	Surr: 4-Bromofluorobenzene	-	97.40	93.20	94.40
	Surr: Dibromofluoromethane	-	103.00	108.00	99.10
	Surr: Tolouene-d8	-	94.00	92.90	100.00
pCi/g	Potassium-40	Act	28.32	24.28	27.36
		Unc	4.81	4.42	4.53
		MDC	0.99	1.41	0.87
	Radium-226	Act	1.22	1.35	1.76
		Unc	0.31	0.34	0.35
		MDC	0.28	0.18	0.20
	Radium-228	Act	1.82	1.90	1.44
		Unc	0.48	0.45	0.45
		MDC	0.25	0.29	0.52
	Gross Alpha	Act	15.00	10.50	17.10
		Unc	7.05	5.75	7.65
		MDC	9.76	9.15	11.20
	Gross Beta	Act	24.50	19.40	27.80
		Unc	6.26	4.79	6.65
		MDC	5.64	4.13	5.38
mg/kg-dry	Br	0.2	2.8	7.3	2.7
	Cl	52	260.0	750.0	1100.0
	SO4	0.75	36.0	46.0	21.0
	sulfide	74	BDL	BDL	BDL
	nitrate	1	0.1	1.4	0.7
	nitrite	1	0.0	0.0	0.0
µS/cm	EC	0.56	1200.0	1900.0	20000.0
	pH	0	8.8	9.2	9.6
mg/kg-dry	alkalnity, bicarbonate	54	150.0	140.0	84.0
	alkalinity, carbonate	54	130.0	270.0	56.0
	alkalinity, total	54	280.0	410.0	140.0
	TP	6.6	220.0	240.0	330.0
	Ag	6.5	0.0	0.0	BDL
	Al	5.1	7500.0	11000.0	17000.0
	As	0.25	12.0	13.0	15.0
	Ba	0.45	40.0	42.0	7600.0
	Ca	17	9400.0	9700.0	19000.0
	Cr	0.25	11.0	22.0	28.0
	Fe	4.8	23000.0	40000.0	38000.0
	K	11	710.0	1200.0	3300.0
	Mg	1.8	4100.0	5400.0	9300.0
	Mn	0.26	570.0	660.0	670.0
	Na	6.5	420.0	850.0	1000.0
	Ni	0.27	20.0	24.0	55.0
	Pb	0.038	11.0	7.8	13.0
	Se	0.25	0.5	0.4	BDL
	Sr	0.051	13.0	24.0	610.0
	Zn	0.64	36.0	43.0	95.0
%	Moisture	0.05	15.0	14.0	10.0
mg/kg-dry	COD	140	-	-	3000.0
% by wt-dry	OC-WB	0.011	BDL	BDL	4.0
mg/kg-dry	O&G	110	370.0	150.0	64000.0

A9. Drill cuttings MIP 5H-horizontal section

			MIP 5H 8555	MIP 5H 8555 DUP	MIP 5H 9998	MIP 5H 11918	MIP 5H 11918
Units	Parameter	MDL	11-Sep-15	11-Sep-15	6-Oct-15	25-Sep-15	6-Oct-15
mg/kg-dry	DRO (C10-C28)	1.4	130000	130000	390000	310000	260000
	ORO (C28-C40)	1.4	1800	1500	25000	24000	20000
% Rec	Surr: 4-terphenyl-d14	-	169	121	250	290	248
µg/kg	GRO C6-C10)	1200	880000	400000	390000	470000	34000
% Rec	Surr: Toluene-d8	-	105	104	103	102	104
µg/kg-dry	Ethylbenzene	1300	BDL	BDL	BDL	BDL	BDL
	m,p- Xylene	2700	BDL	BDL	BDL	BDL	BDL
	o- Xylene	1500	BDL	BDL	BDL	BDL	BDL
	Styrene	1300	BDL	BDL	BDL	BDL	BDL
	Toluene	1300	BDL	BDL	BDL	BDL	BDL
	Xylenes total	4200	BDL	BDL	BDL	BDL	BDL
% Rec	Surr: 1,2- Dichloroethane-d4	-	104.00	103.00	99.20	101.00	102.00
	Surr: 4-Bromofluorobenzene	-	96.40	93.90	94.30	95.20	95.50
	Surr: Dibromofluoromethane	-	98.40	102.00	92.80	99.20	98.00
	Surr: Tolouene-d8	-	96.10	100.00	102.00	99.40	102.00
pCi/g	Potassium-40	Act	25.90	24.63	16.70	21.80	19.69
		Unc	4.25	4.62	4.27	3.74	3.41
		MDC	1.08	1.53	2.73	1.13	1.08
	Radium-226	Act	4.71	4.56	9.15	4.01	4.17
		Unc	0.71	0.74	1.33	0.67	0.63
		MDC	0.22	0.27	0.29	0.25	0.25
	Radium-228	Act	1.34	1.12	0.48	0.72	0.76
		Unc	0.37	0.58	0.89	0.47	0.39
		MDC	0.42	0.61	0.95	0.51	0.57
	Gross Alpha	Act	27.00	38.10	46.80	24.40	23.80
		Unc	9.62	11.10	11.00	9.18	6.75
		MDC	10.20	9.05	4.69	10.30	5.24
	Gross Beta	Act	36.90	29.80	42.90	23.00	28.70
		Unc	8.56	6.84	8.98	6.21	6.34
		MDC	6.62	4.94	5.89	6.17	5.07
mg/kg-dry	Br	0.2	5.2	4.6	3.9	4.8	4.3
	Cl	52	1700.0	1700.0	1300.0	1600.0	1100.0
	SO4	0.75	36.0	35.0	16.0	17.0	13.0
	sulfide	74	BDL	BDL	BDL	BDL	270.0
	nitrate	1	0.2	0.5	0.7	1.0	0.1
	nitrite	1	0.0	0.0	0.0	BDL	0.3
µS/cm	EC	0.56	3900.0	6500.0	24000.0	8900.0	21000.0
	pH	0	10.0	10.0	10.1	11.0	9.8
mg/kg-dry	alkalnity, bicarbonate	54	BDL	BDL	200.0	BDL	BDL
	alkalinity, carbonate	54	280.0	280.0	710.0	820.0	500.0
	alkalinity, total	54	730.0	650.0	910.0	1000.0	510.0
	TP	6.6	160.0	130.0	57.0	59.0	450.0
	Ag	6.5	0.4	0.4	1.3	0.5	BDL
	Al	5.1	6600.0	6600.0	3000.0	3300.0	3000.0
	As	0.25	25.0	22.0	55.0	29.0	34.0
	Ba	0.45	1600.0	1500.0	5500.0	2600.0	4900.0
	Ca	17	22000.0	25000.0	63000.0	58000.0	63000.0
	Cr	0.25	11.0	11.0	14.0	8.2	9.8
	Fe	4.8	27000.0	25000.0	34000.0	18000.0	22000.0
	K	11	2600.0	2600.0	2400.0	2400.0	2500.0
	Mg	1.8	2800.0	3100.0	2400.0	3300.0	3600.0
	Mn	0.26	190.0	230.0	280.0	200.0	270.0
	Na	6.5	1100.0	1100.0	1200.0	970.0	1100.0
	Ni	0.27	92.0	74.0	200.0	87.0	110.0
	Pb	0.038	25.0	25.0	38.0	20.0	24.0
	Se	0.25	4.8	4.6	15.0	6.5	12.0
	Sr	0.051	460.0	580.0	1000.0	640.0	810.0
	Zn	0.64	130.0	730.0	340.0	160.0	220.0
%	Moisture	0.05	14.0	14.0	16.0	15.0	14.0
mg/kg-dry	COD	140	4000.0	4600.0	5300.0	3600.0	3800.0
% by wt-dry	OC-WB	0.011	5.6	5.8	6.5	6.5	7.7
mg/kg-dry	O&G	110	59000.0	83000.0	130000.0	110000.0	110000.0

A10. Drill cuttings MIP 3H-horizontal section

					MIP 13480 3H	MIP 13480 3H DUP	MIP 13480 3H Mud	MIP 14454 5H
Analysis	Method	Units	Parameter	MDL	21-Sep-15	21-Sep-15	21-Sep-15	6-Oct-15
Diesel Range Organics by GC-FID	SW8015M	mg/kg-dry	DRO (C10-C28)	1.4	85000.00	87000.00	230000.00	350000
			ORO (C28-C40)	1.4	1100.00	1100.00	19000.00	19000
		% Rec	Surr: 4-terphenyl-d14	-	187.00	226.00	210.00	245
Gasoline Range Organics by GC-FID	SW8015D	µg/kg	GRO C6-C10)	1200	240000.00	330000	450000.00	430000
		% Rec	Surr: Toluene-d8	-	106.00	102	103.00	101
Volatile Organic Compounds	SW8260B	µg/kg-dry	Ethylbenzene	1300	BDL	BDL	BDL	BDL
			m,p- Xylene	2700	BDL	BDL	BDL	BDL
			o- Xylene	1500	BDL	BDL	BDL	BDL
			Styrene	1300	BDL	BDL	BDL	BDL
			Toluene	1300	BDL	BDL	BDL	BDL
			Xylenes total	4200	BDL	BDL	BDL	BDL
		% Rec	Surr: 1,2- Dichloroethane-d4	-	102.00	101	103.00	101
			Surr: 4-Bromofluorobenzene	-	100.00	92.8	92.20	96.8
			Surr: Dibromofluoromethane	-	102.00	93.4	96.80	100
			Surr: Tolouene-d8	-	98.80	100	99.60	100
Radionuclides	EPA 901.1	pCi/g	Potassium-40	Act	17.66	18.486	12.892	20.073
				Unc	3.21	3.471	2.98	3.799
				MDC	1.20	1.371	1.083	1.055
			Radium-226	Act	9.22	9.715	5.563	5.774
				Unc	1.32	1.371	0.866	0.891
				MDC	0.24	0.335	0.153	0.249
			Radium-228	Act	0.81	1.131	0.486	1.327
				Unc	0.55	0.388	0.346	0.52
				MDC	0.49	0.312	0.826	0.611
	9310		Gross Alpha	Act	55.70	59.2	60	28.8
				Unc	14.70	14.9	15.9	7.88
				MDC	11.50	9.31	10.5	6.53
			Gross Beta	Act	35.40	35	42.5	37.5
				Unc	8.21	7.75	9.6	7.95
				MDC	5.83	4.55	6.14	5.41
Inorganics	SW9056A	mg/kg-dry	Br	0.2	4.5	1.6	11.0	7.0
			Cl	52	1100.0	440.0	2800.0	1800.0
			SO4	0.75	26.0	17.0	39.0	16.0
	SW9034		sulfide	74	BDL	BDL	BDL	140.0
	E353.2		nitrate	1	10.0	5.1	7.9	0.8
	E354.1		nitrite	1	0.0	BDL	0.0	0.0
	A2510M	µS/cm	EC	0.56	9800.0	9100.0	60000.0	21000.0
	SW9045D		pH	0	9.9	9.9	9.8	10.0
	A4500-CO2 D	mg/kg-dry	alkalnity, bicarbonate	54	BDL	BDL	BDL	BDL
			alkalinity, carbonate	54	440.0	300.0	600.0	470.0
			alkalinity, total	54	1300.0	610.0	940.0	550.0
	E365.1 R2.0		TP	6.6	170.0	200.0	190.0	62.0
	SW6020A		Ag	6.5	0.5	0.5	0.5	BDL
			Al	5.1	2500.0	2700.0	3100.0	2900.0
			As	0.25	32.0	35.0	20.0	37.0
			Ba	0.45	590.0	540.0	2000.0	5900.0
			Ca	17	31000.0	29000.0	52000.0	40000.0
			Cr	0.25	8.1	7.6	19.0	12.0
			Fe	4.8	29000.0	30000.0	19000.0	27000.0
			K	11	2600.0	2500.0	2700.0	2500.0
			Mg	1.8	2600.0	2700.0	2000.0	1900.0
			Mn	0.26	200.0	210.0	420.0	240.0
			Na	6.5	2200.0	6000.0	6000.0	780.0
			Ni	0.27	140.0	140.0	140.0	130.0
			Pb	0.038	27.0	27.0	28.0	29.0
			Se	0.25	15.0	16.0	7.3	11.0
			Sr	0.051	570.0	530.0	1600.0	790.0
			Zn	0.64	380.0	480.0	230.0	120.0
Moisture	E160.3M	%	Moisture	0.05	14.0	14.0	36.0	16.0
COD	E4104 R2.0	mg/kg-dry	COD	140	970.0	890.0	2600.0	3700.0
TOC	TITRAMETRIC	% by wt-dry	OC-WB	0.011	10.0	1.5	2.3	11.0
Oil & Grease	SW9071B - OG	mg/kg-dry	O&G	110	20000.0	34000.0	130000.0	130000.0

A11. TCLP Results-inorganics

				Analysis	TCLP Hg	TCLP Metals Analysis By ICP-MS						
				Method	SW7470A	SW6020A						
				Units	mg/L	mg/L						
				Parameter	Hg	As	Ba	Cd	Cr	Pb	Se	Ag
				MDL (mg/L)***	0.00018	0.007	0.002	0.001	0.001	0.001	0.01	0.001
well	section*	length (ft)	type**	TCLP Limit mg/L	0.2	5	100	1	5	5	1	5
MIP 5H	V	4400	C	7/13/2015	BDL	BDL	0.82	BDL	0.0022	0.0400	BDL	BDL
MIP 5H	V	5026	C	7/13/2015	BDL	BDL	0.99	BDL	0.0028	0.0120	BDL	BDL
MIP 5H	B	6798	C	10/6/2015	BDL	BDL	0.84	0.0013	BDL	0.0054	BDL	BDL
MIP 5H	H	8555	C	9/11/2015	BDL	BDL	2.50	BDL	0.0044	0.0066	BDL	BDL
MIP 5H	H	8555	C	9/11/2015	BDL	BDL	2.50	BDL	0.0037	0.0085	BDL	BDL
MIP 5H	H	9998	C	10/6/2015	BDL	BDL	2.80	0.0011	0.0025	0.0120	BDL	BDL
MIP 5H	H	11918	C	9/25/2015	BDL	BDL	2.70	BDL	0.0045	0.0071	0.0110	BDL
MIP 5H	H	11918	C	10/6/2015	BDL	BDL	2.70	BDL	0.0019	0.0072	BDL	BDL
MIP 3H	H	13480	C	9/21/2015	BDL	BDL	2.20	BDL	0.0053	0.0076	BDL	BDL
MIP 3H	H	13480	C	9/21/2015	BDL	BDL	2.30	BDL	0.0061	0.0070	BDL	BDL
MIP 3H	H	13480	M	9/21/2015	BDL	BDL	2.00	0.0016	0.0051	0.0022	BDL	BDL
MIP 3H	H	14454	C	10/6/2015	BDL	BDL	2.70	BDL	0.2500	0.0088	BDL	BDL

* V= vertical, B=bend, H=horizontal

** C=cuttings, M=mud

*** MDL=method detection limit, BDL=below detection limit

A12. TCLP Results-semi-volatile organics

				Analysis Method Units	TCLP Semi-Volatile Organics SW8270 ug/L												
				Parameter	1,4-Dichloro benzene	2,4,5-Trichloro phenol	2,4,6-Trichloro phenol	2,4-Dinitro toluene	Hexa chloro-1,3-butadiene	Hexa chloro benzene	Hexa chloro ethane	m-Cresol	Nitro benzene	o-Cresol	p-Cresol	Penta chloro phenol	Pyridine
				MDL (mg/L)***	0.0082	0.0058	0.005	0.0028	0.0074	0.0046	0.0094	0.0048	0.0046	0.0028	0.0048	0.01	0.061
well	section*	length (ft)	type**	TCLP Limit mg/L	7.5	400	2	0.13	0.5	0.13	3	200	2	200	200	100	5
MIP 5H	V	4400	C	7/13/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	V	5026	C	7/13/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	B	6798	C	10/6/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	H	8555	C	9/11/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	H	8555	C	9/11/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	H	9998	C	10/6/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	H	11918	C	9/25/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	H	11918	C	10/6/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 3H	H	13480	C	9/21/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 3H	H	13480	C	9/21/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 3H	H	13480	M	9/21/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 3H	H	14454	C	10/6/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

* V= vertical, B=bend, H=horizontal

** C=cuttings, M=mud

*** MDL=method detection limit, BDL=below detection limit

A13. TCLP Results-volatile organics

				Analysis	TCLP Volatile Organics									
				Method	SW8260B									
				Units	ug/L									
				Parameter	1,1-Dichloro ethene	1,2-Dichloro ethane	2-Butanone	Benzene	Carbon Tetra chloride	Chloro benzene	Chloro form	Tetra chloro ethene	Trichloro ethene	Vinyl Chloride
				MDL (mg/L)***	0.0047	0.0053	0.017	0.005	0.0028	0.0037	0.0049	0.0049	0.0069	0.0038
well	section*	length (ft)	type**	TCLP Limit mg/L	0.7	0.5	-	0.5	0.5	100	6	0.7	0.5	0.2
MIP 5H	V	4400	C	7/13/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	V	5026	C	7/13/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	B	6798	C	10/6/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	H	8555	C	9/11/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	H	8555	C	9/11/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	H	9998	C	10/6/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	H	11918	C	9/25/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 5H	H	11918	C	10/6/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 3H	H	13480	C	9/21/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 3H	H	13480	C	9/21/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 3H	H	13480	M	9/21/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIP 3H	H	14454	C	10/6/2015	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

* V= vertical, B=bend, H=horizontal

** C=cuttings, M=mud

*** MDL=method detection limit, BDL=below detection limit

Cost Status

Project Title:	Marcellus Shale Energy and Environment Laboratory at West Virginia University
DOE Award Number:	DE-FE0024297

Year 1

Start: 10/01/2014 End:
09/30/2015

Baseline Reporting Quarter

	Q1 (12/31/14)	Q2 (3/30/15)	Q3 (6/30/15)	Q4 (9/30/15)
Baseline Cost Plan	(From 424A, Sec. D)			
(from SF-424A)				
Federal Share	$549,000		$3,549,000	
Non-Federal Share	$0.00		$0.00	
Total Planned (Federal and Non-Federal)	$549,000		$3,549,000	
Cumulative Baseline Costs				
Actual Incurred Costs				
Federal Share	$0.00	$14,760.39	$237,451.36	$300,925.66
Non-Federal Share	$0.00	$0.00	$0.00	$0.00
Total Incurred Costs - Quarterly (Federal and Non-Federal)	$0.00	$14,760.39	$237,451.36	$300,925.66
Cumulative Incurred Costs	$0.00	$14,760.39	$252,211.75	$553,137.41
Uncosted				
Federal Share	$549,000	$534,239.61	$3,296,788.25	$2,995,862.59
Non-Federal Share	$0.00	$0.00	$2,814,930.00	$2,814,930.00
Total Uncosted - Quarterly (Federal and Non-Federal)	$549,000	$534,239.61	$6,111,718.25	$5,810,792.59

Cost Status

Project Title: Marcellus Shale Energy and Environment Laboratory at West Virginia University

DOE Award Number: DE-FE0024297

Year 1

Start: 10/01/2014 End: 09/30/2015

Baseline Reporting Quarter Q5 (12/31/15)

Baseline Cost Plan	(From 424A, Sec. D)			
(from SF-424A)				
Federal Share	$6,247,367			
Non-Federal Share	2,814,930			
Total Planned (Federal and Non-Federal)	$9,062,297			
Cumulative Baseline Costs				
Actual Incurred Costs				
Federal Share	$577,065.91			
Non-Federal Share	$0.00			
Total Incurred Costs - Quarterly (Federal and Non-Federal)	$577,065.91			
Cumulative Incurred Costs	$1,130,203.32			
Uncosted				
Federal Share	$5,117,163.68			
Non-Federal Share	$2,814,930.00			
Total Uncosted - Quarterly (Federal and Non-Federal)	$2,418,796.68			

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