West Virginia University

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Marcellus Shale Energy and Environment Laboratory (MSEEL)
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List of Acronyms

Bcf – Billion Cubic Feet
BET – Brunauer, Emmett and Teller Specific Surface Analysis
CT – Computed Tomography
EDX – NETL's Energy Data eXchange
EPA – Environmental Protection Agency
FIB – Focused Ion Beam
DOE – Department of Energy
HF – Hydraulic Fracturing
ICP-MS – Inductively Coupled Plasma Mass Spectrometry
Mcf – Thousand Cubic Feet
MIP – Morgantown Industrial Park
MOW – Morgantown Ordinance Works
MSEEL – Marcellus Shale Energy and Environment Laboratory
NETL – National Energy Technology Laboratory
NGO – Non-Government Organization
NNE – Northeast Natural Energy LLC.
OSU – The Ohio State University
PLFA – Phospholipid Fatty Acid Analysis
PMP – Project Management Plan
SEM – Scanning Electron Microscopy
SRV – Stimulated Reservoir Volume
TDS – Total Dissolved Solids
TSS – Total Suspended Solids
WAM – Wireless Air Monitoring System
WVU – West Virginia University

μm – Micron

MARCELLUS SEEL NETL PROPOSAL 2014

Project Narrative – Technical Discussion

1 Scientific and Technical Merit

West Virginia University (WVU) and The Ohio State University (OSU) have formed a consortium of university researchers and partners from industry and public sector to develop a research program focused on a dedicated field site and laboratory in the center of the Marcellus Shale unconventional production region of north-central West Virginia. The **Marcellus Shale Energy and Environment Laboratory (MSEEL)** provides a unique opportunity to undertake field and laboratory research over a long time period at a conveniently located facility with a documented history of two previous unconventional gas wells and a strong environmental baseline. Plans include multiple drilling and completion events separated by time intervals of sufficient length to:

- Allow development and validation of improved and cost-effective technology for energy production from unconventional resources
- Undertake baseline and long term site and regional monitoring for the evaluation of the environmental impact and risk of current and developing subsurface and surface technologies; and
- Enhance communications and community understanding of unconventional resource development.

MSEEEL is designed to be a flexible platform for other research efforts beyond those proposed. This proposal will image the subsurface with the latest geological and geophysical techniques and drill a vertical scientific well for the purpose of characterizing the subsurface geology and to monitor a horizontal production well. All wells will be drilled following best practices. The laboratory site provides multiple opportunities to advance and demonstrate new subsurface technologies and to enable surface environmental studies related to unconventional energy development. The MSEEL laboratory will validate new technologies and methods to increase reserves per well, improve efficiency of production in unconventional reservoirs, test and develop environmentally friendly drilling practices, and measure and improve public understanding of unconventional resource development. The proposed MSEEL site provides a controlled environment for testing new technologies to document, minimize, and mitigate the impact of surface operations associated with drilling and production in the premier global unconventional shale resource.

The proposed project will result in a new dedicated laboratory to a) validate enhanced and cost-effective technology for energy production from unconventional resources; b) implement baseline and long term site and regional monitoring for the evaluation of the environmental impact and risk of current and developing subsurface and surface technologies; c) develop predictive and remediation solutions to problems above and below the surface; and d) enhance and improve communications and community understanding. Data and information will be broadly disseminated to shale energy stakeholders to increase resource productivity and enhance environmental stewardship. The Marcellus Shale Energy and Environment Laboratory (MSEEL) will form the basis of a long-term field site and critical test lab as a collaborative research opportunity for partners from industry, academia, government agencies, and NGOs.

This project will contribute substantially to the scientific understanding of the environmental and social impacts of shale development, and to improved extraction and management of subsurface energy resources. The results of this project will allow the industry to gain a better understanding of the respective reservoirs through advanced reservoir characterization, optimized well spacing, and improved completion methods, in the interest of increasing per-well production and reducing well numbers. MSEEL will provide a unique and comprehensive platform to develop and demonstrate best practices to the public and industry.

1.1 Statement of the Problem

The United States and the world have a new energy reality that has opened up abundant, accessible energy sources to restore economies and transform global politics. This new reality was created by the application of new technologies to unlock U.S. hydrocarbon resources in unconventional reservoirs from the Appalachian Basin in the northeast and across North America. Recent success in exploration for and development of unconventional gas and oil resources has caused a revolution in our energy systems, recently reducing the amount of imported energy into the United States to less than half the total for the first time in decades. It has also created some of the greatest scientific and technical challenges to our understanding of hydrocarbon reservoirs.

In the last ten years, tremendous progress has been made in the exploration and development of unconventional gas and hydrocarbon liquids worldwide, especially in North America. The application of horizontal drilling and multi-stage hydraulic fracture stimulation technologies provide economic gas flow in extremely low porosity and permeability unconventional reservoirs. Since 2005, the organic-rich shale units of Middle Devonian Marcellus Shale of the northern Appalachia basin in the eastern United States of America have been one of the most active shale gas/oil plays in the world.

To date, successful mudrock plays have been primarily a function of increased drilling intensity, cost reductions and application of new technology (e.g., steerable rotary bits). Efficiently unlocking gas and oil resources are present in organic-rich mudrocks, in an economically efficient and environmentally responsible manner demands the combined and effective implementation of engineering, geological, geophysical, geomechanical and geochemical concepts in ways that have not been witnessed before. Mudrock systems give rise to large and complex heterogeneities of the storage/flow and mechanical properties of organic mudrocks, ranging from nano-pore flow confinements to macroscopic sedimentary sequencing. Understanding the source and development of rock/kerogen/fluid/gas interactions in organic mudrocks requires the integration of a multitude of geochemical, geophysical, petrophysical, microscopic, mechanical, and elastic measurements in nontraditional ways. New models are needed to understand the mechanistic, fluid-flow and chemical relationships among a multitude of fluid, rock, borehole, and geophysical measurements.

Understanding of key reservoir engineering and geoscience parameters represents an important area that can contribute to improved well architecture and optimal lateral placement. As exploration and production in mudrock reservoirs move forward, optimization of exploration and recovery with the minimum number of wells become more critical to production success. Optimization of exploration requires more knowledge about the nature of hydrocarbon concentrations in shale; optimization of recovery requires improved extraction technology. Equally importantly, optimized exploration and production increases efficiency, and fewer wells decreases environmental impact and risk. Important mudrock reservoir properties include; the distribution of organic content, the “fracability” of the unit (mineralogy and containment), structural discontinuities (faults), present and past stress regimes, and thermal maturity.

The widespread geographic distribution of resource plays, especially in the populous eastern United States, places productive regions in close proximity to communities. This increases the importance of public perception of hydraulic fracturing (HF), which is often expressed as concern for the potential of human exposure to health hazards, pollution, and increased industrial activity. Most technological innovations for shale development are connected, in one way or another, to economics and environmental protection. The EPA and state regulatory agencies are struggling to keep environmental standards for air and water in sync with evolving industry practices. The New Source Performance Standards (NSPS) for crude oil and natural gas production required "green completions" by January, 2015.[1] But in spite of the implementation of these standards and a recent report indicating lower air quality impacts of HF than previously estimated[2], environmental concerns still need to be addressed. Increased attention to environmental stewardship is required throughout the development and production phases.

Gas and oil production from mudrocks on a significant scale arose during the last two decades but is largely limited to the United States. Sizable production increases can be expected in other parts of North America, and the "shale revolution" is likely to spread, with a lag, across the globe. However, the drilling-intense nature of the unconventional production is a factor that will delay the expansion of the U.S. shale revolution in other parts of the world. Basins containing organic-rich mudrocks are widely distributed across the globe in a multitude of present-day environments (Figure 1). MSEEL would provide a basis for spreading the technology beyond the U.S. by increasing the efficiency of production, decreasing the environmental impact and risk.

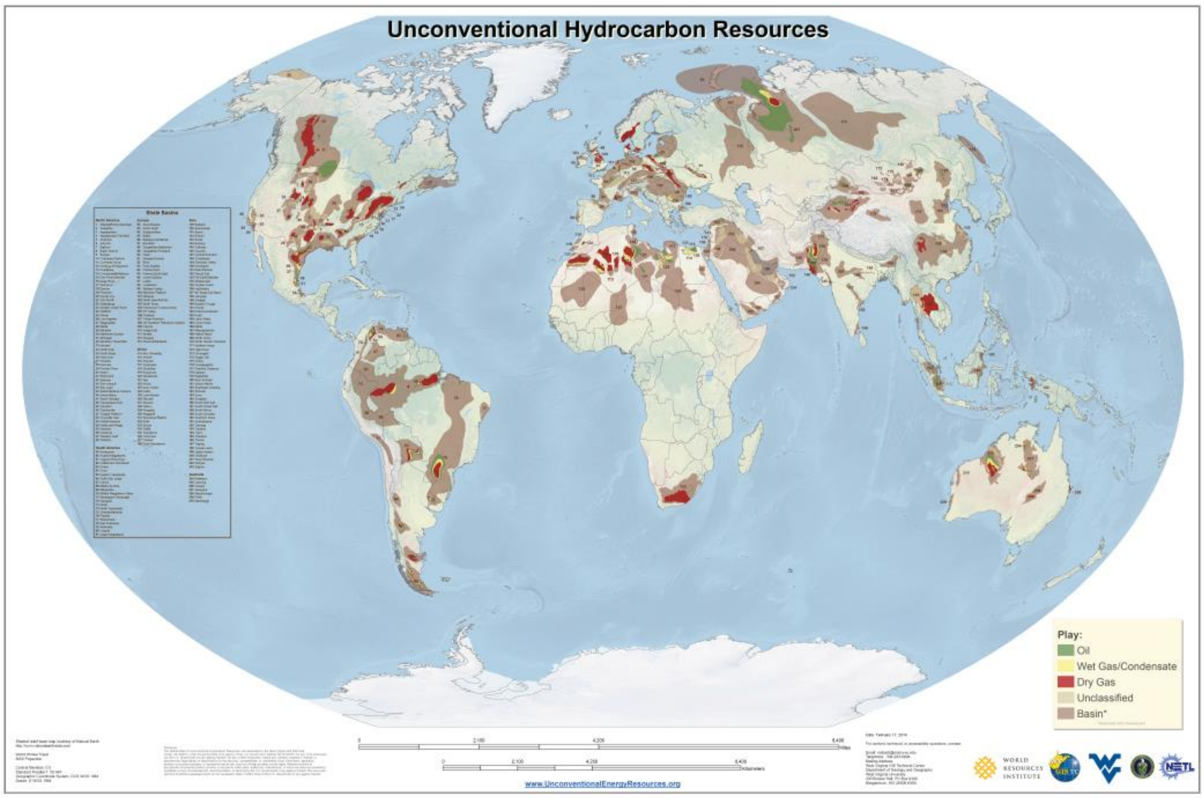

Figure 1. – Global distribution of basins containing unconventional resources is widespread and represents a significant potential to spread the technology beyond the U.S., and supply global energy requirements. Data for the map is from the Atlas of Unconventional Resources (http://www.unconventionalenergyresources.org), and is also available through the NETL Energy Data eXchange (EDX) at http://www.unconventionalenergyresources.com/. All data and results from the proposed MSEEL site will be curated and available through EDX and other online platforms.

1.2 Proposed Advances in Knowledge / Technology

The MSEEL site is located in the heart of the dry-gas area of the Marcellus Shale play in Monongalia

[1] http://www.aaas.org/gr/briefs/energy/fracking.html

[2] http://sustainableshale.org

County, West Virginia (Figure 2). Northeast Natural Energy LLC (NNE) has drilled two previous wells the MIP 4H and MIP 6H were drilled in 2011 (Figures 3 and 4). The two NNE wells are inside the gas "city gate", where the gas is transferred to the local natural gas utility, and are constrained by the natural gas usage of Morgantown. Production from the wells has declined to the point that a third well, the anticipated MIP 5H is required prior to the winter of 2015 (Figure 5). We propose to drill a scientific observation well along the path of the proposed MIP 5H horizontal lateral for sampling and observation (Figure 3). This scientific observation well will be extensively cored, comprehensively logged and instrumented as a microseismic observation well. The scientific observation well will be completed for long-term observation. It is anticipated that in order to meet continued demand an additional 3 wells will eventually be required at the site with an interval spacing of two to three years. It is planned to instrument the MIP 5H with fiber-optic sensing system on the production casing in the horizontal leg to monitor through temperature differentials the fluid entry into the formation during stimulation and subsequent gas production. Coupled with the microseismic, petrophysical and core information from the observation well MSEEL should be able to develop an improved understanding of stimulated reservoir volume (SRV) and comprehensive models of fracture propagation and reservoir behavior. The modelled results will be used to influence the spacing and stimulation of the subsequent wells and be validated with the production results. MSEEL provides a unique situation where new technology can be developed between drilling and completion events, then demonstrated and validated.

The Morgantown Industrial Park, an industrial complex located along the west bank of the Monongahela River across from the city of Morgantown, West Virginia was part of the old Morgantown Ordinance Works (MOW). The MOW has received extensive study and monitoring by the Environmental Protection Agency (EPA) since the 1980s with extensive evaluations of soil, groundwater, sediment, and seeps were conducted in selected areas. The MSEEL site is located out of and uphill of the areas of study, but groundwater wells and soil downhill from the MSEEL site were sampled several times a year from 1992. The entire extensive and long-term environmental database and analysis is available from EPA[3], and will be used to develop a baseline that will be submitted with additional sampling of drilling and completion fluids and solids, air, water and noise during drilling of the proposed MIP 5H. Research at MSEEL will allow us to develop the methodology and baseline parameters to characterize and quantify chemical alterations in the surface environment that might stem from unconventional energy production.

To date, there has been no comprehensive field study that addresses all three topics: baseline measurements, subsurface development, and environmental monitoring with unconventional resource development, and no study that can replicate and validate the results with subsequent drilling and completion events. The only way to integrate the three is to conduct long-term research on a single site. MSEEL in cooperation with other NETL sponsored researchers provides a unique and diverse team of geoscientists, hydrologists, engineers, ecologists, and health professionals to meet the challenge of comprehensively identifying and demonstrating the surface and subsurface technologies required for best practices in environmentally responsible shale development, from drilling to completion through production.

The MSEEL site is located just off the interstate highway and across the Monongalia river from City of Morgantown and provides excellent access to researchers from West Virginia University, other sponsored researchers, the Department of Energy's National Energy Technology Laboratory scientists and engineers, and with nearby airports for visiting scientists and engineers from across the U.S. and the world.

[3] http://www.epa.gov/reg3wcmd/ca/wv/webpages/wvd980552384.html#community provides a gateway to environmental information on the Morgantown Industrial Park.

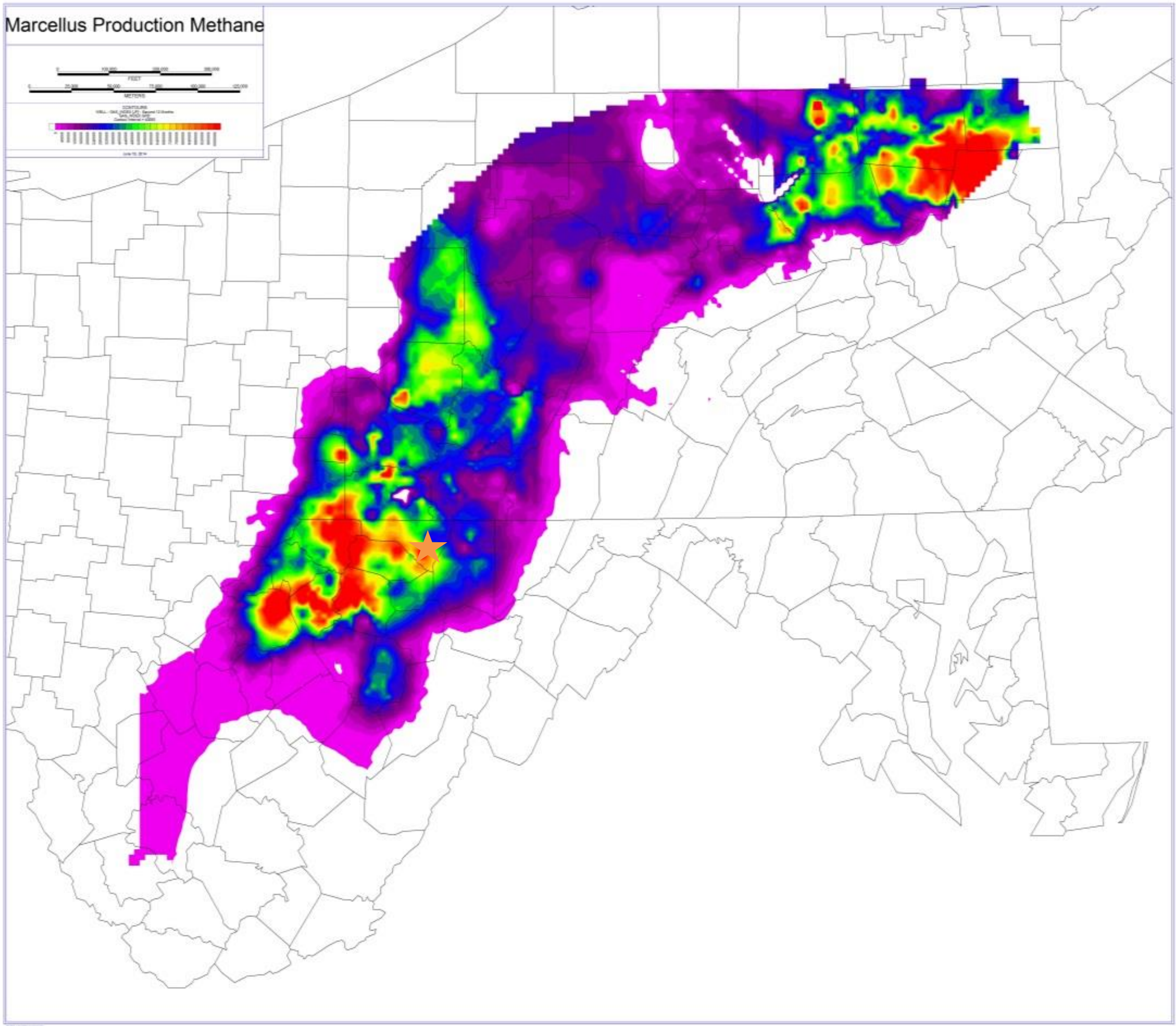

Figure 2. – Map showing areas of higher (red) and lower (purple) gas productivity using normalized gas production in thousands of cubic feet (Mcf) for Marcellus Shale wells during the second and third six-month production periods. Contour interval is 40,000Mcf with the best wells significantly exceeding 1 billion cubic feet (Bcf) during the twelve month period. The proposed MSEEL site in Monongalia County, West Virginia is indicated by a star. Data is from the Atlas of Unconventional Resources (http://www.unconventionalenergyresources.org), and is also available through the NETL Energy Data eXchange (EDX) at http://www.unconventionalenergyresources.com/.

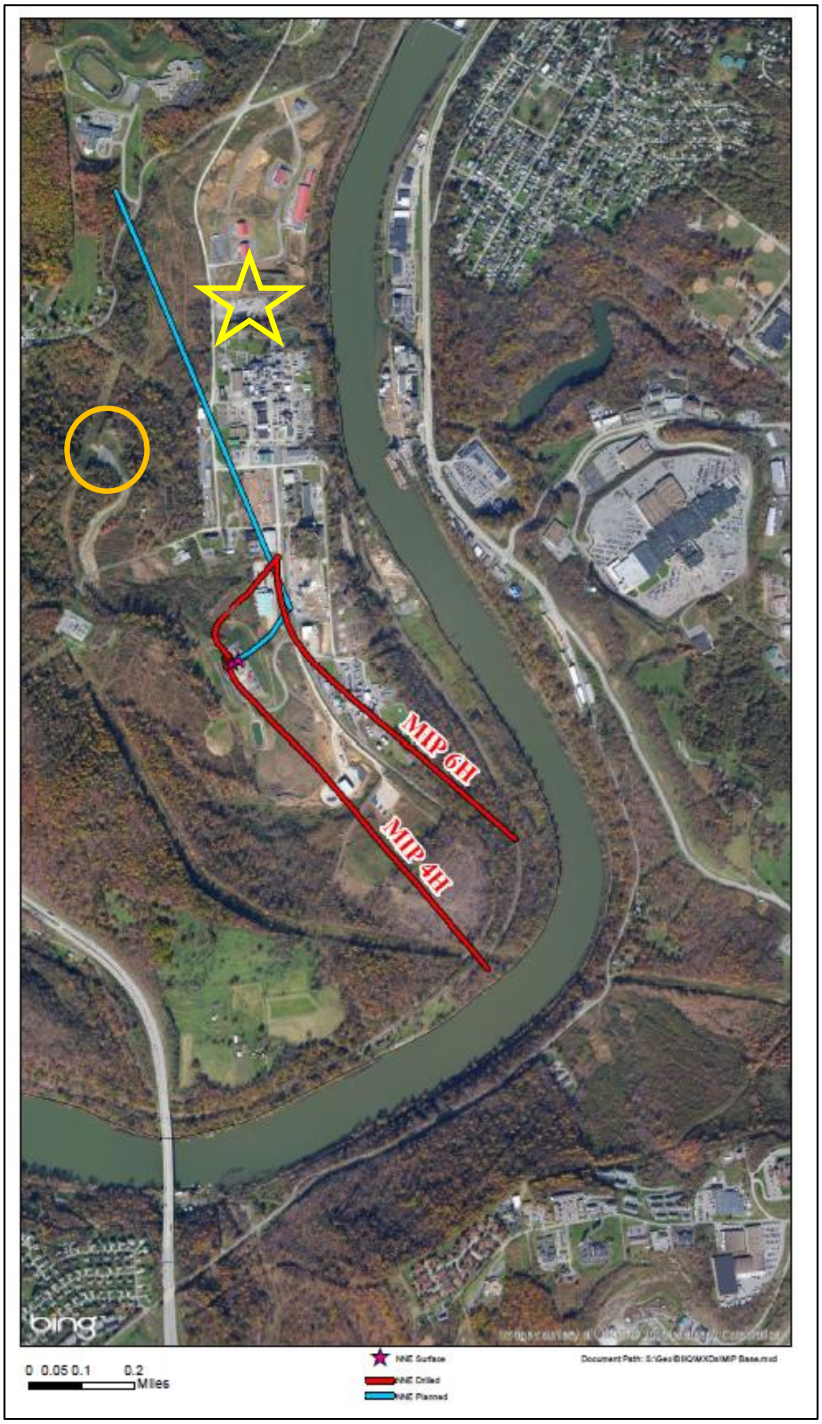

Figure 3. – Image of the MSEEL site in the Morgantown Industrial Park. The Northeast Natural Energy MIP 4H and MIP 6H were drilled in 2011. Data from the initial pilot hole and these two wells will be part of the subsurface baseline for evaluating the NNE MIP 5H (blue line). A scientific observation well will be sited and drilled along the path of the lateral. The exact location of the observation well will be determined in consultation with NNE, NETL, project participants and microseismic consultants. One potential location of the observation well is indicated (yellow star), and it is anticipated that the well could be used for subsequent horizontal wells. City of Morgantown is to the northeast map quadrant and gas "city gate" is highlighted with orange circle.

Figure 4. – MIP 4H drilling in June, 2011 showing the drilling operations on a state-of-the-art pad with berms and lining. The City of Morgantown is in the background.

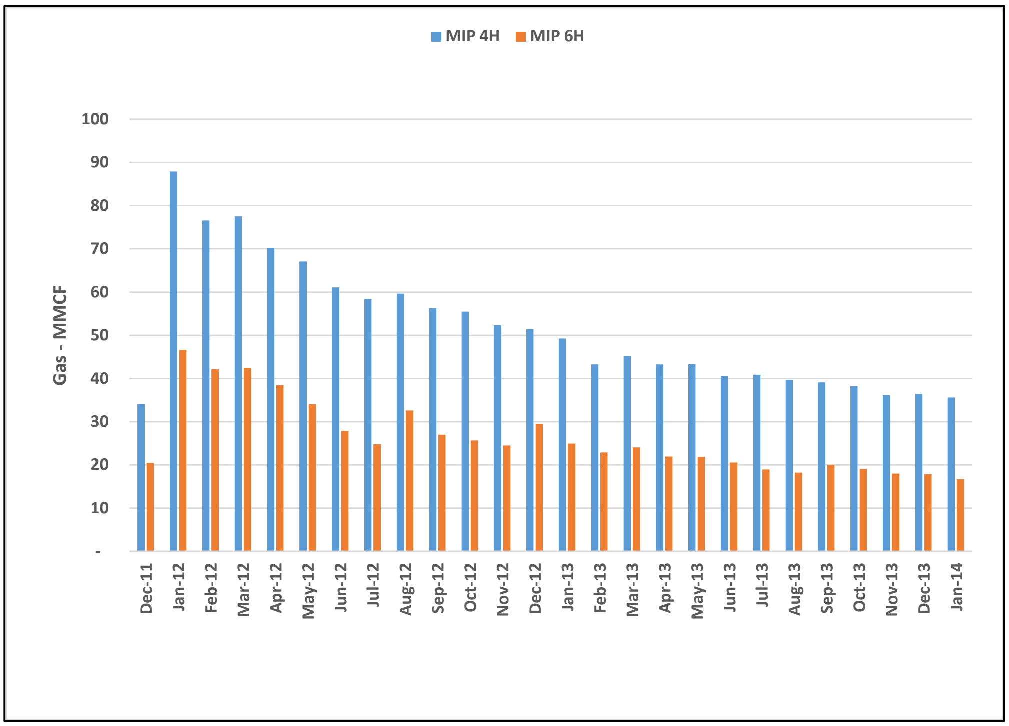

Figure 5. – Monthly gas production from NNE's previous wells showing the decline in production that dictates drilling of an additional well in 2015. Production trends also show the difference in performance of two adjacent wells that may be attributed to differences in drilling, lateral length and completion, and with the scientific observation well will form a baseline to evaluate the proposed MIP 5H.

1.3 Relevance to DOE Goals and Objectives of FOA

The proposed Marcellus Shale Energy and Environment Laboratory (**MSEEL**) directly address **Topic 1 Field Validation using Dedicated Research Well(s) and/or Wells of Opportunity**. It will also be open to independent proposals submitted under Topic Area 2 and research efforts of NETL. MSEEL provides a well-documented and long-term site with dedicated facilities to observe the surface and subsurface. MSEEL provides access both to a number of wells at a single development site, and initial plans that can be easily modified for technical surface and subsurface testing (subject to review and approval by DOE-NETL). MSEEL also will develop online systems for the collection curation and dissemination of samples and data to research personnel that can form the basis for testing, demonstration and validation of advanced technologies.

MSEEL will identify and apply cost-effective technologies that make a material difference to shale energy production by increasing the producible volume of the wells. It will also provide a long-term laboratory to expand and improve on existing technologies and methodologies involved in unconventional energy production over the life cycle of shale energy production. New approaches to drilling and completion can significantly reduce days on a well and costs, thereby increasing production rates and estimated ultimate recovery, while reducing environmental and societal impacts. In the production phase, there are technical challenges to maintaining production rates, and reducing wellbore and surface facility maintenance by reduced scaling, corrosion, and microbial contamination. Finally, there is often a rejuvenation stage to offset production decline, remediate sub-economic wells, and determine approaches to recompletion and work-over strategies.

Shale units exhibit heterogeneity and anisotropy over a wide range of length scales from outcrop to nanometer-scale micropores (Figure 6). Although high-resolution (micro-computed tomography [microCT], nanoCT, and focused ion beam milling/scanning electron microscopy imaging[FIB/SEM]) shale imaging has become more mainstream providing detailed information for conceptual model building, the volume typically imaged (often ~ 10x10x10 μm=1000 cubic microns) is an infinitesimal sample (~ 10-27) of a reservoir. Much more study is required to understand the variety of pore space morphologies and their impacts on fluids flow. Modeling of fluid flow (gas and liquids) through shale requires the usage of grid blocks on the meter-scale or larger. Scaling up of conceptual and numerical models at the pore to meso-scale will be needed, but scaling up requires incorporating observations and measurements at the larger scales as well and validation with production data in controlled environments. MSEEL will bring together researchers focused on shale heterogeneity at multiple scales around a single producing location.

MSEEL offers the opportunity to improve our understanding of the nature and long-term process and impacts of unconventional resource development from the nano-scale to a single well to the local and regional scale, develop improved technologies and engineering practices to ensure these resources are developed safely and with minimal environmental impact, and improve the efficiency of production to increase supply of U.S. oil and gas resources in order to enhance national energy security and further reduce energy imports.

1.4 Non-Duplicative Research

The broad long-term and integrative approach of this project has not been adopted in industry-funded studies to date. It is particularly unlikely that industry or private-sector associations will undertake a comprehensive study of this nature with sufficient time between events to permit analysis. A study that includes baseline environmental measurements prior to drilling coupled with completion and ongoing monitoring measurements during production over several temporally spaced events (five years budgeted).

In order to gain acceptance from the mainstream public, studies such as MSEEL can only be conducted by a third party, such as a university, which is viewed as having a balanced perspective on unconventional development and environmental issues. At the same time, the participation of NNE and other industrial partners in MSEEL leverages limited public-sector funds and is essential for real-world drilling, completion and production activities. Funds will be leveraged from NETL and DOE investments in other programs at WVU and OSU.

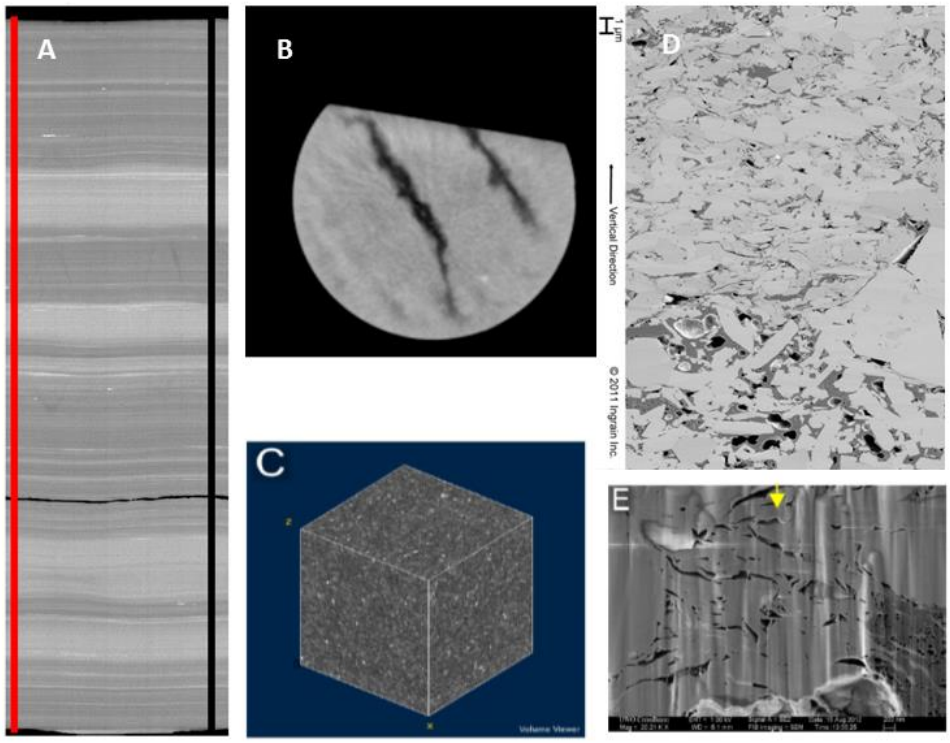

Figure 6. - Anisotropy and heterogeneity at various scales. A. 4 inch slabbed core (Marcellus Shale Clearfield Co., Pennsylvania), B. X-ray CT scan of 4 inch diameter showing density anisotropy and heterogeneity (Marcellus Shale Clearfield Co., Pennsylvania), C. X-ray microCT volume showing shale structure at 5 micron resolution (Montney Formation), D. 24 micron wide SEM image of FIB-milled Marcellus Shale, Taylor County, West Virginia, and E. 2 micron wide FIB-SEM image from the region outlined in yellow in (D) showing heterogeneous micropore development. (E. Burns Cheadle unpublished; C. Timothy Kneafsey unpublished)

2 Impact/Benefit

2.1 Impact/Benefit of Proposed Research

Given the necessarily comprehensive nature of the proposed research, there are multiple areas of direct application of this project to address critical gaps of knowledge of the characterization, basic subsurface science, and completion/stimulation strategies for the Marcellus Shale and other unconventional resources to enable more efficient resource recovery from fewer wells, and to document and minimize the surface environmental and societal impacts.

In the subsurface, MSEEL will develop, demonstrate, and validate through monitoring of periodic horizontal wells integrated technologies to maximize the efficiency of unconventional energy production and minimize environmental impact by increasing the producible volume of the reservoir. Challenges to be addressed by data collected and analyzed at the SEEL sites include:

- Development of integrated data and modeling approaches for reservoir-scale fracture simulations based on geophysical data, image logs, and lithology, and field testing to validate approaches.
- Scrutinizing petrophysical, reservoir and production data to establish the effectiveness of geologic versus geometric based fracture stage design. Evaluating innovative stage spacing and cluster density practices to optimize production performance within given acreage.
- Data driven integration of geophysical, fluid flow and mechanical properties logs, microseismic and core data to better to characterize subsurface rock properties and faults and fracture systems to improve our understanding of the extent of the SRV in order to determine well spacing strategies that optimize overall recovery in unconventional reservoirs while keeping costs low.
- Matching reservoir lithology and fluid types to understand the long-term interaction of fluids and gases with reservoir rock to determine stimulation design and proppant selection in different areas and lithologies to increase production.

The long-term access to the MSEEL site and wells provides testing and demonstration of future new technologies and/or scientific insights that can lead to new approaches enabling dramatic improvements in drainage radius and recovery efficiency.

On the surface MSEEL will implement baseline and long-term monitoring to characterize and quantify alterations in the air and water that might stem from unconventional energy production. This information is critical to understanding the potential for short- and long-term risks in an unbiased and transparent manner. The proposed MSEEL site provides well documented baseline and long-term monitoring of environmental parameters. During all operations, air quality, noise, and light around drilling operations will be measured using wireless air monitoring systems. Sampling and chemical analysis of drilling fluids, muds, and cuttings along with hydraulic fracturing fluids and flowback water will occur during all stages of well development.

To address societal factors MSEEL will evaluate past and ongoing local government (including city, towns, and county) policymaking responses to shale gas development and its related community impact at the MSEEL site. Based on public records and interviews, the project will provide a longitudinal and comparative assessment of what factors shape local governments' policy making response. The study will contribute to understanding the role of communities and local governments in adapting to hydraulic fracturing, including the response of elected officials to community opinions. The project will provide unprecedented access to direct economic activity level data, and potential access to both upstream and downstream linkage relationships. We will work directly with participating contractors to create an accurate accounting of direct impacts on which to base assessments of economic and societal impacts assessments. Indirect and income induced income impacts will be estimated using regional input-output models for Monongalia County where the test site is located, the state of West Virginia, and a multi-state region comprising West Virginia, Ohio, and Pennsylvania.

To place MSEEL into the regional context of development of unconventional resources across the Appalachian basin and the U.S. we propose to use enhanced and existing online geographic information systems (GIS), relational databases and modeling capabilities of EDX and the Unconventional Resource Atlas to model economic and societal impacts of development scenarios including well pad and compressor station density, road cover, pipeline development, etc. using regulatory and sociological constraints.

In addition the MSEEL site and wells will accommodate field development and testing by other NETL sponsored investigators to address the topics listed above and additional topics that have not been discussed. Finally, the project will help to create goodwill among operators, communities, technology providers, mineral owners and landowners.

3 Technical Approach

West Virginia University in cooperation with The Ohio State University and Northeast Natural Energy LLC proposes to undertake a comprehensive assessment of subsurface and surface areas at proposed Marcellus Shale Energy and Environment Laboratory (MSEEL) site near Morgantown West Virginia. *The overarching purpose of the proposed project is to establish a long-term laboratory site where near-term and long-term subsurface and surface research can be conducted, demonstrated and validated leading ultimately to a full-life cycle assessment of multiple drilling, completion and production operations for unconventional hydrocarbon energy development***.** Finally online relational geospatial databases will be used to store and disseminate to broad research team a comprehensive and integrated data set and communicate translational research results and methodologies to industry to improve the cost-effectiveness, reduce real or perceived environmental impact, and increase production from drilling and completion well operations.

3.1 Statement of Project Objectives (SOPO) and Technical Approach

Title: Marcellus Shale Energy and Environment Laboratory (MSEEL)

OBJECTIVES MSEEL will provide a long-term research site with an existing well documented production and environment baseline from two previous wells. A dedicated scientific observation well will be used to collect detailed subsurface data and to monitor and test technologies in additional production wells drilled periodically over the project lifetime. The site offers a unique opportunity to enable an open, collaborative, and integrated program of science and technology development and testing to minimize environmental impacts, while maximizing economic benefits.

SCOPE OF WORK The proposed MSEEL project provides a long-term (6+ years) field site to develop and validate new knowledge and technology to improve resource recovery and minimize environmental implications of unconventional petroleum development. The site provides a well-documented baseline of production and environmental characterization. The MSEEL site will have one to multiple drilling events separated by sufficient time to analyze data providing the ideal testing conditions for researchers. MSEEL will use the latest information technology to enable a broad integrated program of open, collaborative of science and technology development/testing. The proposed initial plans provides for the collection of samples and data, and/or the testing and demonstration of advanced technologies, but the phased approach allows for flexibility to incorporate new technology and science.

TASKS TO BE PERFORMED

PHASE 1 Management Plan: Database Design and Baseline Characterization at Marcellus SEEL Site

Objectives are to characterize the subsurface geological and engineering framework that determine performance of the two existing wells; and carry out baseline air, water, noise, and light investigations on the surface prior to drilling of additional wells at the MSEEL site. Once baseline studies are complete, plans will be developed for the placement of vertical scientific observation well and locations of surface monitoring facilities. Phase I will end with the drilling, sampling, and coring of the vertical scientific observation well and initial characterization of the surface and subsurface environment.

Task 1.1 - Project Management and Planning (Required Task as Written)

The recipient shall work together with the DOE project officer upon award to develop a project management plan (PMP). The PMP shall be submitted within 30 days of the award. The DOE project officer shall have 20 calendar days from receipt of the PMP to review and provide comments to the recipient. Within 15 calendar days after receipt of the DOE's comments, the recipient shall submit a final PMP to the DOE project officer for review and approval.

The recipient shall review, update, and amend the PMP (as requested by the DOE project officer) at key points in the project, notably at each go/no-go decision point and upon schedule variances of more than 3 months and cost variances of more than 10%, which require amendments to the agreement and constitutes a re-base lining of the project.

The PMP shall define the approach to management of the project and include information relative to project risk, timelines, milestones, funding and cost plans, and decision-point success criteria.

The recipient shall execute the project in accordance with the approved PMP covering the entire project period. The recipient shall manage and control project activities in accordance with their established processes and procedures to ensure subtasks and tasks are completed within schedule and budget constraints defined by the PMP. This includes tracking and reporting progress and project risks to DOE and other stakeholders. **Leads:** Carr, Taylor. **Deliverables:** Approved PMP.

Subtask 1.1.1 – Marcellus Shale Energy and Environment Laboratory (SEEL), Ongoing Project Management: In order to maintain project control a part-time project manager will work to insure timely and accurate reporting. **Lead:** Taylor. **Deliverables:** Assembly and transmission of periodic and special topical, budget and final reports in consistent format as required by NETL and the "Federal Assistance Reporting Checklist". Monthly and special meetings of project personnel will be scheduled and held by WEBEX or other online collaborative tools. Briefings will be prepared at all key project decision points and project phase transitions and at the project closeout meeting. A summary of project efforts, findings and conclusions in the context of planned research and project objectives will be generated.

Subtask 1.1.2 – Marcellus Shale Energy and Environment Laboratory (MSEEL), Ongoing Data Generation and Loading: In order to insure timely and accurate loading of all data a part-time data manager with assistance of student personnel will receive all data and analyses. **Lead:** M. Sharma. **Deliverables:** Complete and timely digital and raster data covering activities at the MSEEL site and the analyses generated by research personnel.

Task 1.2 – Construct Online Collaborative and Technology Transfer Platforms

Subtask 1.2.1 – Marcellus Shale Energy and Environment Laboratory (SEEL) Relational Geodatabase and Collaboration Platform: Build, modify and enhance pre-existing online relational geodatabases to collect, store, preserve, distribute and share technical data and results. Use the NETL Energy Data Exchange (EDX) (https://edx.netl.doe.gov/) and internal data-access portals to develop a MSEEL geodatabase as an online system to support internal coordination and collaboration. Test and use database to store data from surface and subsurface baseline studies. MSEEL geodatabase is intended to improve coordination and reliable access to information and research products for research teams and NETL collaborators. **Leads:** Carr, M. Sharma, All domain experts. **Deliverable:** Online relational geodatabase linked to EDX to provide collaborative platform.

Subtask 1.2.2 - Develop Marcellus Shale Energy and Environmental Laboratory (SEEL) Online Technology Transfer and Information Transfer Site: Use pre-existing online geodatabases to provide regional basin-scale and North America context and improve dissemination (tech transfer) of research-driven products. Provide a cross-cutting system to ensure lasting access to research products for future use by external researchers actively engaged in work relevant to shale energy and environmental research and to the interested public. **Leads:** Carr, M. Sharma. **Deliverable:** External web-site with interactive viewer modeled on the National Atlas of Unconventional Resources (http://www.unconventionalenergyresources.com/).

Task 1.3 - Baseline Environmental and Public Policy Characterization

Subtask 1.3.1 Statistical Variability Test for Surface Sampling Plan: Spatial statistical variability of baseline surface and subsurface parameters will be determined. Three to five samples of air, meteorological, surface water, noise, and light will be analyzed from key sub-environments on the sites. Available data from the Environmental Protection Agency will be analyzed. These measurements will be utilized to design the sampling plan to be used in all monitoring, including for the baseline, drilling, completion and production. **Lead:** Ziemkiewicz. **Deliverable:** Results of analysis and sampling plan will be distributed to participants.

Subtask 1.3.2 Air Quality Baseline Measurements: Hydrocarbon levels and particulate matter generated by machinery and vehicular traffic will be measured by solar/battery-operated wireless air monitoring systems (WAMS: 4 module units and one base unit), which will be positioned at the proposed drilling site. Fugitive emission fluxes of methane and background meteorology (temperature and humidity, net radiation, sensible heat flux, evaporation, precipitation, and soil moisture) will be measured by a solar- powered meteorological and flux station installed at each site. Meteorological stations and WAMS will transmit data to the central base station. **Leads:** McCawley, Lin. **Deliverables:** Report and data output from WAMS air monitoring system and methane emissions and measurements from towers will be posted to the MSEEL database.

Subtask 1.3.3 Groundwater Baseline Measurements: Hydrocarbons, inorganics, radiochemicals, and basic physical parameters of groundwater will be analyzed from extensive EPA monitoring. Water-quality parameters include field measures: alkalinity, barometric pressure, dissolved oxygen, pH, specific conductance, total dissolved solids (TDS), total suspended solids (TSS), and hardness. Common stable isotopes will also be measured. **Leads:** Ziemkiewicz, Donovan. **Deliverables:** All data and accessible samples from literature will be analyzed and significant results posted to the MSEEL database.

Subtask 1.3.4 Noise and Light Baseline Monitoring: Photometric and electroacoustic measurements will be taken of light and noise levels associated with production processes. **Leads:** Ziemkiewicz, McCawley. **Deliverables:** Noise and light levels and changes will be posted to the MSEEL database.

Task 1.4 - Baseline Geologic and Petroleum Engineering Characterization

Subtask 1.4.1 – Collect existing subsurface geologic and engineering data: NNE has previously drilled a vertical pilot well and two horizontal wells at the SEEL site (MIP 4H and MIP 6H). The horizontal wells have been on production since second half of 2011 (Figures 3-5). Geologic, geophysical and engineering data will be assembled and analyzed, and significant results posted to the MSEEL database. **Leads:** Carr, Ameri. **Deliverables:** Drilling, logging of original pilot well, completion and production data for the NNE's MIP 4H and MIP 6H will be collected and posted in digital form to the MSEEL database for analysis. Analysis of performance of previous horizontal production wells.

Subtask 1.4.2 – Locate vertical well and design sampling plan: Design a sampling plan for the scientific observation well to capture and preserve all significant digital data and physical samples. Locate a vertical scientific observation well to best serve to characterize the target horizon along the path of the horizontal lateral and to provide the best offset for microseismic observation. **Leads:** Northeast Natural Energy LLC (NNE), Wilson and Siriwardane. **Deliverables:** With input from industrial partners and service companies locate the best position for the vertical scientific and observation well. Design a detailed logging and sampling plan that maximizes data collected from the well, while preserving samples for future analyses.

Subtask 1.4.3 – Drill and core a vertical scientific observation well: Drill and conventional core the vertical scientific observation well. Conventional core will be recovered through the Marcellus and associated units. Well will be extensively logged and sidewall cores will be taken to supplement conventional core. **Leads**: Northeast Natural Energy LLC (NNE), Carr, Bilgesu. **Deliverable:** Drilling report, collection and curation of samples, and preliminary sample analyses. Drilling, logging and core data will be collected and posted in digital form to the MSEEL database for analysis. Samples of core will be preserved for future analyses.

Subtask 1.4.4 – Geophysical Logging: Run an extensive suite of geophysical well logs in the vertical observation well that include a full suite of traditional tools, and geomechanical (full-wave form sonic) and lithologic/organic (e.g., pulsed neutron spectroscopy). All log data stored and available through the dedicated MSEEL Web database. **Lead:** Carr, Ameri. **Deliverables:** Digital geophysical well logs and initial interpretations.

Subtask 1.4.5 – Sampling of Vertical Observation Well: Core of key intervals, cuttings samples at regular intervals during drilling, and sidewall cores of selected geologic units will all be obtained. Portions of the core will be preserved for microbial and redox studies as well as more conventional geochemical and physical property analysis. Sidewall cores will be taken from key geologic formations above the shale target formations and all core samples will be scanned using X-ray computed tomography (XCT), and gamma ray scanner. Samples, mud logs, geologic logs, and mud samples will be collected and photographed. **Leads:** Aminian, Cole (OSU). **Deliverables:** Photographs, XCT scanned images of the core, and core gamma ray log, mud logs, chip sample analysis to be posted on the SEEL Web Database. Mud logs and field description of the cuttings will also be made available. Cores and chip samples will be stored at the West Virginia Geological Survey Core Repository where they can be accessed by the public.

Subtask 1.4.6 – Rock Mineralogy and Physical Properties on Core Samples: Petrographic, FIB-SEM, BET, porosity, and X-ray computed tomography measurements will be made on core samples that have not been initially preserved for microbial and redox studies. In addition to He (or Kr) gas adsorption as well as Hg intrusion porosimetry, use high-precision steady state, pulse decay transient and image based modeling techniques for shale characterization under well-defined reservoir conditions. Mercury porosimetry will be used in concert with BET analysis to probe pore structures and pore volume. Dry rock bulk density (ρ_b) and grain density (ρ_g) will be determined. Novel neutron scattering methods in concert with electron microscopy will be used to quantify the nanometer-to-macro porosity and connectivity in shale and interface formations as a function of depth. **Leads:** Weislogel, Ameri, Cole (OSU). **Deliverables:** Laboratory measurements of total and kerogen pore volumes, porosity, permeability, sorption parameters and pore size distribution of shale samples. Thin sections, SEM scans, physical properties, and photomicrographs of core samples as described above will be available through the MSEEL database.

Subtask 1.4.7 – Rock Geochemistry on Core: Total organic carbon (TOC) and the C:N ratio will be determined using a Costech elemental combustion system. This instrument is interfaced to a Picarro cavity ring down spectrometer Carbon Isotope Analyzer, which we use to determine $\delta^{13}C$ on the CO_2 evolved from combustion. Quantitative mineralogy will be determined by X-ray diffraction along with detailed textural and elemental mapping using scanning electron microscope. Major, minor, and trace element geochemistry will be conducted on cores with a combination of laser ablation (Photon Machines Excite II Excimer Laser) fitted with a cryogenic laser ablation platform (GeoMed Analytical Volante 4000) and solution-based ICP-MS (Thermo Fisher Element II High Resolution ICP-MS) analysis. Noble gas geochemistry (He, Ne, Ar, Kr, Xe and isotopic composition (e.g., 3He/4He, 20Ne/22Ne, 21Ne/22Ne, 20Ne/36Ar, 40Ar/36Ar, 38Ar/36Ar, 84Kr/36Ar, 132Xe/36AR) will be analyzed for cores using a Thermo Fisher Helix SFT Noble Gas Mass Spectrometer. **Leads:** Ameri, Cole (OSU), Darrah (OSU). **Deliverables:** Results of rock chemical analysis will be available on the MSEEL database.

Subtask 1.4.8 – Microbial Sampling: Twenty-five sidewall cores in the Devonian Marcellus will be sampled and preserved for microbial studies, including biomass estimates, biosignatures, and community genomic (metagenomic) analyses. Bulk microbial density in pore fluids and the rock matrix will be assessed using phospholipid fatty acid analysis (PLFA), and cell abundances in cores and extracted core materials (fluids, rock matrix) enumerated using microscopy. Nucleic acids from microbial communities will be extracted from rock cores and fluids, and genomes sequenced for analyses of microbial diversity and function. **Leads:** S. Sharma, Mouser (OSU). **Deliverables:** Database of PLFA, community genomic sequences, and images available to all researchers.

Subtask 1.4.9 – Develop recommendations for the optimal landing interval in the Marcellus: Based on analysis of organic content and mechanical properties derived from logs and core in the vertical well make recommendations for optimal landing interval for the horizontal production well. **Leads:** Northeast Natural Energy LLC (NNE), Carr. **Deliverables:** Recommendations developed with NNE for optimal landing interval in the Marcellus Shale.

Task 1.4 - Baseline Economic, Public Opinion and Policy Assessment

Subtask 1.4.1 – Community and Public Perception Baseline Assessment: With two previous wells drilled on the proposed MSEEL site in 2011 there is a history of public policy and sociological impacts of the perceived risks of unconventional hydrocarbon development. Based on public records and interviews a baseline line study will document the history over the last three years. **Leads:** Barnes. **Deliverables:** Documentation of history of public perception and consequences of past unconventional hydrocarbon development at the NNE well site.

Subtask 1.4.2 Regional Economic Impact Baseline Assessment: The economic impact of the rapid increase in gas production **Leads:** Jackson, Carr. **Deliverables:** Documentation of the local economic impact of previous horizontal wells and the regional impact of Marcellus unconventional hydrocarbon production at multiple scales from county through state to region.

PHASE 2 Drill and Monitor MIP 5H Horizontal Production Well at Marcellus SEEL Site

A horizontal well, the Northeast Natural Energy MIP 5H is scheduled to be drilled and completed in the summer of 2015 (Figure 3). It is anticipated that additional wells will follow at approximately two to three year intervals and the observation well is designed to monitor all wells. Objectives are : to characterize the fracture systems through geophysical logging while drilling and microseismic measurements; characterize the subsurface geological and engineering framework and monitor the well completion and performance; characterize the natural, drilling, and fracture stimulation fluids in the holes; sample and monitor air, water, noise, and light during horizontal drilling; and institute long-term monitoring after completion and during production. All data generated by this project will be posted on the SEEL website, and openly shared with the research community. Analysis of all surface and subsurface data will used to develop recommendations for improve best practices that can be tested in the subsequent horizontal wells.

Task 2.1 – Drill, sample, monitor and log while drilling the NNE MIP 5H: Northeast Natural Energy MIP 5H will be drilled, sampled and logged according to plans developed by NNE in cooperation with project personnel. Drilling and completion will follow best practices. **Lead:** Northeast Natural Energy LLC, Carr. **Deliverables:** Drilling information and logs.

Subtask 2.1.1 – Environmental Monitoring While Drilling: Surface sampling will be repeated at regular intervals, as determined by statistical design. Water wells, light, noise, meteorological parameters, and air sampling will continuously record data. **Leads:** Ziemkiewicz, McCawley, Lin. **Deliverables:** All measurements will be posted to the MSEEL database in near real-time for curation and future analysis.

Subtask 2.1.2 – Drilling Fluid and Cuttings Sampling: Sample and analyze drill cuttings and drill fluid returns to establish background chemistry, including NORM. Fluids recovered from the subsurface after drilling will be characterized for major cations and anions, minor and trace metals, pH, alkalinity, total dissolved organics, and H_2S. Isotopes of O, H, and Sr will be measured. TDS, TSS, pH and alkalinity measurements will be carried out using standard methods (2540 C, 2540 D, 2320 B). Major, minor, and trace element geochemistry and noble gasses will be conducted on cuttings using the same approach outlined in subtask 1.4.7. All drill cuttings and drill fluid samples will be collected, analyzed, and stored for future analysis. **Leads:** S. Sharma, Ziemkiewicz, Cole (OSU). **Deliverables:** Samples will be preserved and made available for continued analysis. Results will be posted in the MSEEL database.

Subtask 2.1.3 – Geophysical Logging: A conventional logging while drilling (LWD) suite including gamma ray, resistivity and density/neutron/photo-electric will be undertaken in the horizontal borehole. **Leads:** Carr. **Deliverables:** All log measurements will be posted in log ASCII standard format (LAS) in the MSEEL database for project participants.

Subtask 2.1.4 – Fiber Optic Temperature and Acoustic Monitoring: A permanent fiber-optic sensing system will be run on the outside of the horizontal production casing. Monitor the points of fluid entry into the Marcellus during fracture stimulation. Also monitor during flowback and production through time to evaluate the amounts coming from each zone. **Leads:** Northeast Natural Energy LLC., Aminian, Siriwardane. **Deliverables:** Data and report of fiber optic measurements. Report on integration of microseismic with well log for fracture determination posted in the MSEEL database.

Subtask 2.1.5 –Drilling and Well Construction Data Collection: Collect data on performance of drilling process and determine the relationship between operating parameters such as weight on bit and rotary speed with the formation characteristics such as hardness, density and porosity within the shale formations and overlaying sediments. Collect data on cement properties to determine strength under operating conditions. **Leads:** Ilkin Bilgesu. **Deliverables:** Data and report on well drilling and cementation of casing to be posted to the MSEEL database.

Task 2.2 – Sample and monitor the surface and subsurface during the completion of the Northeast Natural Energy MIP 5H:

Subtask 2.2.1 – Environmental Monitoring: During hydraulic fracture stimulation and flowback, surface sampling will be repeated at regular intervals, as determined by statistical design. Water, light, noise, meteorological parameters, and air sampling will continuously record data. **Leads:** Ziemkiewicz, McCawley, Lin. **Deliverables:** All measurements will be posted to the MSEEL database in near real-time for curation and future analysis.

Subtask 2.2.2 – Fluid and Gas Sampling: Fracture stimulation fluid, flowback, and production fluid and gas samples will be collected, analyzed, and stored. Quantitative analysis results for radioelements, cation, anion, trace elements, TDS, TSS, and other chemical parameters as outlined for the vertical well. **Leads:** S Sharma, Ziemkiewicz. **Deliverables:** Samples will be preserved and made available for continued analysis. Results will be posted to the MSEEL database.

Subtask 2.2.3 – Fiber Optic Temperature and Acoustic Monitoring: The permanent fiber-optic sensing system will monitor the points of fluid entry into the Marcellus during fracture stimulation. Also monitor during flowback and production through time to evaluate the amounts coming from each zone and cluster. Under normal gas production, they will provide information is provided on open perforations and clusters contributing to the total gas volume. Sensors also will serve as monitoring tools to identify zones where cross flows or leaks are located. **Leads:** Aminian Ameri, Wilson. **Deliverables:** Data and report of fiber optic measurements posted to MSEEL database.

Subtask 2.2.4 – Microseismic Monitoring: During the hydraulic fracture stimulation and flowback period of completion of the MIP 5H a microseismic survey will be carried out utilizing the vertical observation well. **Leads:** Wilson, Siriwardane. **Deliverables:** Data and report of microseismic measurements posted to MSEEL database.

Task 2.3 – Undertake long-term monitoring during production at the Marcellus SEEL site:

Subtask 2.3.1 – Environmental Monitoring: Surface sampling will be repeated at regular intervals, as determined by statistical design. Water, light, noise, meteorological parameters, and air sampling will continuously record data. **Leads:** Ziemkiewicz, McCawley, Lin. **Deliverables:** All measurements will be posted to the MSEEL database in near real-time for curation and ongoing analysis.

Subtask 2.3.2 – Production Monitoring: The permanent fiber-optic sensing system will monitor the points of fluid entry into the Marcellus during production. Production of gas and fluid will be collected for advanced geochemical analysis. **Leads:** Aminian, Northeast Natural Energy LLC. **Deliverables:** All production measurements will be posted on the MSEEL database for ongoing analysis.

Task 2.4 – Analysis and modeling of subsurface and surface data and samples from the Marcellus SEEL site:

Subtask 2.4.1 – Analysis and Modeling of Well Drilling and Completion: Analysis and modeling data on performance of drilling process will help to understand the parameters controlling the efficiency of the operation in local shale formations. There are many formation properties and operating factors and their relationship is very complex resulting in variations in the performance of drilling operations. Further, Cement in the wellbore is the main barrier to eliminate communication between formations and it is intended to keep its strength during the productive life of the well. Cement performance can be modified in future wells by changing the composition with proper additives. **Leads:** Bilgesu. **Deliverables:** Interpretive report on well drilling and cementation of casing through the MSEEL database.

Subtask 2.4.2 – Fracture Modeling: An integrated fracture model will be evaluated using the microseismic survey with well log, core and fiber optic measurements. Fracture interpretations will be displayed in the context of subsurface geology and well performance. A key goal of these efforts will be to determine the relationship of microseismic activity to preexisting faults and fracture systems and completion practices. Existing fracture propagation models will be calibrated using the microseismic survey and fiber optic measurements. Calibrated models will be evaluated during subsequent hydraulic fracturing at the site. Existing fracture propagation and fluid flow models will be used to determine stimulated reservoir volumes and to predict improvements to reservoir response and performance. **Leads:** Wilson, Siriwardane. **Deliverables:** Data and report of microseismic measurements. Report on integration of microseismic with well log and fiber optic measurements for fracture determination.

Subtask 2.4.3 – Reservoir Simulation: Model and identify the best practices for field implementation, and to demonstrate enhanced shale gas recovery using experimental and numerical studies integrated with the results of the production wells at the MSEEL site. **Leads:** Ameri, Aminian. **Deliverables:** New strategies and technologies for reservoir characterization and simulation to enhance shale gas recovery.

Subtask 2.4.4 – Geostatistical Well Analysis: Use the extensive subsurface log and core data developed at the proposed MSEEL site with existing regional subsurface and surface datasets to build stochastic models using geostatistical approaches coupled with spatial analysis or regionalized variables to predict mudrock lithofacies and geomechanical properties that effect reservoir performance at well and basin-scales. **Leads:** Carr. **Deliverable:** Tools to produce meaningful, predictable and mappable series of geologic, engineering and environmental models at the core-scale, well-scale and basin-scale using the more limited publically available information.

Subtask 2.4.5 – Develop techniques for low-cost treatment of flowback and produced water: test low-cost passive treatment process comprised of membrane materials, and capacitive deionization. Components previously tested in laboratories show promising results for removing a wide range of dissolved solids including radioactive elements and salts. In particular, chloride and sodium removal efficiencies were found to be as high as 65% and 48%, respectively along with effective removal of radioactive elements (e.g., strontium). **Leads:** Lin. **Deliverable:** Optimize process configuration and operating conditions using flowback and produced fluid from the MSEEL site.

Task 2.5 - Economic, Public Opinion and Policy Assessment

Subtask 2.5.1 – Community and Public Perception Assessment: Evaluate local government policymaking responses to continued unconventional hydrocarbon resource development and its related community impact. Provide a longitudinal and comparative assessment of factors shaping local governments' policy making response. **Leads:** Barnes. **Deliverables:** Assessment of factors shaping local government responses to unconventional hydrocarbon development.

Subtask 2.5.2 Regional Economic Impact Assessment: Evaluate the regional economic impact of the continued unconventional resource development and rapid increase in gas production on the region **Leads:** Jackson, Carr. **Deliverables:** A report on the economic impact of the wells at the MSEEL site within the regional framework of the Appalachian basin.

Task 2.6 – Document results and develop recommendations to improve environmental and economic performance of subsequent horizontal production wells.

PHASE 3 Drill and Monitor Subsequent Additional Horizontal Production Wells at Marcellus Shale Energy and Environment Laboratory Site

Objectives are to monitor the surface and subsurface during additional horizontal wells anticipated at the MSEEL site as they are drilled and hydraulically fractured and produced. These wells will incorporate the latest technology and offer an opportunity to demonstrate and verify improvements in economic and environmental performance. It is difficult to outline the exact approach, but the Northeast Natural Energy plans to drill up to three (3) additional wells at an approximate two to three year intervals at the MSEEL site. The result, the proposed MSEEL project, provides a basis for long-term shale energy and environment laboratory that can be used to develop, test and validate new science and technology. It is anticipated that any continued effort could develop new technology to characterize the fracture systems through geophysical logging/sampling of new horizontal wells and monitoring using a combination of the scientific vertical well and the new horizontal well using advanced technique; verification of modeling to characterize the subsurface geological and engineering framework to predict well performance; improve our understanding of natural, drilling, and fracture stimulation fluids; improve approaches to sample and monitor air, water, noise, and light during horizontal drilling; and institute long-term monitoring after completion and during production. All data generated by this project will be available through the MSEEL database, and openly shared with the research community involved with the site. Analysis of all surface and subsurface data will be used to develop recommendations for improving best practices that can be tested in each of the subsequent horizontal wells.

3.2 Justification of Project Tasks and Subtasks

The MSEEL proposal will leverage and enhance existing online relational geodatabases for unconventional hydrocarbon resources that were developed for the US Department of Energy National Energy Technology Laboratory to bring together the proposal team and to long-term storage and provide seamless access to NETL and NETL sponsored research personnel (**Task1.2**). The team will document and analysis baseline environmental, geologic engineering and societal data using a combination of a retrospective approach by leveraging the long-term environmental monitoring of the Morgantown Industrial Park (1980's to present) prior to the drilling of the two existing Marcellus Shale horizontal wells (2011 to present) with new site specific baseline environmental monitoring (Task 1.43). The proposed vertical scientific well will provide detailed subsurface rock samples (whole core and sidewall core), and the capability to monitor (microseismic) the MIP 5H potential additional horizontal wells (e.g., MIP 1H and MIP 3H) (**Task 1.4**). The horizontal MIP 5H will be drilled in fall of 2015 and coupled with monitoring in the horizontal well bore (LWD and Fiber-optics), through the adjacent vertical scientific well (microseismic) and on the surface (air, noise, fluids and gases) will provide an unprecedented subsurface and surface understanding of unconventional resource development from drilling to completion and finally production (**Tasks 2.1, 2.2, and 2.3**). The project will have approximately two years to analyze and model the data from the MIP 5H and develop recommendations for improved best practices to improve production while minimizing environmental impact prior to the drilling of subsequent horizontal wells (**Task 2.4**). MSEEL provides multiple and flexible opportunities to develop and validate improved and cos-effective technology for energy production from unconventional resources.

3.3 Verification/Validation Efforts

As a result of the location behind the natural gas "city gate", MSEEL is a unique field site and dedicated laboratory with the potential of one to four distinct drilling and completion events each separated by two years or more years of production. There is an existing database to develop an environmental and unconventional resource production baseline, which will be augmented with additional environmental and subsurface measurements. The scientific observation well can be used over multiple years. The surface and subsurface data will be used to build models and recommendations that can be verified and validated and if necessary modified and re-verified during each drilling and completion event.

3.4 Quality and Suitability of Facilities, Equipment, and Materials

The Department of Geology and Geography maintains a state-of-the-art GIS and remote sensing laboratory, equipped with numerous workstation computers, which will be available for this project. The Department has a full suite of industrial and research quality software and high-end computing hardware from Schlumberger (PETREL and Eclipse), IHS (PETRA and SMT), Landmark, Jason-Fugro, ESRI, CMG and other software companies for subsurface geologic and geophysical interpretation. In addition, the Department of Geology and Geography shares facilities with the West Virginia GIS Technical Center which has a full time staff of ten and can provide technical assistance and expertise. The Department has a state-of-the-art full immersion virtual reality CAVE. The WVU Stable Isotope Laboratory of Dr. S. Sharma is setup for C/N and compound specific hydrocarbon and biomarker research using an Element Analyzer connected to the two High Flow outlets of the Conflo IV and a GasBench Device connected to the Delta V Advantage Mass-spectrometer. The Conflo IV device allows immediate switching between the different peripherals. The compound specific isotope analysis of hydrocarbons and biomarkers will be carried out the GC-Isolink attached to the Low Flow outlet of the Conflo IV device to Delta V Advantage mass spectrometer.

Laboratory facilities within the WVU Department of Petroleum and Natural Gas Engineering include advanced pulse decay permeation measurement equipment, specially designed for pulse decay measurement techniques using corrosive gases such as carbon dioxide and methane. This equipment allows real-time non-destructive testing of samples. Additional facilities include the Precision Petrophysical Analysis Laboratory (PPAL). Shale core samples are being analyzed under steady-state conditions with representative reservoir net stress applied using a tri-axial core holder to apply confining stress on all three axes. The design of the laboratory allows for even warming and constant temperature, and water pressures up to a maximum of 10,000psi. The data acquisition system and mechanical control system are paired with a computer with the necessary software (LabView) to operate the system and collect the data.

At Ohio State University laboratories include shared wet-lab and instrument space containing fume hoods, constant temperature rooms, and experimental apparatuses for conducting chemical, geochemical, and biotechnology research. Equipment is available for the handling of anaerobic samples. Community genomic assembly and binning is performed on a dedicated Dell R910 Power-edge server. Core analysis facilities include: probe permeameter, pulsed decay permeameter, mercury porosimeter, Archimedes work station (bulk & grain density), BET surface area analyzer, PANalytical XRD, FEI FEG SEM with QEMSCAN software, Picarro cavity ring down spectrometer, Costech elemental analyzer (COHNS), X-ray computed tomography (XCT), Stirred batch hydrothermal reactors, Gamma spectral core scanner, High P-T biaxial resistivity and triaxial acoustic velocity core holders, and Dean Stark and soxhlet fluid extraction systems. Laser ablation fitted with a cryogenic laser ablation platform and solution-based ICP-MS analyses is available for major, minor, and trace element geochemistry. Noble gas geochemistry will be analyzed for cores using a Thermo Fisher Helix SFT Noble Gas Mass Spectrometer.

3.5 Project Schedule/Timeline and Milestones

Marcellus Shale Energy and Environment Laboratory (MSEEL)

Year and Quarter: FY 2015 Q1, FY 2015 Q2, FY 2015 Q3, FY 2015 Q4, FY 2016 Q1, FY 2016 Q2, FY 2016 Q3, FY 2016 Q4, FY 2017 Q1, FY 2017 Q2, FY 2017 Q3, FY 2017 Q4, FY 2018 Q1, FY 2018 Q2, FY 2018 Q3, FY 2018 Q4, FY 2019 Q1, FY 2019 Q2, FY 2019 Q3, FY 2019 Q4, FY 2020 Q1, FY 2020 Q2, FY 2020 Q3, FY 2020 Q4

Task Number	Task Name	Start Date	Completion Date
1	**Phase 1- Baseline plus Project Management**	1-Oct-14	30-Sep-20
1.1	Develop PMP Plan	1-Oct-14	30-Nov-14
1.1.1	*Project Management*	1-Oct-14	30-Sep-20
1.1.2	*Data Generation & Loading*	1-Oct-14	30-Sep-20
1.2	Construct Online Collaborative & Tech Transfer Platforms	1-Oct-14	30-Nov-14
1.2.1	*Relational Geodatabase and Collaboration Platform*	1-Oct-14	31-Mar-15
1.2.2	*Online Technology Transfer Platform*	1-Oct-14	30-Nov-15
1.3	Baseline Environmental Characterization	1-Oct-14	30-Sep-15
1.3.1	*Statistical Variability Test for Surface Sampling Plan*	1-Oct-14	31-Dec-14
1.3.2	*Air Quality Baseline*	1-Jan-15	30-Sep-15
1.3.3	*Water Quality Baseline*	1-Oct-14	30-Sep-15
1.3.4	*Noise and Light Baseline*	1-Apr-15	30-Sep-15
1.4	Baseline Geologic & Engineering Characterization	1-Oct-14	30-Sep-15
1.4.1	*Collect existing subsurface geologic and engineering data*	1-Oct-14	31-Mar-15
1.4.2	*Locate vertical well and design sampling plan*	1-Apr-15	30-Jun-15
1.4.3	*Drill and core a vertical scientific observation well*	1-Jul-15	30-Sep-15
1.4.4	*Geophysical Logging*	1-Jul-15	30-Sep-15
1.4.5	*Sampling of Vertical Observation Well*	1-Jul-15	30-Sep-15
1.4.6	*Rock Mineralogy and Physical Properties on Core S amples*	1-Jul-15	30-Sep-15
1.4.7	*Rock Geochemistry on Core*	1-Jul-15	30-Sep-15
1.4.8	*Microbial Sampling*	1-Jul-15	30-Sep-15
1.4.9	*Characterization of Drilling Fluids*	1-Jul-15	30-Sep-15
1.5	Baseline Economic, Public Opinion, and Policy Assessment	1-Oct-14	30-Sep-15
1.5.1	*Assess past Community and Public Perceptions & Policy*	1-Oct-14	30-Jun-15
1.5.2	*Regional Economic Impact Baseline Assessment*	1-Oct-14	30-Jun-15
2	**Phase 2 - MIP 5H Horizontal Well and Analysis**	1-Oct-15	30-Sep-20
2.1	Drill, sample, monitor and log while drilling the NNE MIP 5H	1-Oct-15	30-Nov-15
2.1.1	*Environmental Monitoring While Drilling*	1-Oct-15	30-Nov-15
2.1.2	*Drilling Fluid and Cuttings Sampling*	1-Oct-15	30-Nov-15
2.1.3	*Geophysical Logging*	1-Oct-15	30-Nov-15
2.1.4	*Fiber Optic Temperature and Acoustic Monitoring*	1-Oct-15	30-Nov-15
2.1.5	*Drilling and Well Construction Data Collection*	1-Oct-15	30-Nov-15
2.2	Sample and monitor during completion of the NNE MIP 5H	1-Nov-15	31-Dec-15
2.2.1	*Environmental Monitoring*	1-Nov-15	31-Dec-15
2.2.2	*Fluid and Gas Sampling*	1-Nov-15	31-Dec-15
2.2.3	*Fiber Optic Temperature and Acoustic Monitoring*	1-Nov-15	31-Dec-15
2.2.4	*Microseismic Monitoring*	1-Nov-15	31-Dec-15
2.3	Sample and monitor during production of the NNE MIP 5H	1-Jan-16	30-Sep-20
2.3.1	*Environmental Monitoring*	1-Jan-16	31-Dec-18
2.3.2	*Production Monitoring*	1-Jan-16	30-Sep-20
2.4	Analysis and modeling of data and samples from MSEEL site	1-Sep-15	30-Sep-20
2.4.1	*Analysis and Modeling of Drilling and Completion*	1-Sep-15	31-Dec-17
2.4.2	*Fracture Modeling*	15-Nov-15	31-Mar-20
2.4.3	*Reservoir Simulation*	15-Dec-15	30-Sep-20
2.4.4	*Geostatistical Well Analysis*	1-Sep-15	30-Sep-20
2.4.5	*Low-cost treatment of flowback and produced water*	15-Oct-15	31-Mar-19
2.5	Baseline Economic, Public Opinion, and Policy Assessment	1-Sep-15	31-Dec-19
2.5.1	*Assess Community and Public Perceptions & Policy*	1-Sep-15	31-Dec-19
2.5.2	*Regional Economic Impact Assessment*	1-Sep-15	31-Dec-19
3	**Phase 3 Potential Additional Horizontal Wells**	1-Oct-18	30-Sep-20
3.1	Evaluate any new NNE well	1-Oct-18	31-Mar-18
3.2	Monitor during completion new NNE well	1-Dec-17	30-Jun-18
3.3	Monitor during production from new NNE well	16-Dec-17	30-Sep-20
3.4	Analysis and modeling of data from MSEEL site	1-Oct-17	30-Sep-20
3.5	Document improved environmental and economic performance	1-Nov-17	30-Sep-20

	Key Deliverables and Milestones	Completion Date
Deliverable 1	Kickoff Meeting	30-Nov-14
Deliverable 2	Project Management Plan	30-Nov-14
Deliverable 3	Project Briefings	Periodic
Deliverable 4	Onine Collaborative Platform	1-Jul-15
Deliverable 5	Public Web Site	1-Sep-15
Deliverable 6	Publication of Baseline Analysis	31-Mar-16
Deliverable 7	Drill & Complete Scientific Observation Well	30-Sep-15
Deliverable 8	Drill & Complete NNE MIP 5H	31-Dec-15
Deliverable 9	Publication of Analysis of NNE MIP 5H Monitoring Results	31-Dec-19
Deliverable 10	Recommendations for Subsequent NNE Wells	30-Jun-19
Deliverable 11	Final report and Project Close-out	30-Sep-20

Figure 7. – Project Schedule and time line broken down by project phase and by task/subtask identified in the SOPO showing tasks and major milestones/deliverables.

4 Management Approach and Capabilities

4.1 Project Organizational Structure; Roles and Responsibilities

The MSEEL management structure will enable the management of a long-term field laboratory for testing of new technologies, the online structure to share data and analyses across institutions and research teams, and the ability to validate new knowledge or technology for understanding the nature of resource recovery as well as the environmental implications of unconventional resource development (Figure 7). This team has developed a set of common goals, a framework for managing the research, and agreed-upon mechanisms for communication and decision making. The lead organizations have pledged their best talents, infrastructure, and tools to this endeavor. WVU, home to the several highly regarded energy research projects, has demonstrated its in-depth technical project management expertise by successfully managing interdisciplinary energy research collaborations for over 30 years.

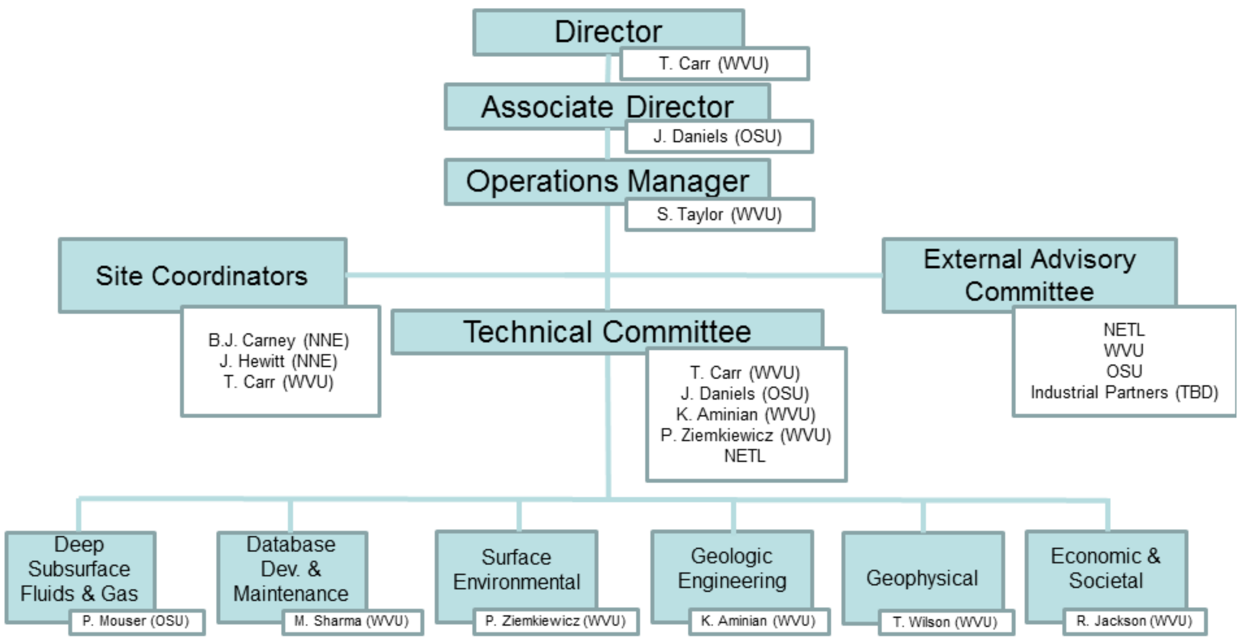

Figure 8. – Project Organization listing leads for key focus areas. Additional personnel are listed in the budget and bios are provided. The strong technical team at the core of project demonstrates MSEEL commitment to delivering a field site and laboratory for the collection of samples and data, and/or the testing and demonstration of advanced technologies to improve resource recovery as well as minimize environmental impact of unconventional energy resource development.

The centerpiece of the MSEEL is the cooperation of public and private sectors to create a long-term easy-access field laboratory that provides a retrospective baseline coupled with several distinct drilling and completion events to provide ideal testing conditions. This concept has driven our partnership, management approach, and all other parts of the organization were developed around this concept. Under the management of the Center Director, our organization provides the structure for accomplishing the goals defined in this proposal. The purpose of this leadership team is to ensure that project communications and operations are managed smoothly and transparently and to allow flexibility to incorporate other research and demonstration tasks that may arise from NETL and NETL sponsored researchers.

The project will manage intellectual property proprietary information under the direction of the Director and Advisory Committee. Each partnering organization has strong intellectual property experience, including legal, patent, and technology transfer staff. Technical developments will be monitored and reviewed to determine the applicability of research disclosures, patent filings, or trade secret developments. In addition, the operations staff for this project has extensive experience with Intellectual Property Management under Federally sponsored R&D projects. As part of the standard project management process for a research project of this size, a Project Management Plan and Risk Management Plan will be developed with the approval of NETL and updated as the project progresses. These will include milestone definition and schedule, and a project timeline.

Role of Participants

A large team of geoscientists, engineers and others have been assembled and individual bios are provided in the RESEARCH AND RELATED SENIOR/KEY PERSON file. Only leads of focus areas as shown in Figure 8 are listed in the table below.

Key Personnel	Key Relevant Experience	Percent Effort
Director – T. Carr (WVU)	• Research petroleum geology especially unconventional resources • Database development • Petrophysics and Geostatistics	11%
Associate Director – J. Daniels	• Director, Subsurface Energy Resource Center at The Ohio State University • Applied geophysicist: surface and borehole geophysical methods applied to subsurface science	11%
Operations Manager – S. Taylor	• Management of over 1.1B in energy related infrastructure, Deployment, research and development projects • Oversight of technical, schedule, environmental, intellectual property and cost aspects of complex and multi-partnered research projects.	33%
Site Supervisor – BJ Carney	• Vice-President Northeast Natural Energy • Fifteen years petroleum experience in the Appalachian basin	10%
Deep Subsurface Fluids & Gas Focus Area Lead – P. Mouser	• Research in deep subsurface, including fluids, microbial, and deep sampling, with a focus on groundwater characterization	10%
Database Development & Maintenance Focus Area Lead – M. Sharma	• Focus on GIS database and infrastructure development for energy related projects. • GIS Project lead, West Virginia GIS Technical Center	8%
Surface Environmental Focus Area Lead – P. Zienkiewicz	• Over 30 years' experience managing energy related environmental research programs. • Current research focus on power industry water management, mine drainage, and shale gas effects on watersheds.	11%
Geologic Engineering Focus Area Lead – K. Aminian	• Unconventional natural gas resource development, natural gas production and storage, reservoir characterization and modeling, coalbed methane development.	8%

	• Recent research focus on enhanced liquid recovery by CO_2 sequestration in gas/condensate reservoirs.	
Geophysical Science Focus Area Lead – T. Wilson	• Research in Fracture Modeling and Microseismic Analysis of unconventional gas reservoirs. • Recent focus in 3-d and 4-d seismic analysis and interpretation.	11%
Economic & Societal Analysis Focus Area Lead – R. Jackson	• Interests in regional economic development, technological change, energy and environmental systems and simulation, and energy policy analysis. • Recent focus unconventional gas development policies and economic impacts.	8%

Table 1. – Roles of leads in MSEEL Project of focus areas as shown in Figure 7. Individual bios are provided in the RESEARCH AND RELATED SENIOR/KEY PERSON file.

4.2 Organizations' Corporate Experience in Managing Similar Projects

As land-grant institutions in the 21st century, WVU and OSU deliver high-quality education, excel in discovery and innovation, model a culture of diversity and inclusion, promote health and vitality, and build pathways for the exchange of knowledge and opportunity between the state, the nation, and the world. At WVU, the work proposed in this application will take place in laboratories in the Benjamin M. Statler College of Engineering & Mineral Resources building, the newly-renovated Brooks Hall that houses Geology and Geography, and the Engineering Research Building. Additionally, the center will be housed in the National Research Center for Coal and Energy, where we will have a dedicated virtual and physical environment for collaboration both at the WVU site and with our remote partners.

4.3 Knowledge, Capabilities, Experience, and Availability of Key Personnel

The knowledge, capabilities, experience (technical and managerial), and availability along with description of effort of key personnel are provided with the percentage of time devote to the project in Table 2. Resumes of all key project personnel are included in the "RESEARCH AND RELATED SENIOR/KEY PERSON" file. Labor effort at WVU is reported as percent.

Name - Role - Task	Organization	% Effort	Description of Effort
Dr. T. Carr - PI - Task 1, 2, 3	WVU	10%	Project Director, Principal Investigator and Institutional Lead for West Virginia University. Focus in Geology
Dr. J. Daniels - CO-PI -	OSU	10%	Co-Project Director, CO-PI, and Insitutional Lead for Ohio State University. Focus in Geophysics
B.J. Carney - Site Manager	NEE-LLC	10%	Site Manager, Institutional Lead. 10% effort dedicated, other as required for Site Management
Dr. S. Ameri - CO-PI - Task 2, 3	WVU	10%	CO-PI, Departmental Lead. Focus in Petroleum and Natural Gas Engineering
Dr. K. Aminian - CO-PI - Task 2, 3	WVU	10%	CO-PI, Focus in Petroleum and Natural Gas Engineering
Dr. M. Barnes - CO-PI - Task 2, 3	WVU	10%	CO-PI, Focus in Geology
Dr. I. Bilgesu - CO-PI - Task 2, 3	WVU	10%	CO-PI, Focus in Petroleum and Natural Gas Engineering
Dr. D. Cole - CO-PI -	OSU	5%	CO-PI, Focus in Geochemistry
Dr. T. Darrah - CO-PI -	OSU	5%	CO-PI, Focus in Geochemistry

Dr. J. Donovan - CO-PI - Task 2, 3	WVU	10%	CO-PI, Focus in Hydrogeology
J. Fillhart - Staff - Task 2, 3	WVU	10%	Staff, Focus in Environmental Science and Data Acquisition
Dr. R. Jackson - CO-PI - Task 2, 3	WVU	10%	CO-PI, Departmental Lead. Focus on Regional Economics
Dr. H. Li - CO-PI - Task 2, 3	WVU	10%	CO-PI, Departmental Lead. Focus on Air Quality and Air Sampling
Dr. L.S. Lin - CO-PI - Task 2, 3	WVU	10%	CO-PI, Focus on Water Treatment and Water Quality
Dr. M. McCawley - CO-PI - Task 2, 3	WVU	10%	CO-PI, Departmental Lead. Focus in Public Health Impacts.
Dr. P. Mouser - CO-PI -	OSU	5%	CO-PI, Focus in Geo- and Biochemistry
Dr. M. Sharma - CO-PI - Task 2, 3	WVU	10%	CO-PI, Focus in GIS database and infrastructure development.
Dr. S. Sharma - CO-PI - Task 2, 3	WVU	5%	CO-PI, Focus in Geology
Dr. H Siriwardane - CO-PI - Task 2, 3	WVU	10%	CO-PI, Departmental Lead. Focus in Geomechanics
S. Taylor - Operations Manager - Task 1	WVU	30%	Operations Manager. Responsible for day-to-day project oversight and reporting.
Dr. A. Weislogel - CO-PI - Task 2, 3	WVU	5%	CO-PI, Focus in Geology
Dr. T. Wilson - CO-PI - Task 2, 3	WVU	10%	CO-PI, Focus in Geophysics
Dr. P. Ziemkiewicz - CO-PI - Task 2, 3	WVU	10%	CO-PI, Departmental Lead. Focus in water impacts and environmental baseline.
Table 2. Availability of Key Personnel			NOTE - WVU and OSU provide effort estimates as %

4.4 Technology Transfer

In addition to providing all reports in a timely manner, MSEEL will work with NETL throughout the project to develop and implement an effective and active Technology Transfer program that works to get the critical data and technology assessments and environmental techniques (tools, methods, instruments and products) – along with the analysis and insights – into the hands of researchers. Critical to the plan is developing and enhancing online relational geodatabases to collect, store, preserve, distribute and share technical data and results. We will use the NETL Energy Data Exchange (EDX) (https://edx.netl.doe.gov/) and internal data-access portals to develop a SEEL geodatabase as an online system to support internal coordination and collaboration and with NETL and NETL sponsored researchers. MSEEL is striving to place all data in a digital and retrievable format that will create a usable database for future research projects.

MSEEL will enhance existing web tool such as National Atlas of Unconventional Resources (http://www.unconventionalenergyresources.org/) to place MSEEL within a regional basin-scale and North America context and improve dissemination (tech transfer) of research-driven products to the broadest possible audience. The system will be designed to ensure lasting access to research products for future use by external researchers actively engaged in work relevant to shale energy and environmental research and to the interested public.

Key criteria of success for the project are validation and utilization of the environmental, technology, and process research results and know-how obtained via the project for operation of other wells in the Marcellus and other unconventional resource plays in the U.S. and globally. Key quantitative criteria will be developed to measure success that increases production and ensures environmental compliance.