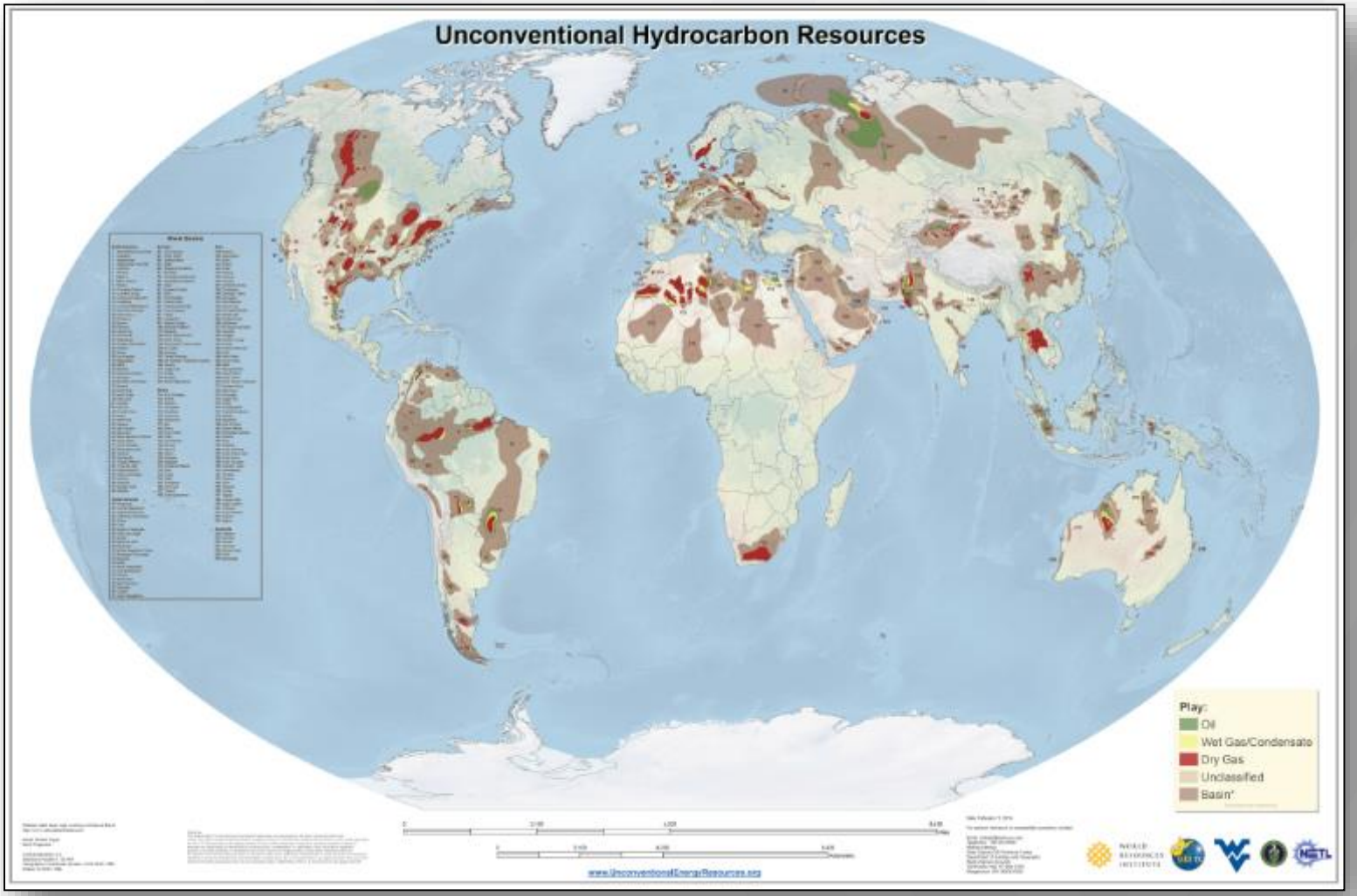
MARCELLUS SHALE ENERGY AND THE MSEEL PROJECT

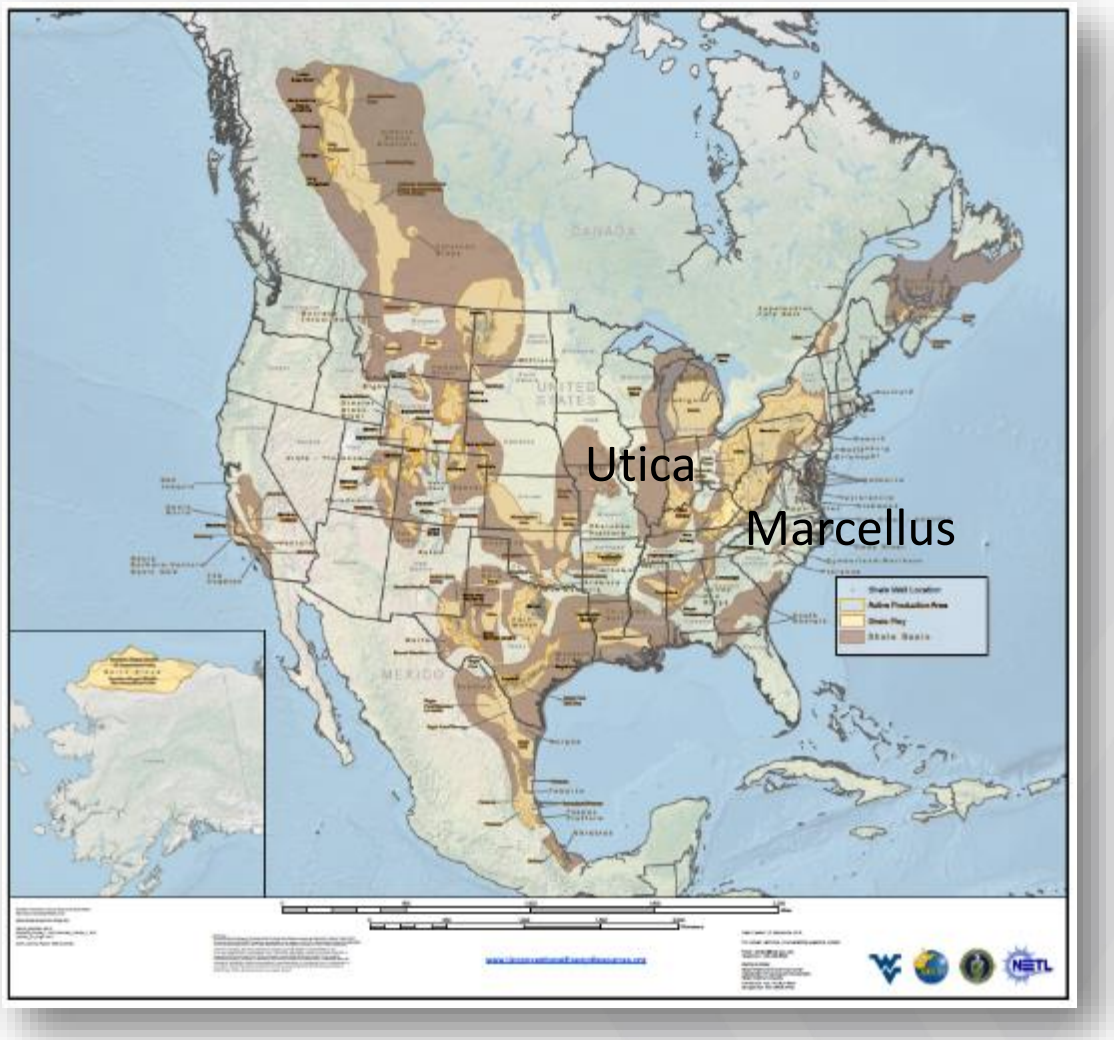
West Virginia University
ENERGY INSTITUTE

Presented by: Tim Carr
FGV June 2018
West Virginia University

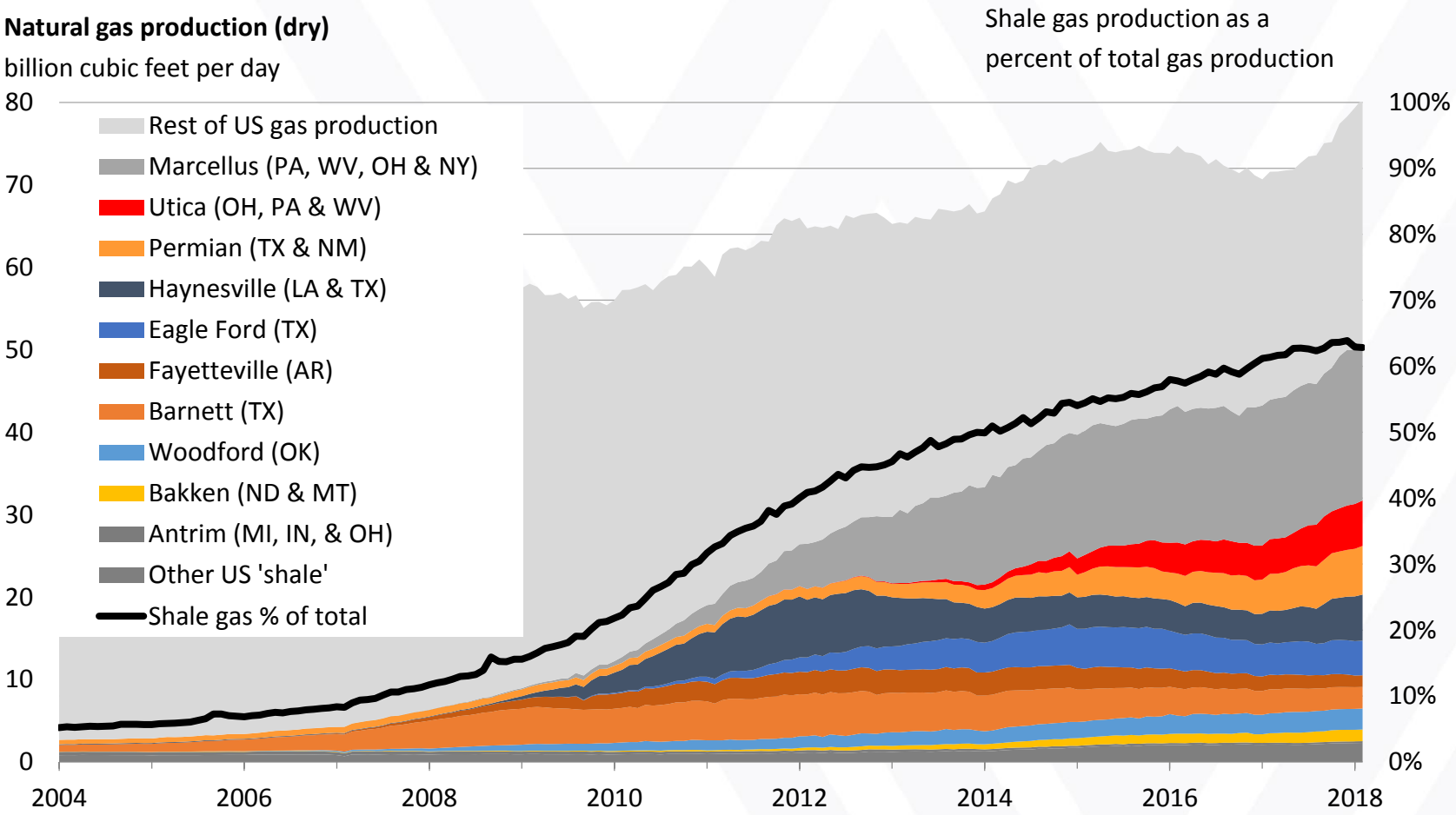
Global Shale (Mudrock) Basins



North America Mudrock Basins



U.S. shale gas production was 50.6 Bcf/d (1.4 Bcm/d) in February 2018, about 63% of total U.S. dry production (80 Bcf/d – 2.3Bcm/d)



Sources: EIA Natural Gas Monthly, STEO through February 2018 and DrillingInfo.

1 billion cubic feet Bcf = ~2.8 million cubic meters
1 thousand cubic feet (Mcf) = ~ 28.3 cubic meters

MARCELLUS SHALE ENERGY AND ENVIRONMENT LABORATORY

MSEEL

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

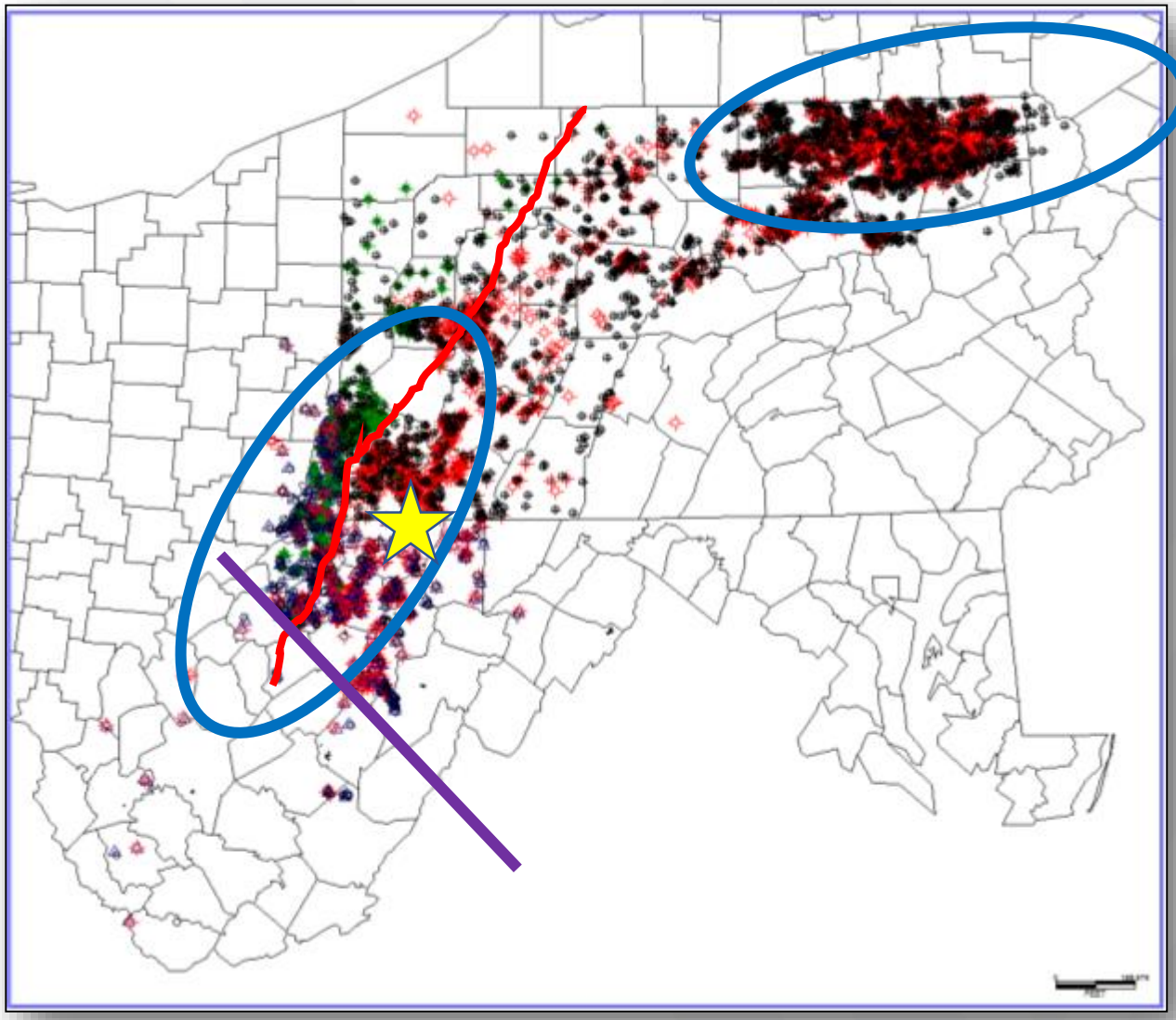
Schlumberger

NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

northeast NATURAL ENERGY

THE OHIO STATE UNIVERSITY

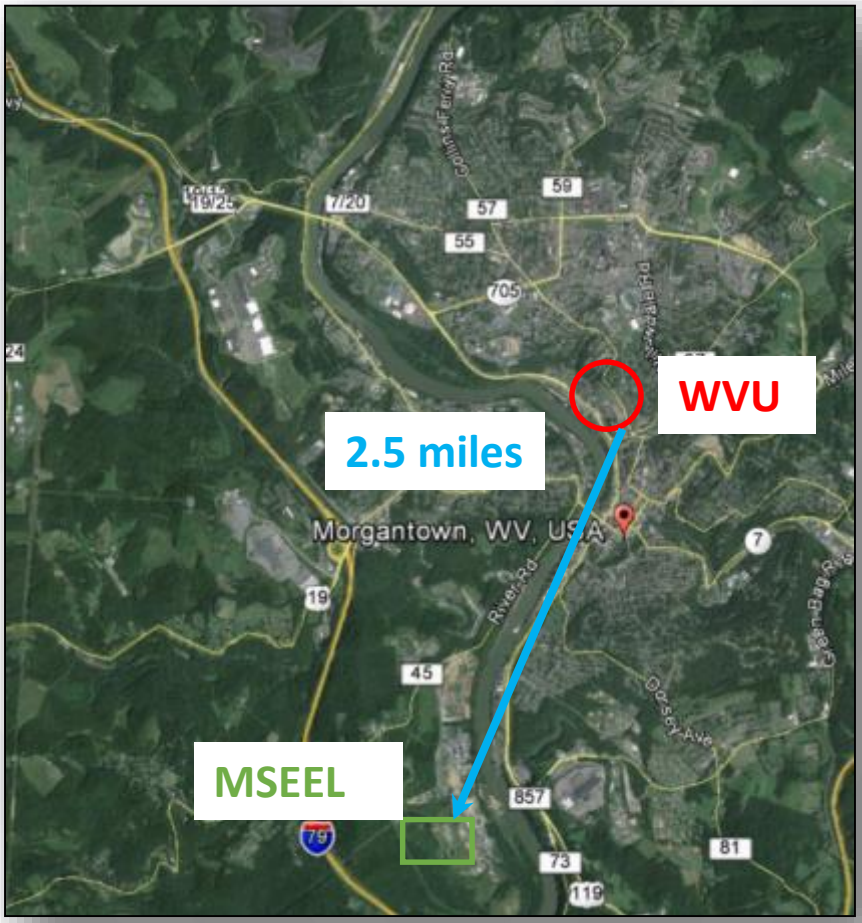
Marcellus Horizontal Wells



13,079 Wells

MSEEL Site


MIP-5H
MIP-3H
MIP-SW
MIP-6H
MIP-4H
0.6 km
0.4 mi


WVU
2.5 miles
Morgantown, WV, USA
MSEEL
79
857
73
119
81
45
19
7
705
55
57
59
7/20
River Rd
Dorsey Ave

MSEEL - Drilling MIPU 3H and 5H

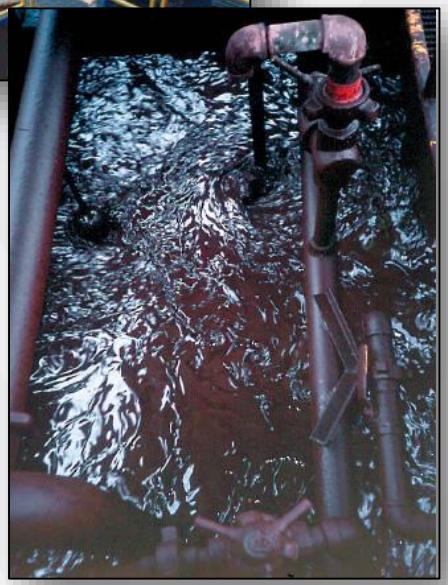
Increased Expectations for Environmental Standards

Increased Expectations for Environmental Standards

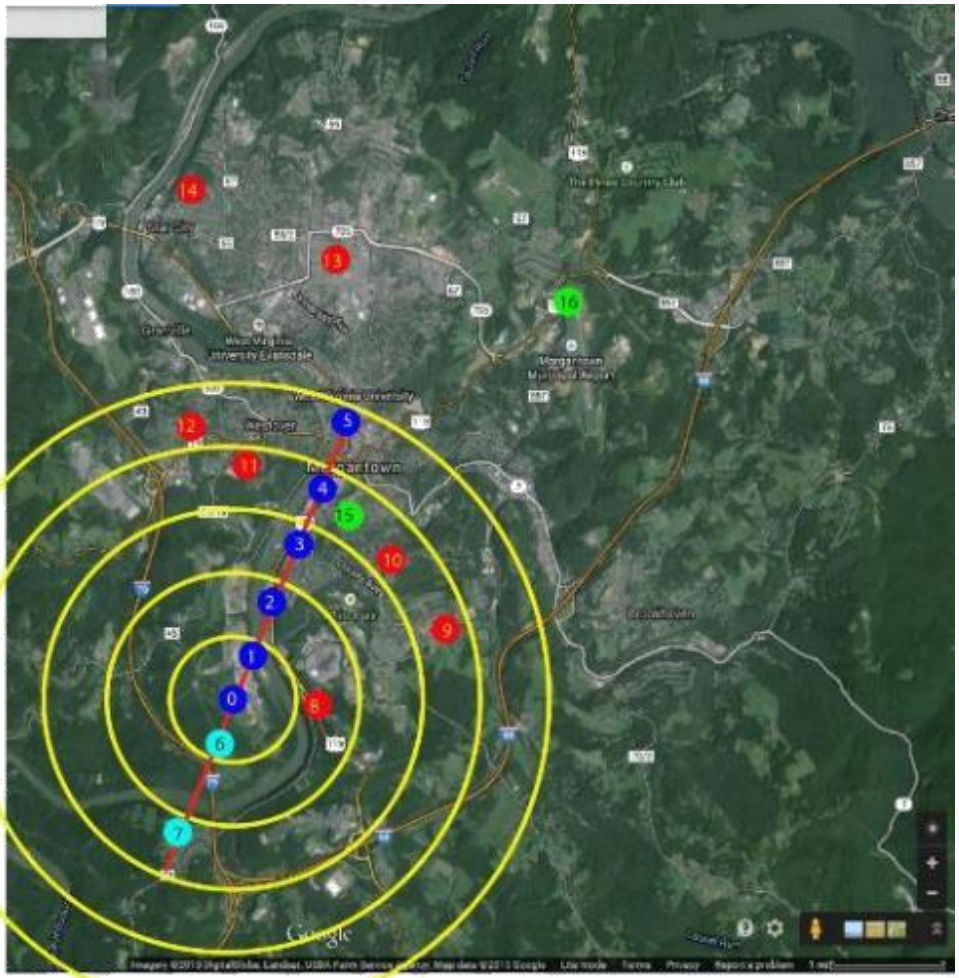
Industry is expected to adopt much more rigorous operational and environmental standards than have been the norm in the past all of which add to the F & D cost of any project

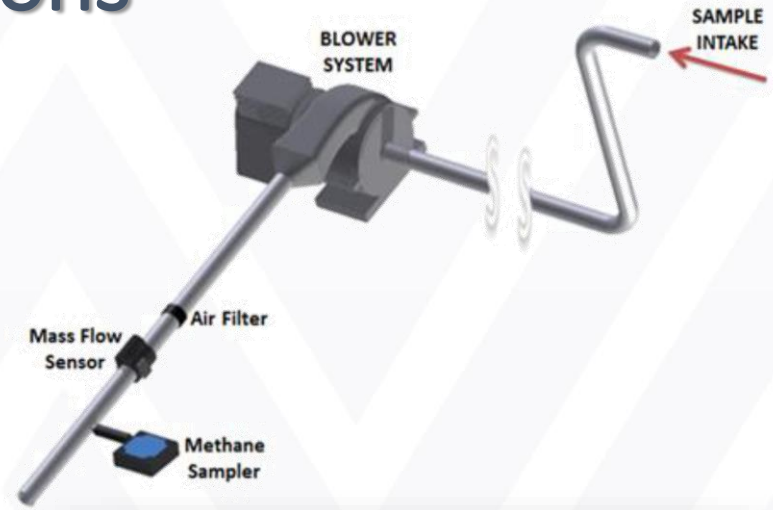
Increased Expectations for Environmental Standards

Closed Loop Drilling



MSEEL Environmental Monitoring Air Emissions





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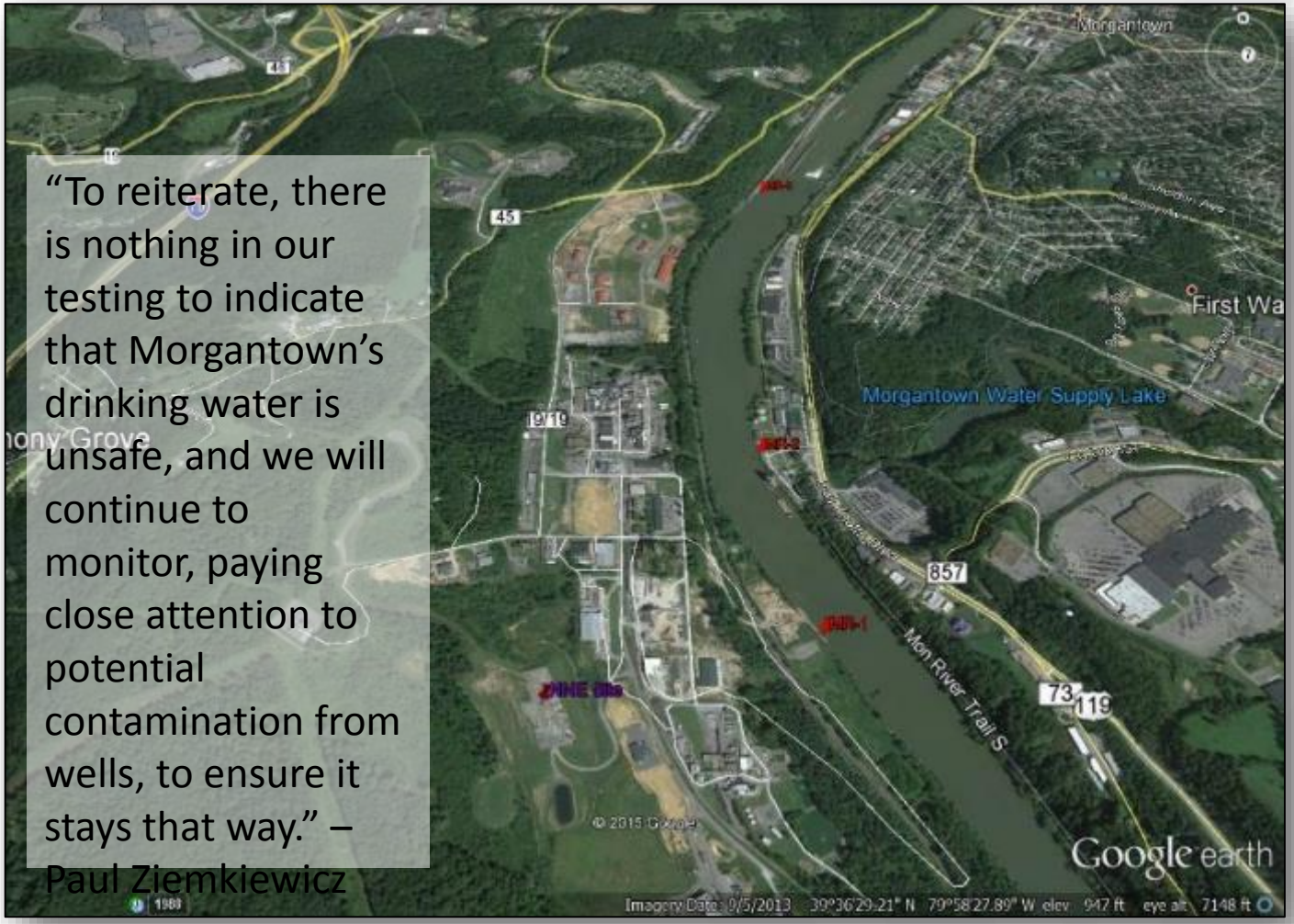
Michael McCawley – WVU
Derek Johnson – WVU

Environmental Monitoring
Surface Water



"To reiterate, there is nothing in our testing to indicate that Morgantown's drinking water is unsafe, and we will continue to monitor, paying close attention to potential contamination from wells, to ensure it stays that way." – Paul Ziemkiewicz

Drilling and Produced Water Waste Monitoring

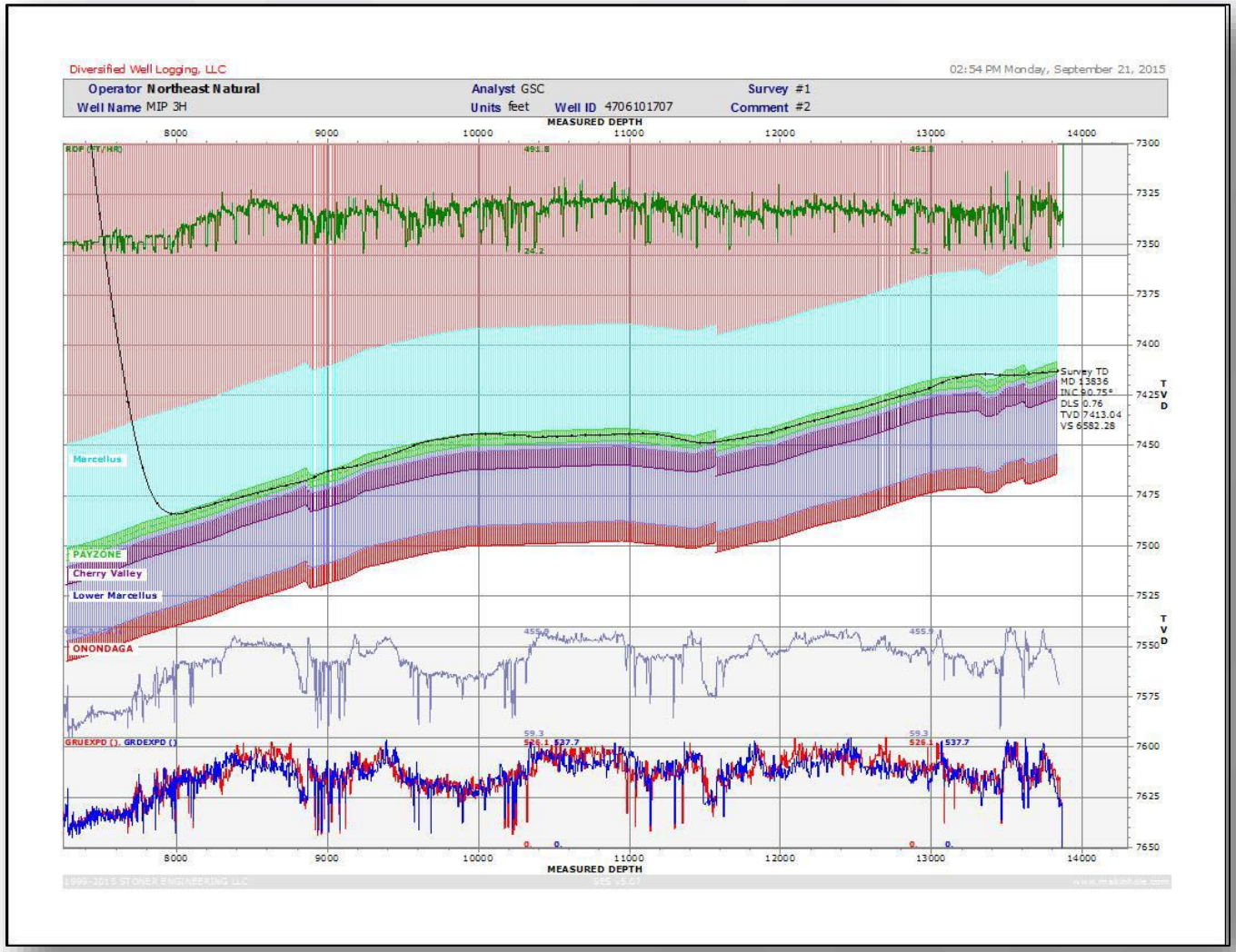
Cuttings

Mud

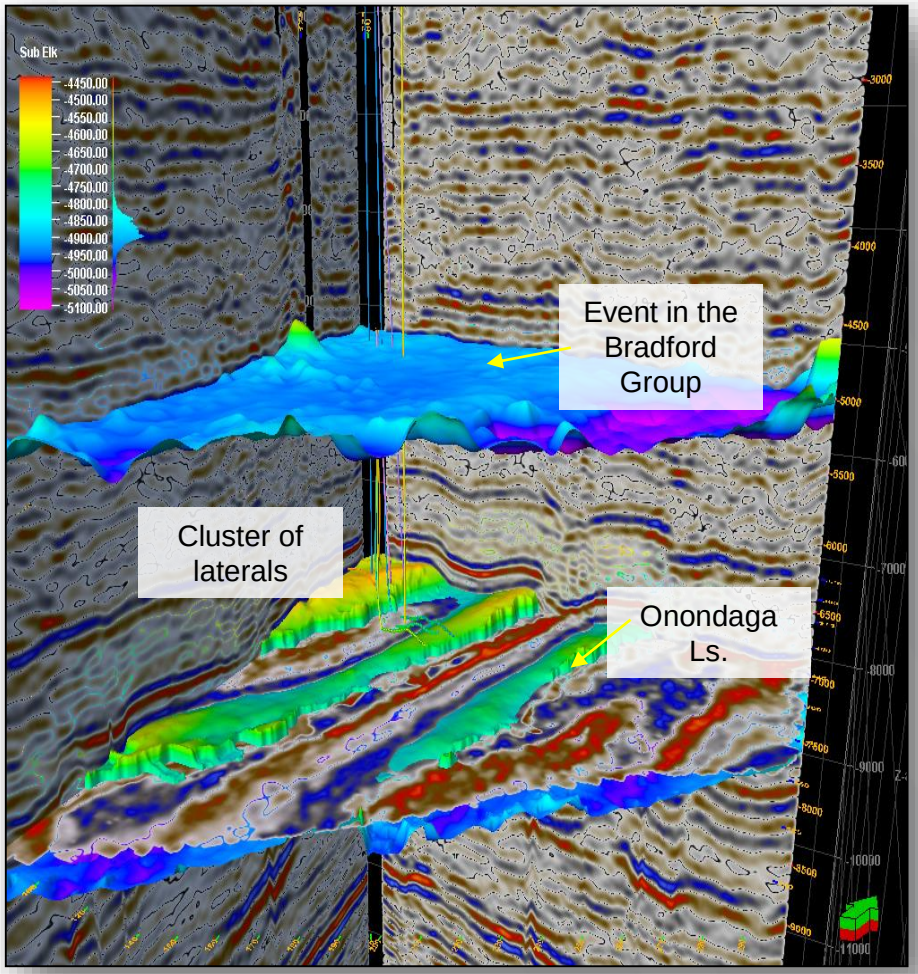
Shale Revolution
New Ideas and New Technology

- Horizontal Drilling and Hydraulic Fracture Stimulation have been Around for Decades
- The Shale Boom has Emerged from Smart Development
  - 3D Seismic - Map
  - Down Hole Sensors While Drilling - Headlights
  - Steerable Bits and Precision Guidance – Steering Wheel
  - Microseismic, Tiltmeters and Fiber-optics to Monitor Stimulation – Headlights
  - Computerized Pump and Blending Controls – Steering Wheel
- Real-Time Data Integration
  - Remote Access
  - Automated Rigs
  - Closed Loop Systems
  - Computer-Controlled Power - Bifuel, CNG and LNG
- A Drilling Rig is a Computer with a Drill Bit Attached to One End
  - Petabytes of Data Generated with Each Well

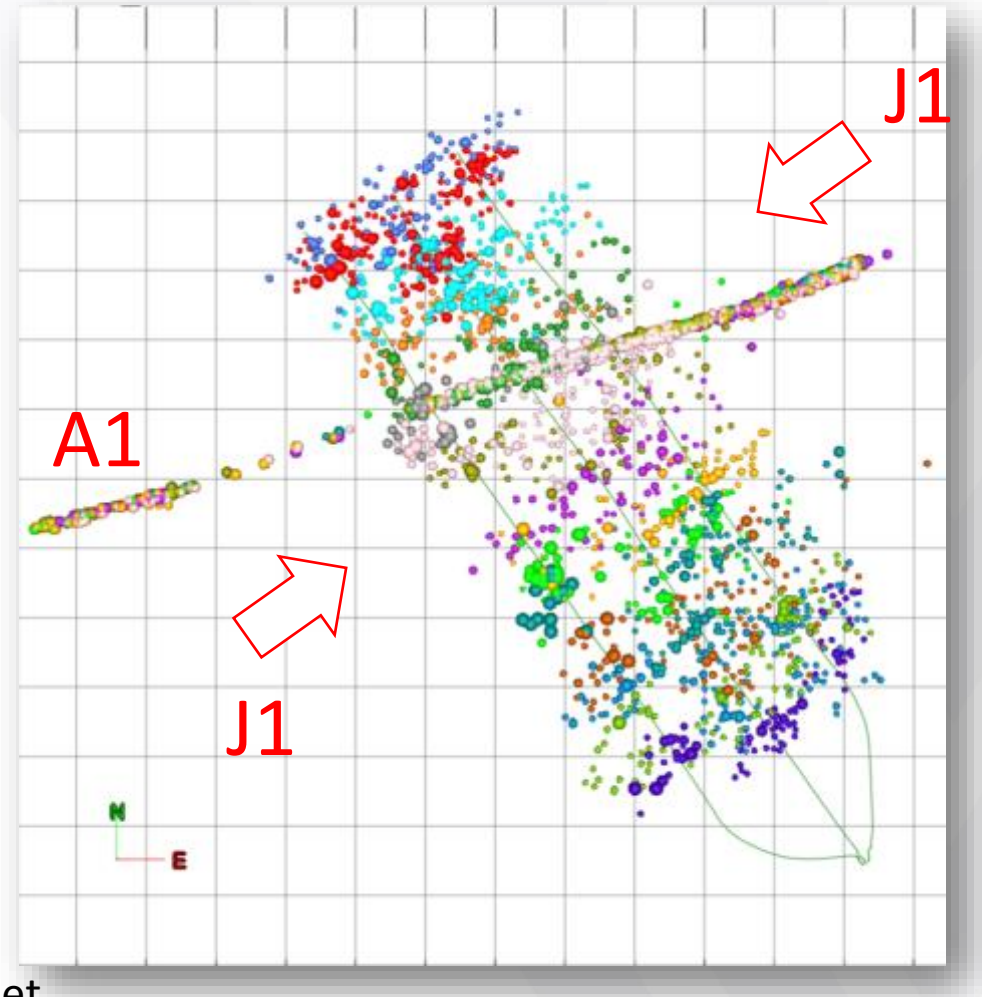
Geosteering MIP-3H



Effective drilling and hydraulic fracture stimulation benefits from a good understanding of subsurface structure



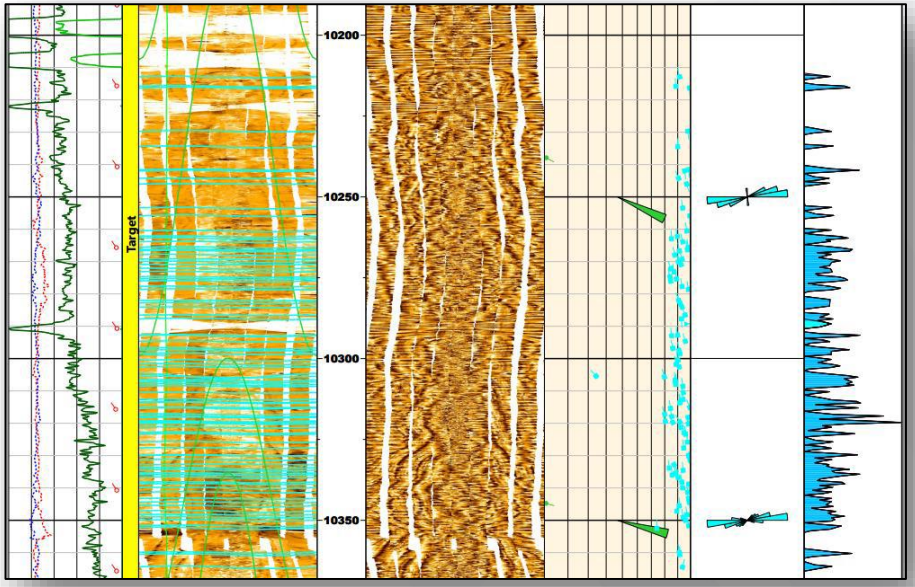
Geologic Failure

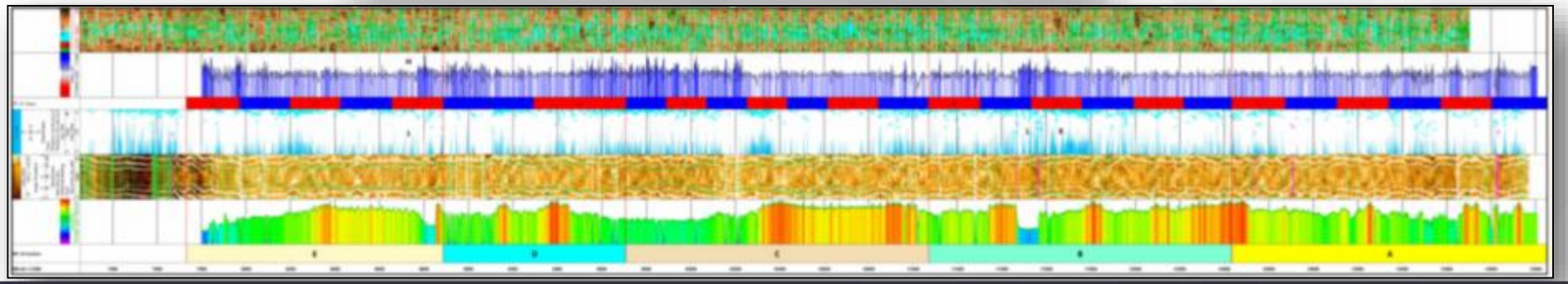


Each square 500 x 500 feet

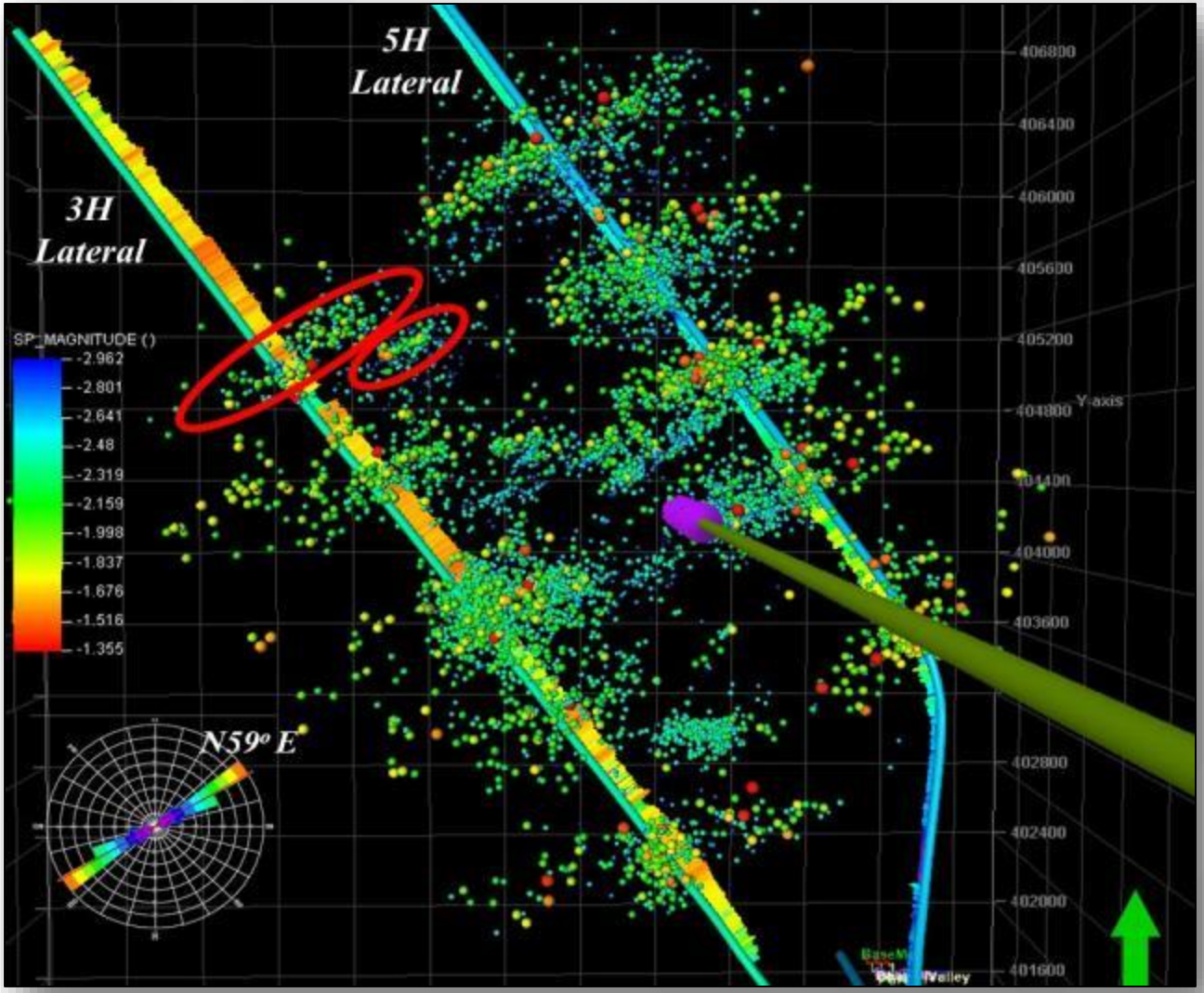
MSEEL - LOGGING LATERAL

High Definition open hole logs in lateral with synthetic mud

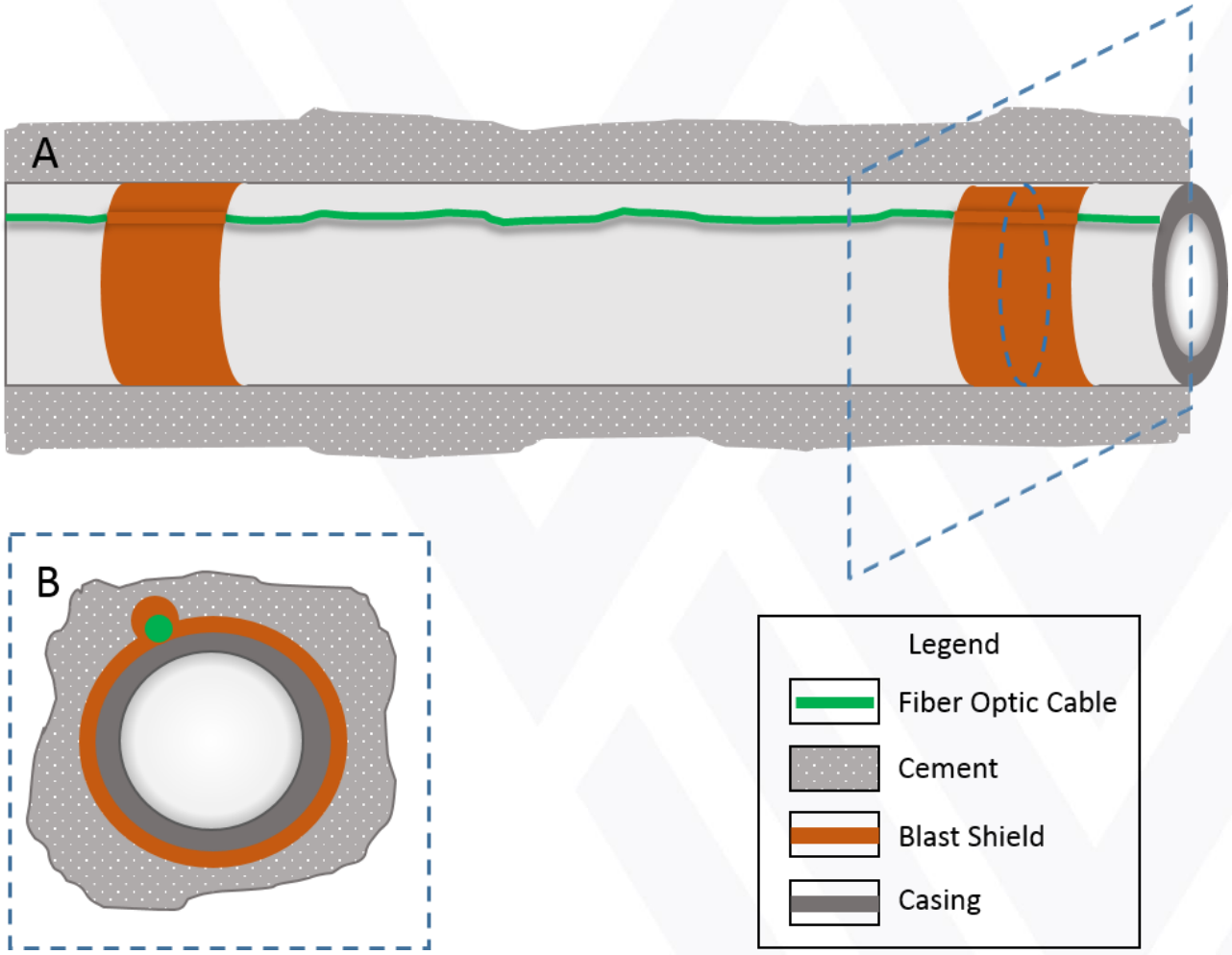




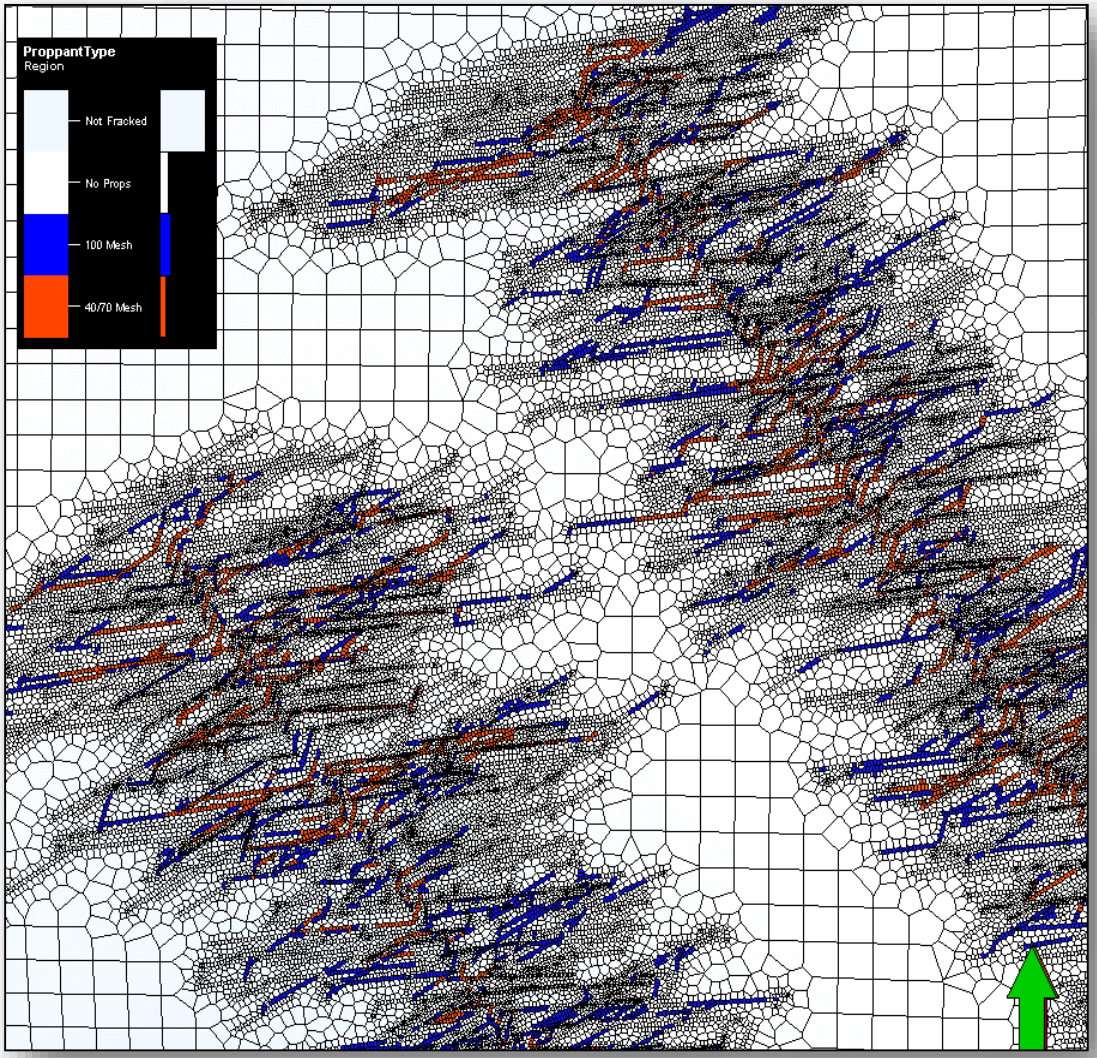
MSEEL - Microseismic



MIP-3H Fiber-Optic Schematic

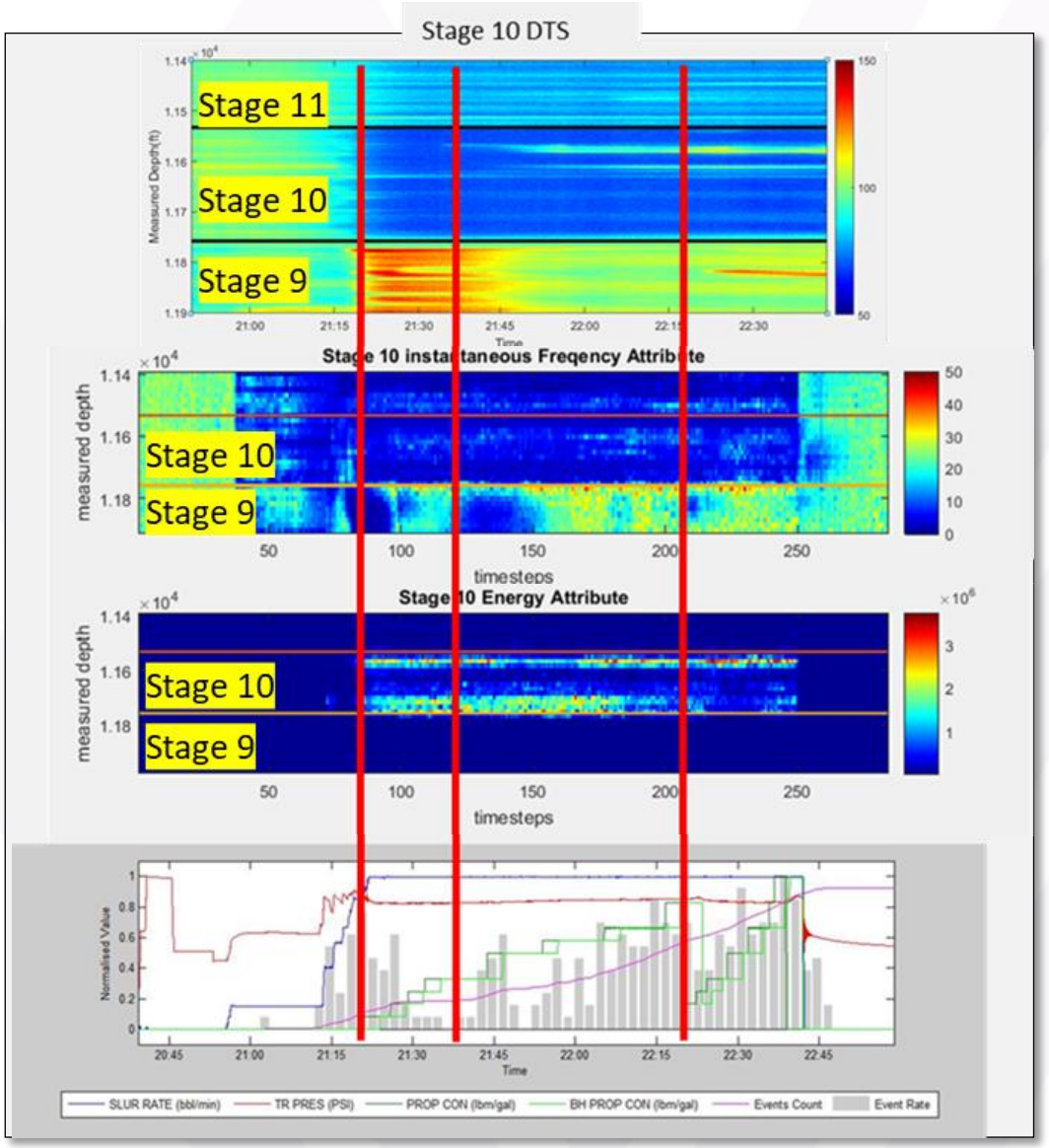


Unconventional Fracture Model (UFM)



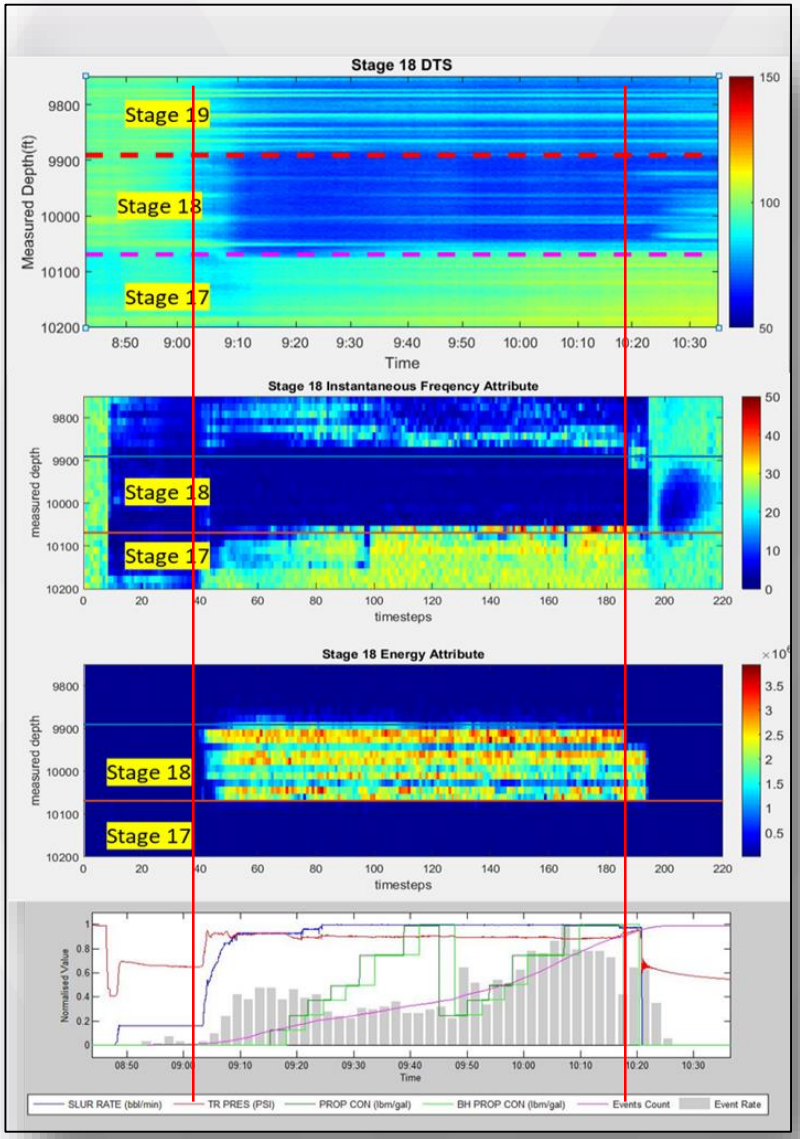
MSEEL
Completion MIPU 3H and 5H

DAS-DTS Data Geometric Completion



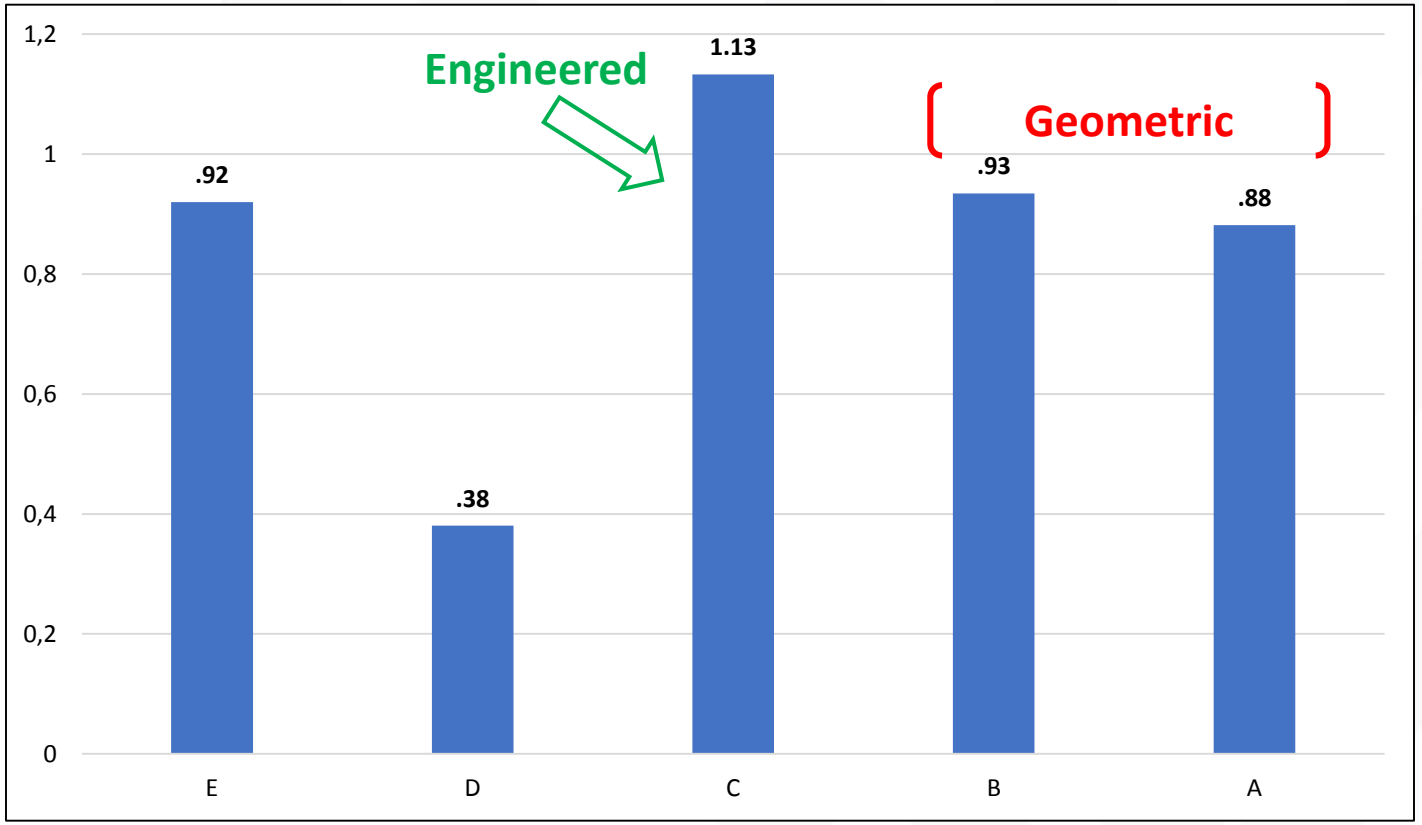
DAS-DTS Data Engineered Stage

DTS data and stimulation parameters compared with energy, instantaneous frequency, instantaneous amplitude, and dominant frequency. The temperature rise and the low frequency zones are not significant in stage 17 while stage 18 is stimulated.



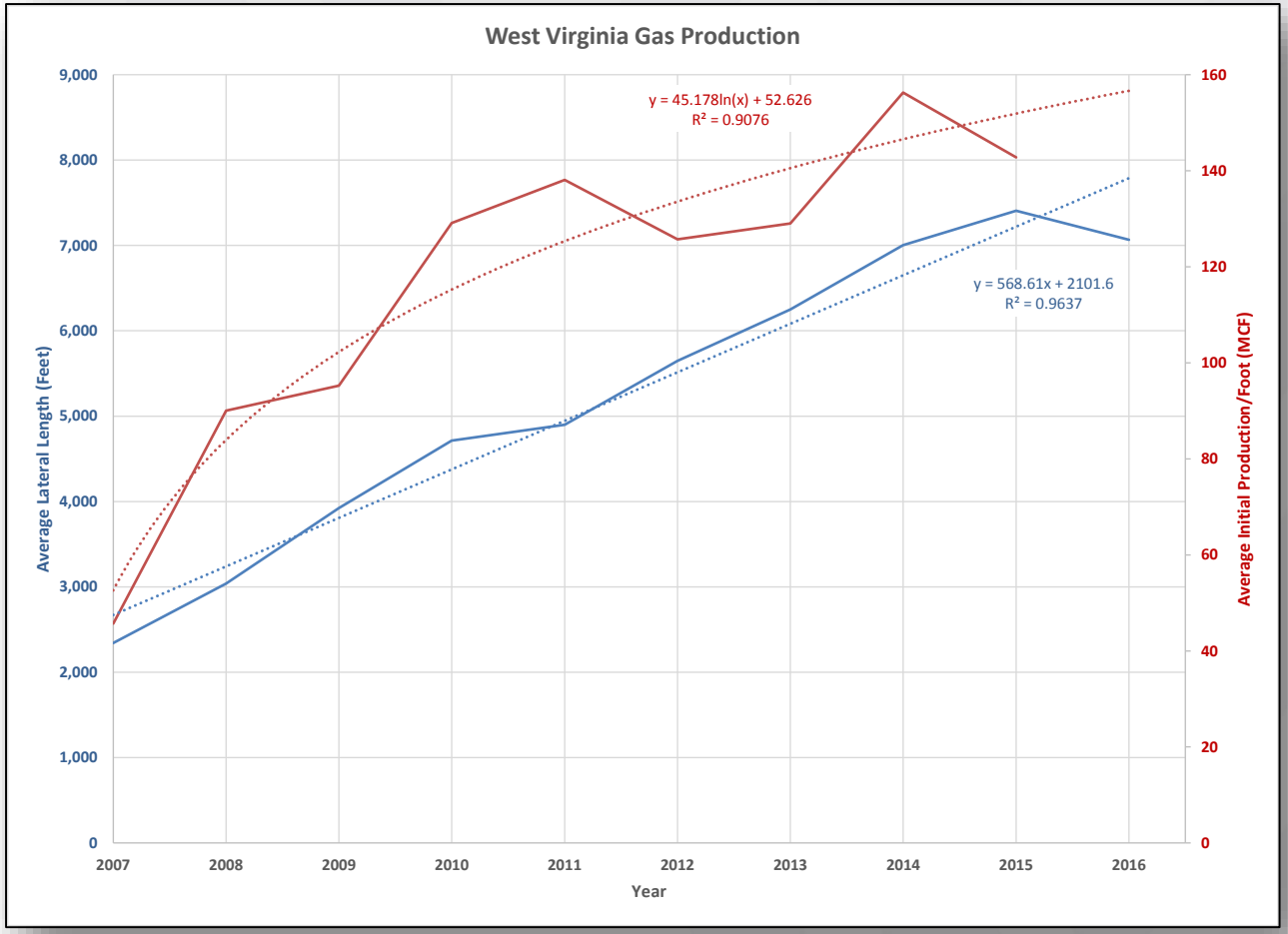
Results = Future Productivity Increase

MIP 3H Gas Production – mcf/ft

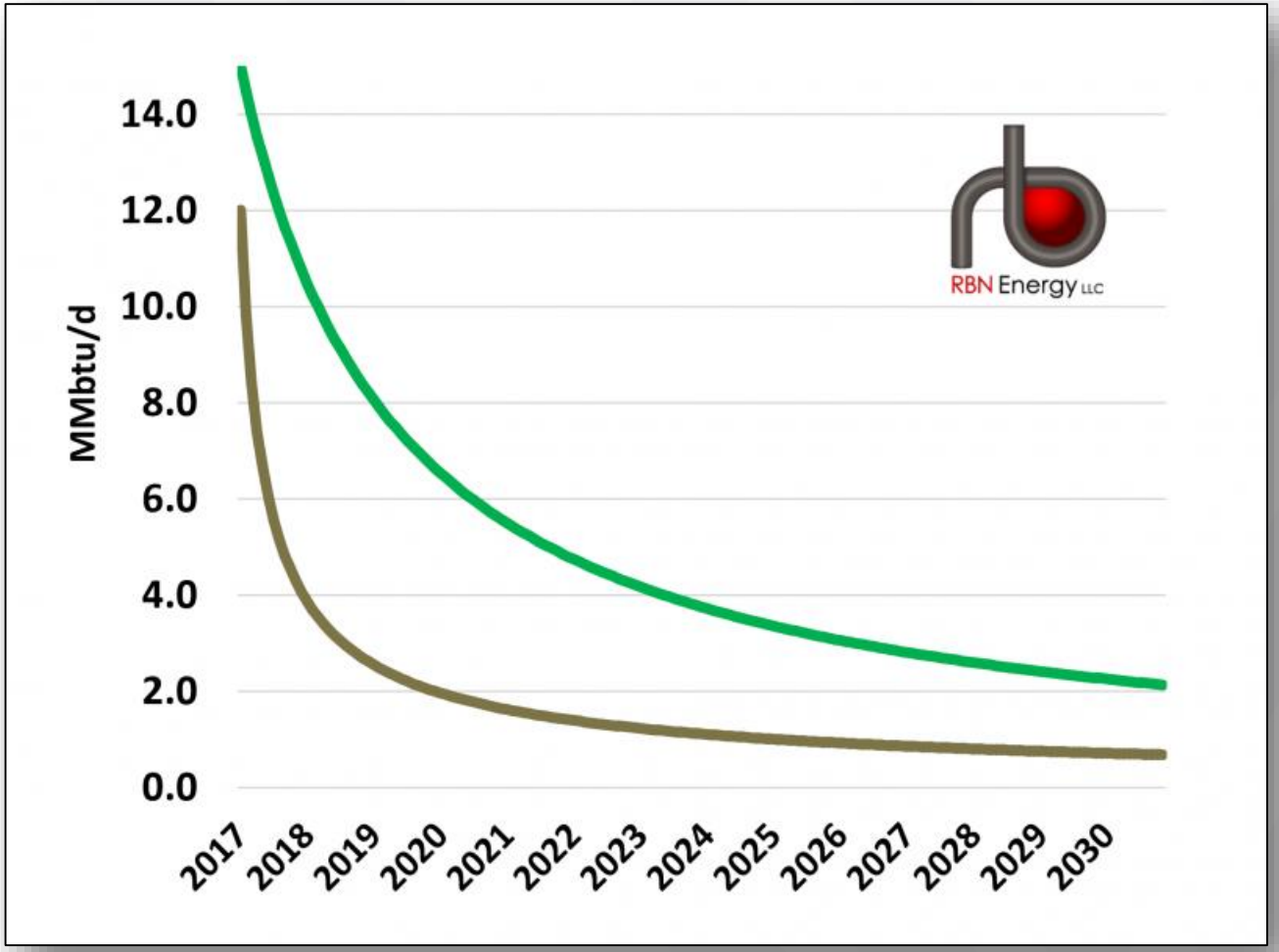


- Engineered design using data obtained during MSEEL has ~20% increased production compared to standard completion techniques
- EUR for future wells could be ~10-20% greater ***IF*** we can exploit the technologic advantages gained through MSEEL in a more cost-effective fashion

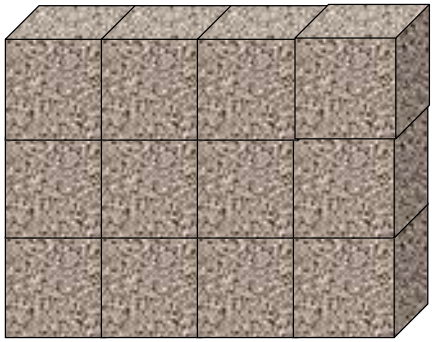
Drilling Efficiency
Average Well By Year Drilled



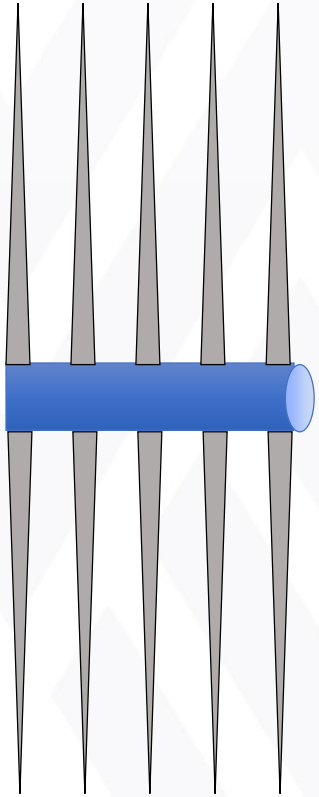
Decreased Declines Per Well



Increased Productivity Per Well

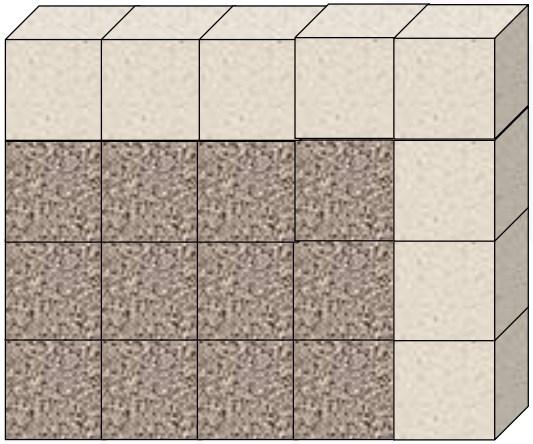


Proppant 1,157 to 1,342 lbs/ft.
12 cubic feet of sand per foot

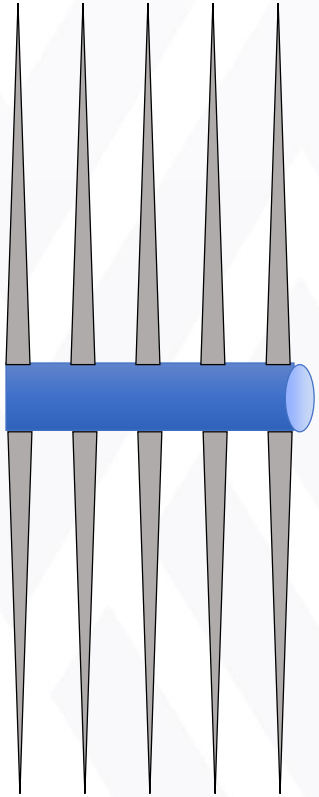


2011 ~30 days drilling
Total Completed Horizontal
MIP-4H – 3,782 Feet
MIP-6H – 2,342 Feet

Increased Productivity Per Well

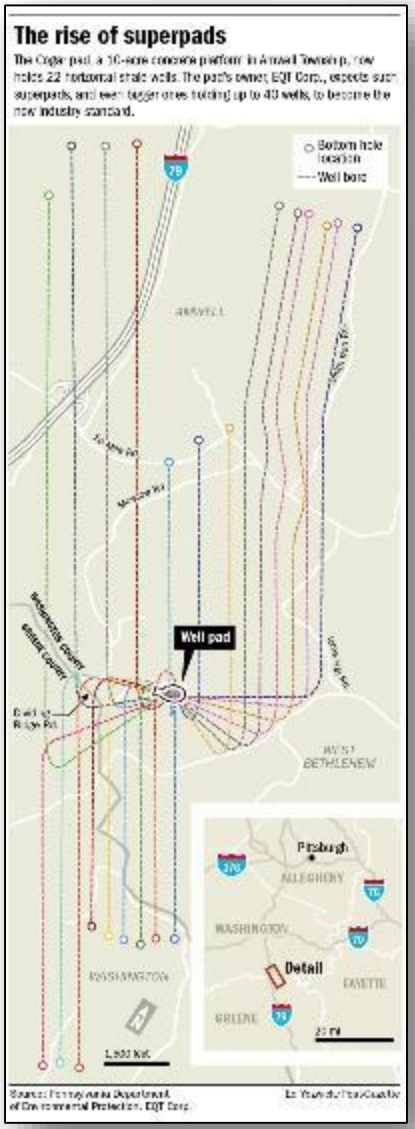


Proppant 1,858 to 1,917 lbs/ft.
20 cubic feet of sand per foot

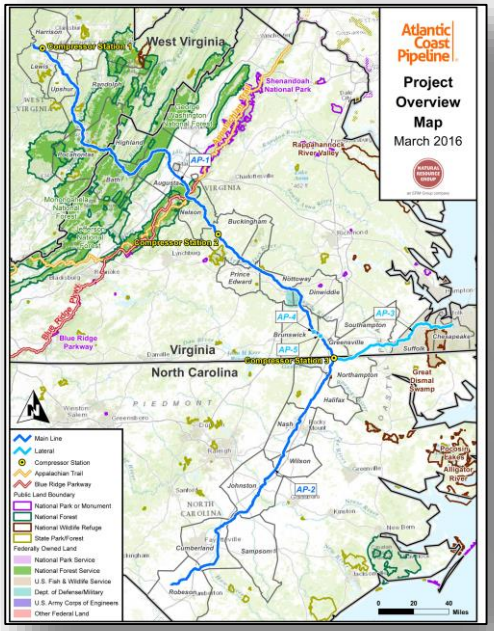


2011 ~30 days drilling
Total Completed Horizontal
MIP-4H – 3,782 Feet
MIP-6H – 2,342 Feet
Proppant 1,157 to 1,342 lbs/ft.
12 cubic feet of sand per foot

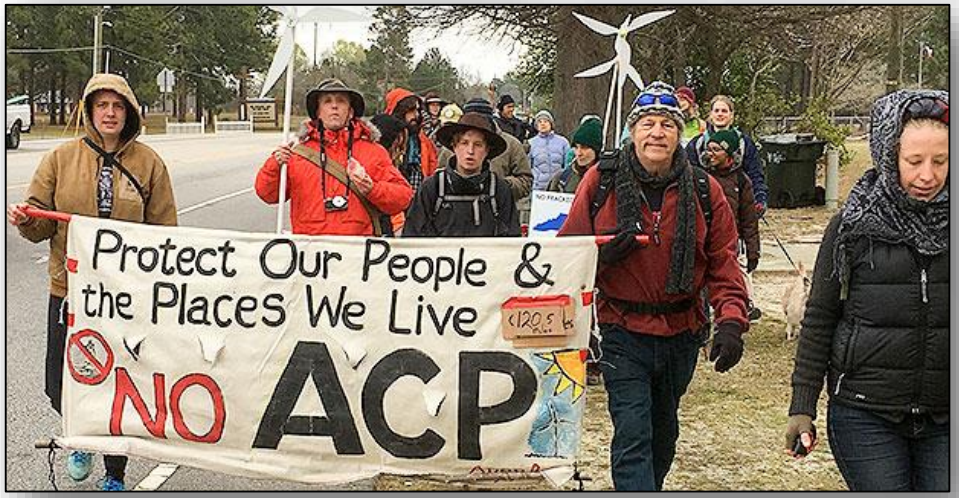
2015 ~7 days drilling
Total Completed Horizontal
MIP-3H – 6,058 Feet
MIP-5H – 5,784 Feet

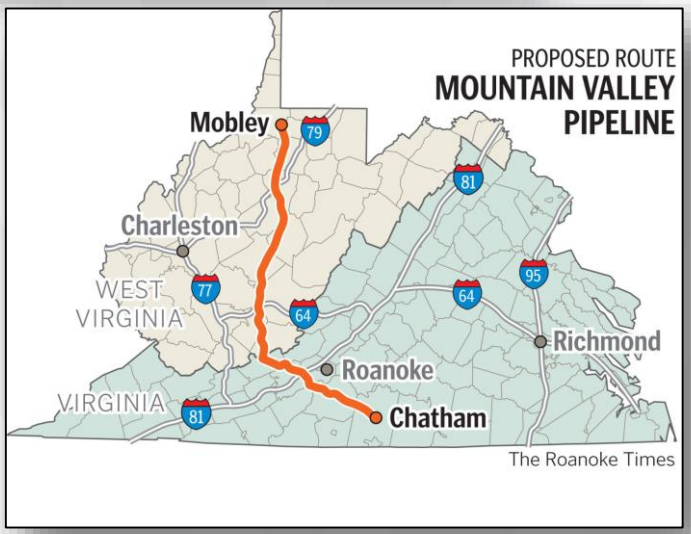

The rise of superpads
Bottom hole location
Well bore
Well pad
Pittsburgh
Detail
WASHINGTON
FAYETTE
WEST BETHLEHEM

Super Pads


Atlantic Coast Pipeline
Project Overview Map
March 2016
West Virginia
Virginia
North Carolina
Compressor Station 1
Compressor Station 2
Compressor Station 3
Shenandoah National Park
Blue Ridge Parkway
Main Line
Lateral
Compressor Station
Appalachian Trail
Blue Ridge Parkway
Public Land Boundary
National Park or Monument
National Forest
National Wildlife Refuge
State Park/Forest
Federally Owned Land
National Park Service
National Forest Service
U.S. Fish & Wildlife Service
Dept. of Defense/Military
U.S. Army Corps of Engineers
Other Federal Land
Miles


the FIRE
CATCHING
NO
PIPE


Protect Our People &
the Places We Live
NO ACP


PROPOSED ROUTE
MOUNTAIN VALLEY
PIPELINE
Mobley
Charleston
WEST
VIRGINIA
VIRGINIA
Roanoke
Chatham
Richmond
79
81
77
64
64
95
81
The Roanoke Times

Shale Revolution Affects Everything New Ideas Approaches & Technology

Development of shale gas or tight gas resources requires:

- **Attraction of capital is one of the greatest challenges. Return on initial capital is over a longer period of time)**
- **Sufficient land to be able to manage the drilling treadmill of continuous development**
- **Time and recognition that the development of the resource will require a number of years of "science and learning" prior to commercial development**
- **A strong commodity price to enable sufficient returns on investment**
- **A strong and disciplined company strategy is critical for cost effective exploration and development**
- **Application of technology in terms of drilling, stimulation and monitoring the foundation for success**
- **Continued regionally low cost natural gas may inhibit the attractiveness of unconventional resource**
- **Work to develop societal consensus**
- **Government both central and local has an important role to play in resource play development**

Building Partnerships for Research, Education, and Outreach

This research was funded by a grants from US Department of Energy's National Energy Technology Laboratory and the Department of State

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Northeast Natural Energy