Unlocking the Tight Oil Reservoirs of the Powder River Basin, Wyoming

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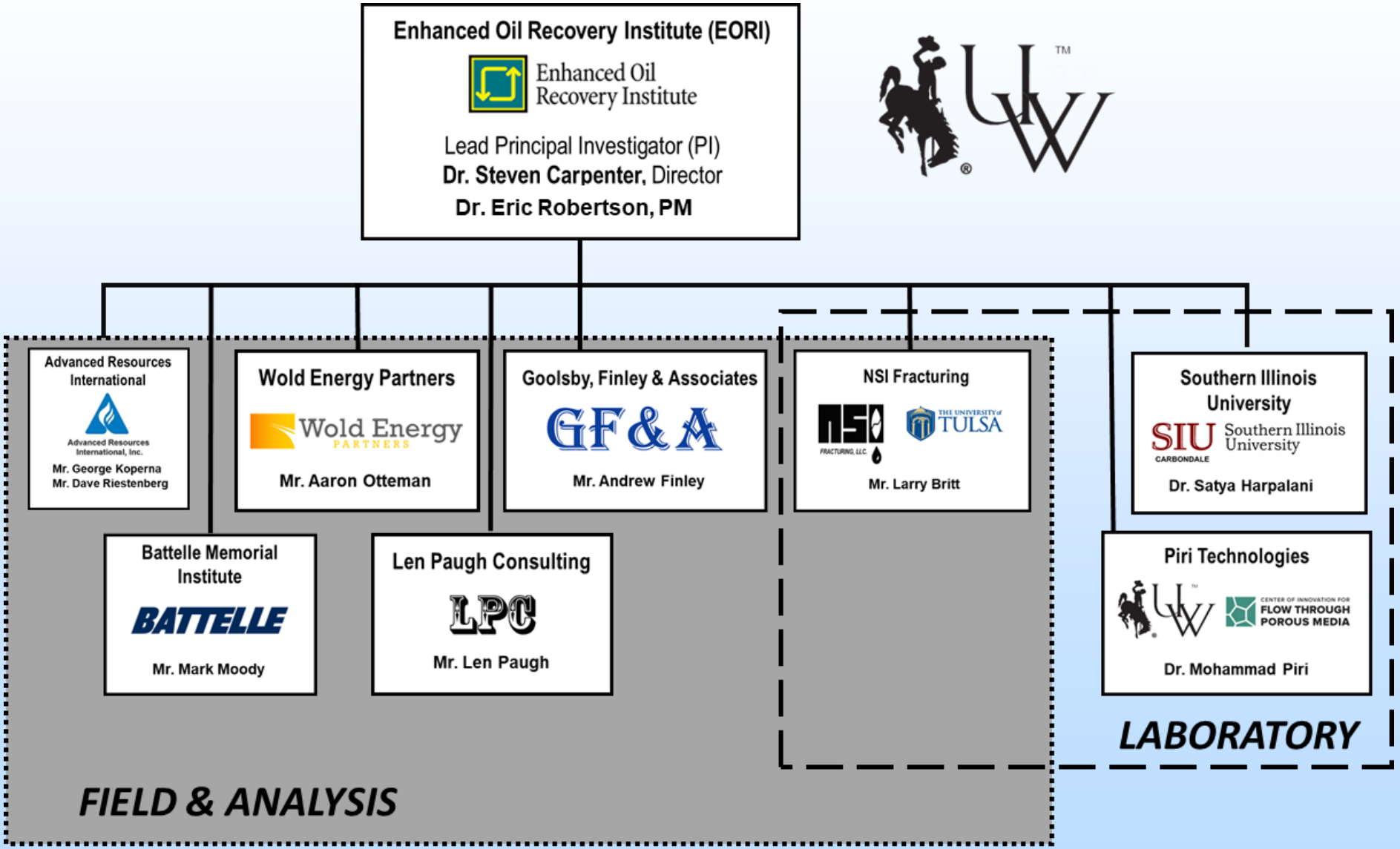
U.S. Department of Energy - National Energy Technology Laboratory

Oil & Natural Gas - 2020 Integrated Review Webinar

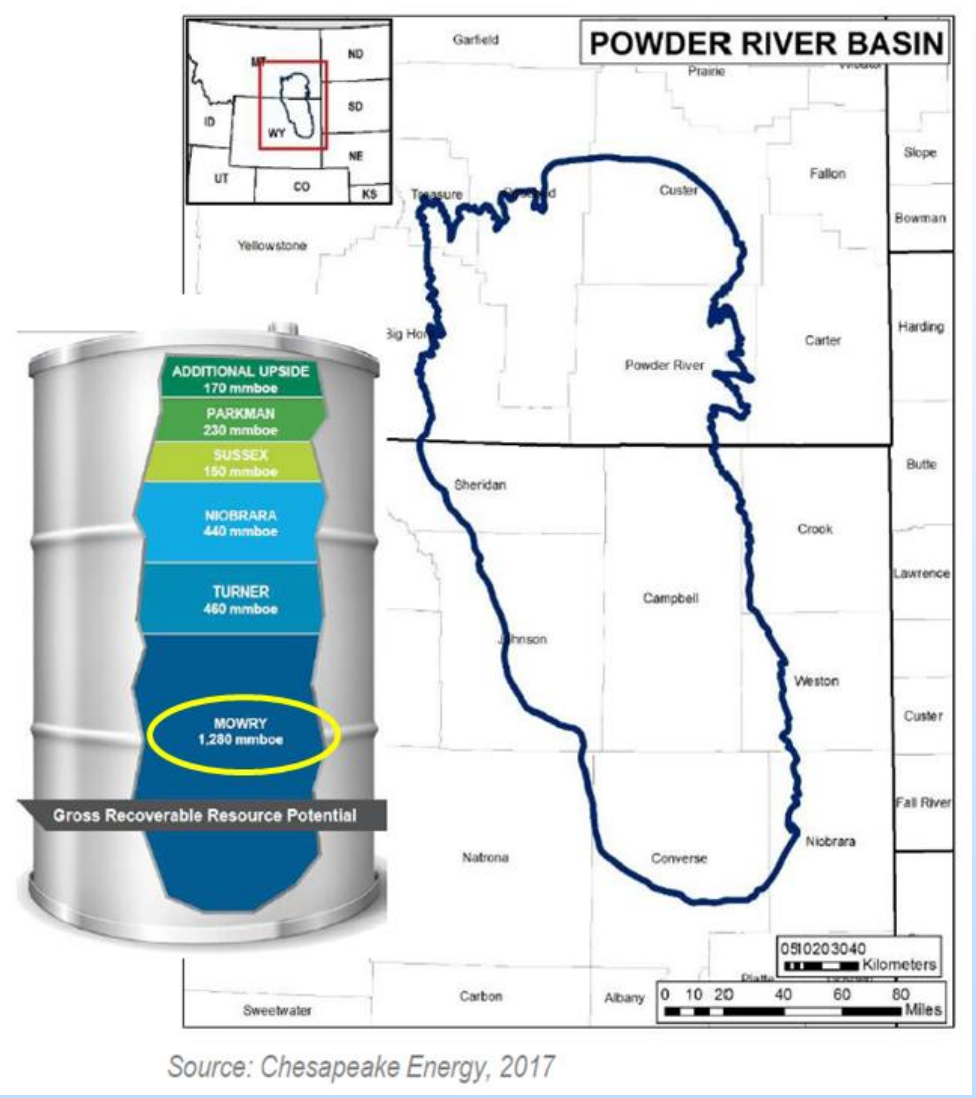
Project Cost, Dates, and Objectives

- Project Cost (Total for 4 years, plus 1-year NCTE): $14,425,550
  - $7,893,649 Federal share
  - $6,531,900 Cost share (45.28%)
- Important Dates:
  - Project Kickoff meeting: October 2019
  - NCTE granted: July 2020
  - Project Completion: June 2024
- Objectives:
  - Establish field laboratory in emerging PRB plays
    - Shale plays: Belle Fourche and Mowry
    - Tight sands: Frontier
  - Create basin-wide development strategy plan

Project Participants



Background



Source: Chesapeake Energy, 2017

Source: Advanced Resources International, 2020

- The PRB is a premier, emerging tight oil basin in the U.S.
  - 5,000 bbl in 2010
  - >130,000 bbl in 2019
- Currently, Parkman, Niobrara, and Turner contribute most to production
- Mowry (focus of project)
  - By far largest unconventional resource in basin
  - 1,280 MMBOE gross recoverable resource potential

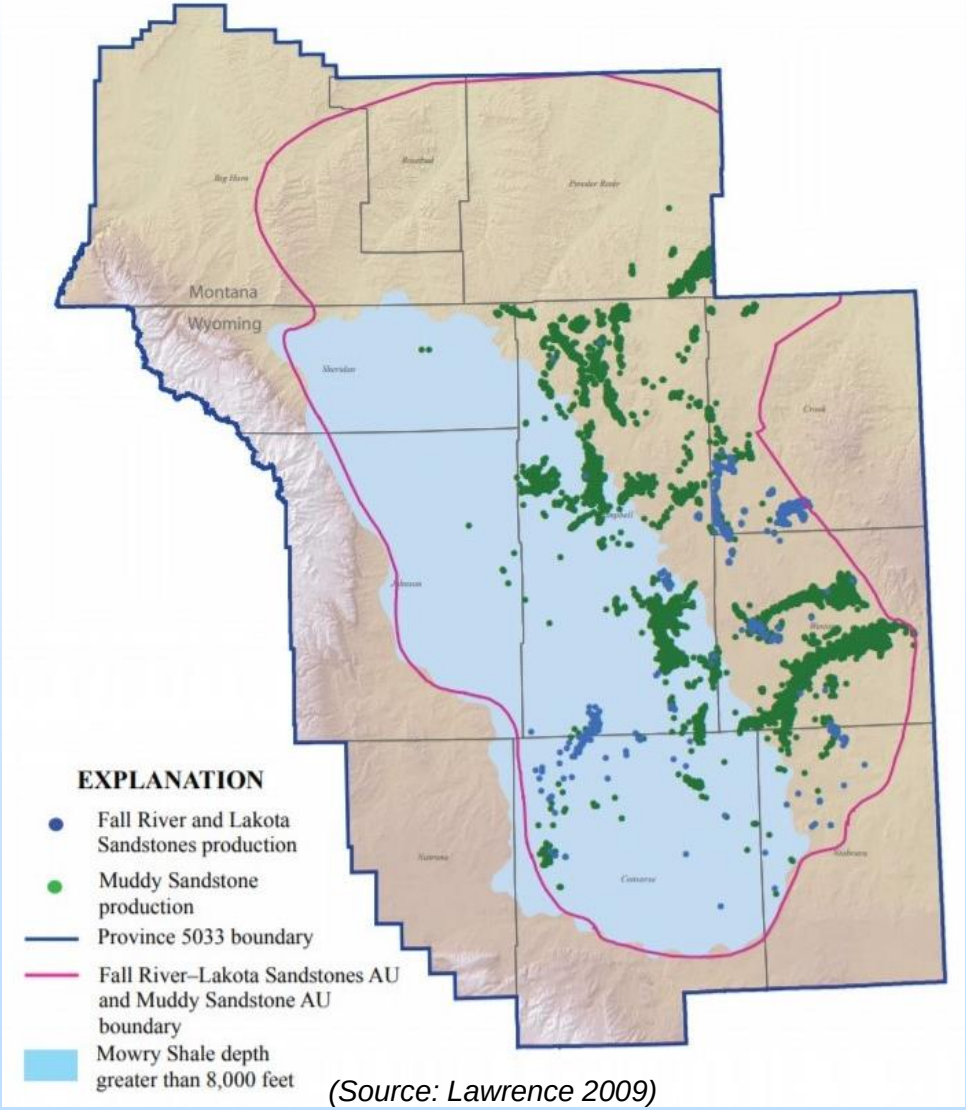
Background

- Mowry shale is the most prolific source rock in PRB
- Unconventional production from Turner, Frontier, and Mowry
  - In 2019:
    - Turner contributed 67,000 bbl/D
    - Frontier produced >10,000 bbl/D
    - Mowry shale produced 3,000 bbl/D

Source: Enverus, 2020

Background

- Mowry shale characteristics in PRB
  - TOC ranges from 2 to 3+% Type II and Type III kerogen
  - Expelled 11.9 BBO in the basin (Momper & Williams, 1984)
  - Mowry is extensive and pervasive across the PRB
    - Thickness ranges between 150 ft and 200 ft everywhere in PRB
    - Graphic indicates extent of the Mowry at greater than 8000’ of burial depth (the Mowry “kitchen” area)



(Source: Lawrence 2009)

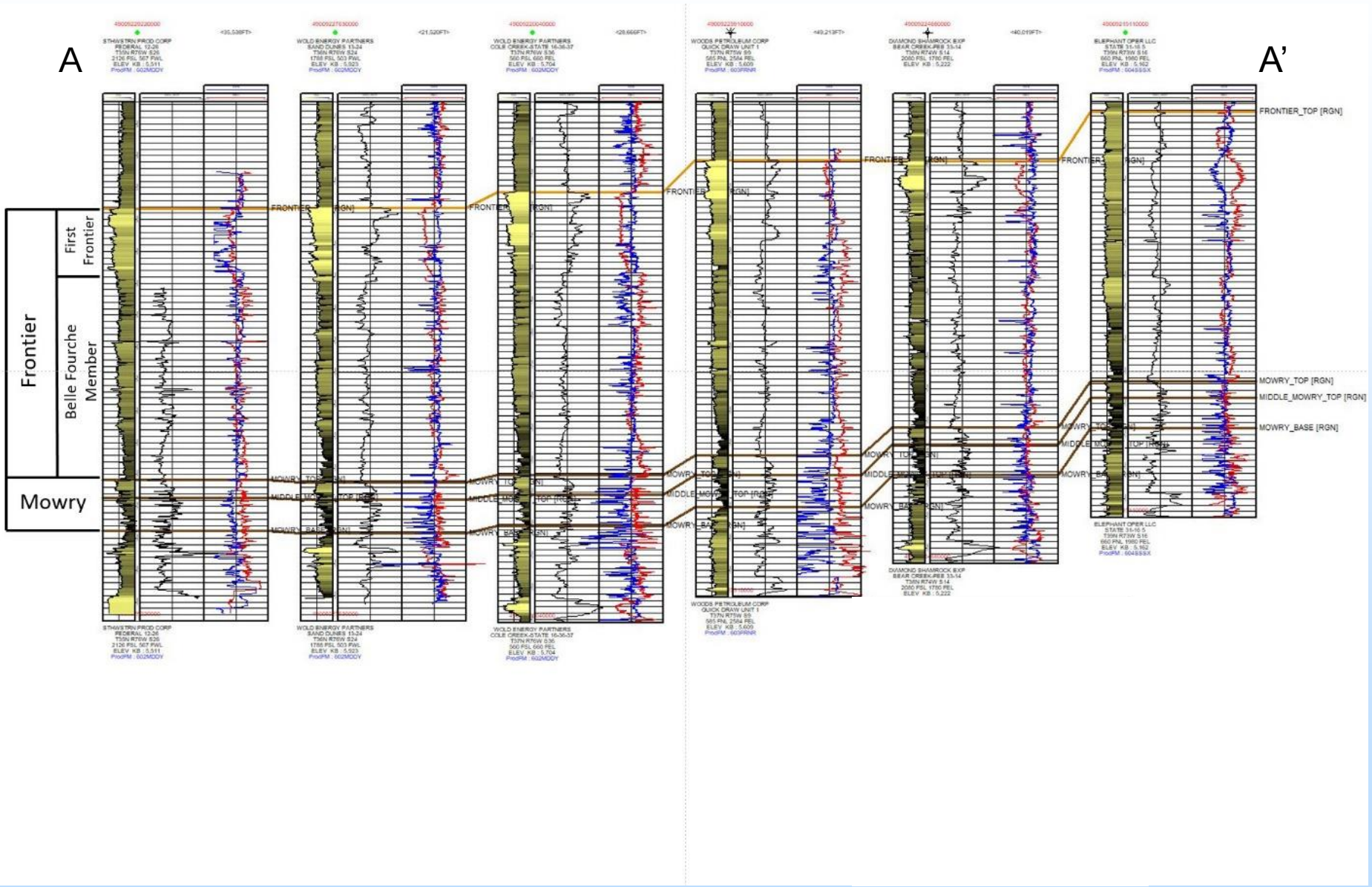
Technical Approach/Project Scope

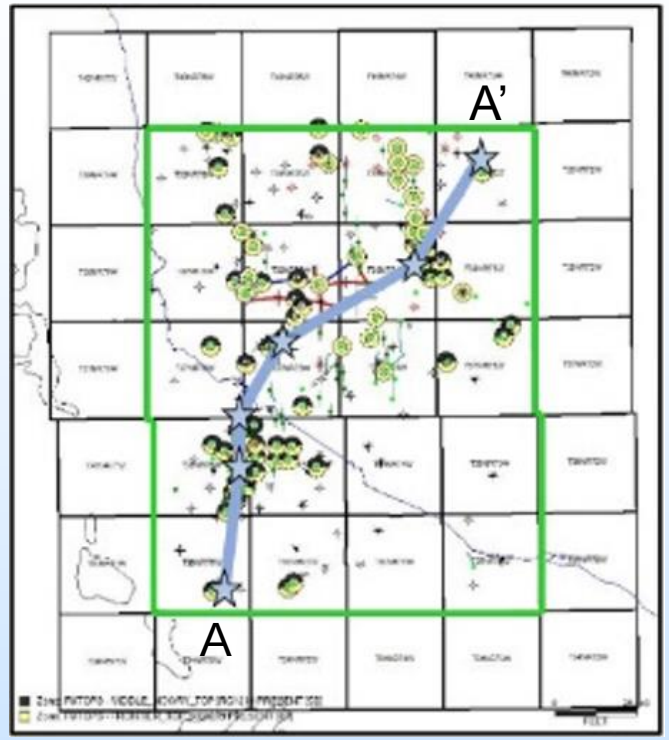
- Develop “optimized” completion design for emerging shale play
  - Characterize (basin-wide) Mowry, Belle Fourche, and Frontier formations in southern PRB
    - Detailed geological mapping across southern PRB from well logs
  - Learn from recent and current completion practices
    - Perform SOA analysis and MVA using recent completion data (type, stage spacing, proppant volumes, etc.) to develop optimized completion design
    - Incorporate machine learning to aid optimization
  - Characterize rock
    - Collect core from pilot hole or other appropriate location
    - Pore-scale visualization of fluid movement
    - Geomechanical studies: mineralogy, stress, permeability, fracture mechanics

Technical Approach/Project Scope

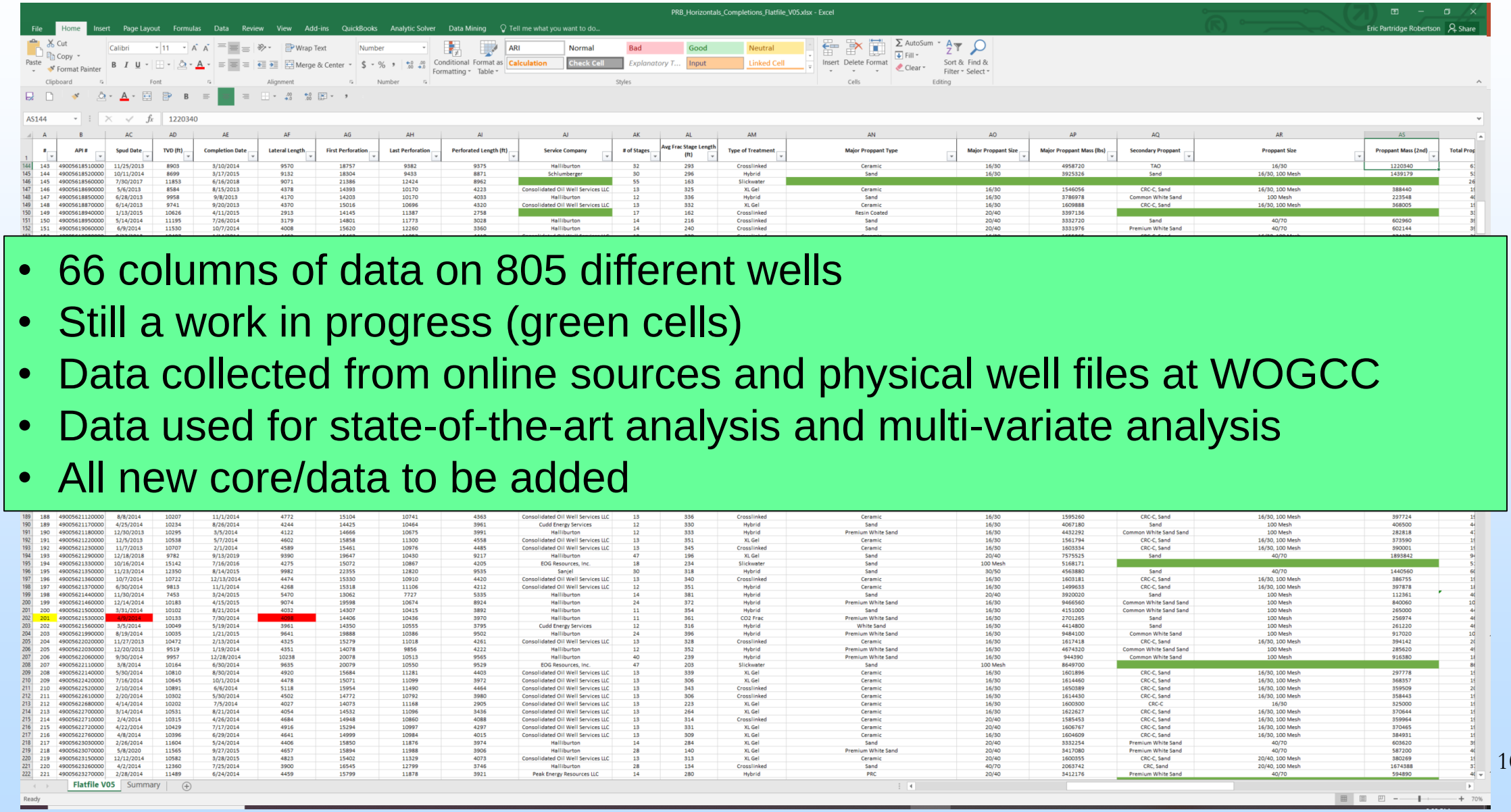
- Drill and complete new horizontal well (field laboratory)
  - Incorporate latest technology to monitor completion and production in real time
- Refine completion design as informed by feedback from field laboratory
- Share development strategy with stake holders
  - Developmental benefits, impacts, and challenges
  - Technical and economic viability for proposed strategy
  - Project risks and mitigation strategies
- Identify possible consortium members – additional operators

Basin-Wide Geological Model of Frontier, Belle Fourche, and Mowry



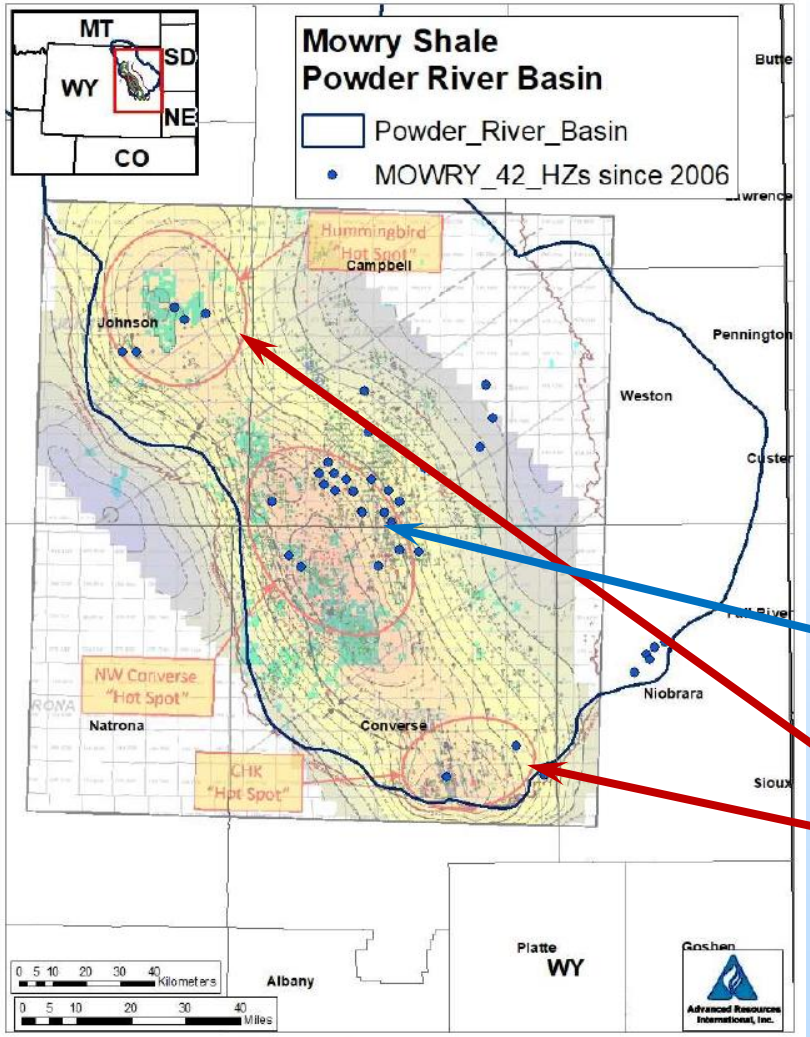


Historical Well Completions Data



- 66 columns of data on 805 different wells
- Still a work in progress (green cells)
- Data collected from online sources and physical well files at WOGCC
- Data used for state-of-the-art analysis and multi-variate analysis
- All new core/data to be added

Completion Practices: a State-of-the-Art Analysis

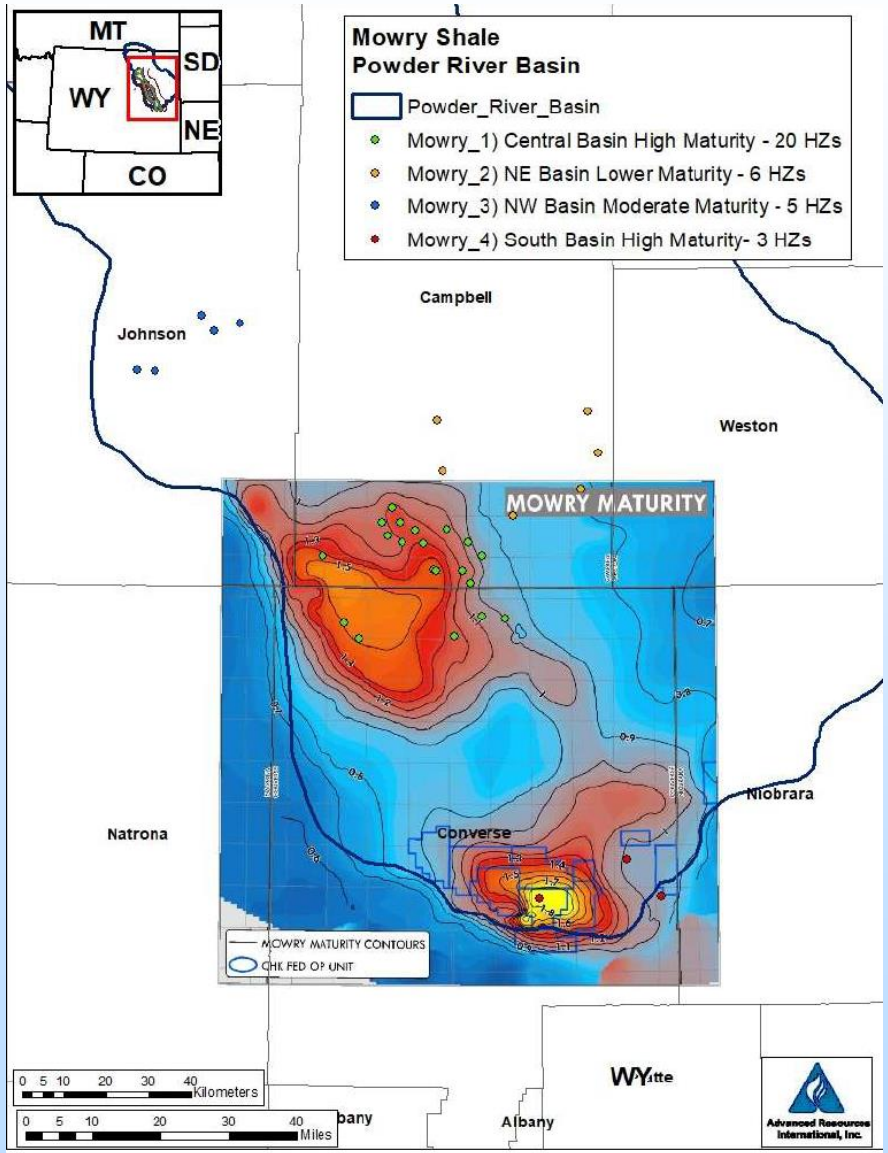


Source: Samson Resources, 2018.

- Finished SOTA analysis on Turner, Frontier, and Mowry formations
- Results of Mowry analyses shown here as examples:
  - 42 horizontal wells in emerging play, one-third completed after 2018
  - 26 wells located in south-central portion of basin
  - Most recent activity occurring in areas of higher thermal maturity

Completion Practices: a State-of-the-Art Analysis

- Mowry Results (as example):
  - Mowry partitioned into four categories (see map)
    - Central basin, high maturity (green dots)
    - NE basin, low maturity (orange dots)
    - NW basin, moderate maturity (blue dots)
    - South basin, high maturity (red dots)
  - Partitions further separated by time-slice to show changes in completion designs over time
  - Key learnings:
    - Lateral length has increased with time (currently approaching 9,000 ft) along with number of fracture stages
    - Proppant/stage increased from 50 tons to 370 tons
    - EUR/1000 ft increased from 20 MBOE to 42 MBOE



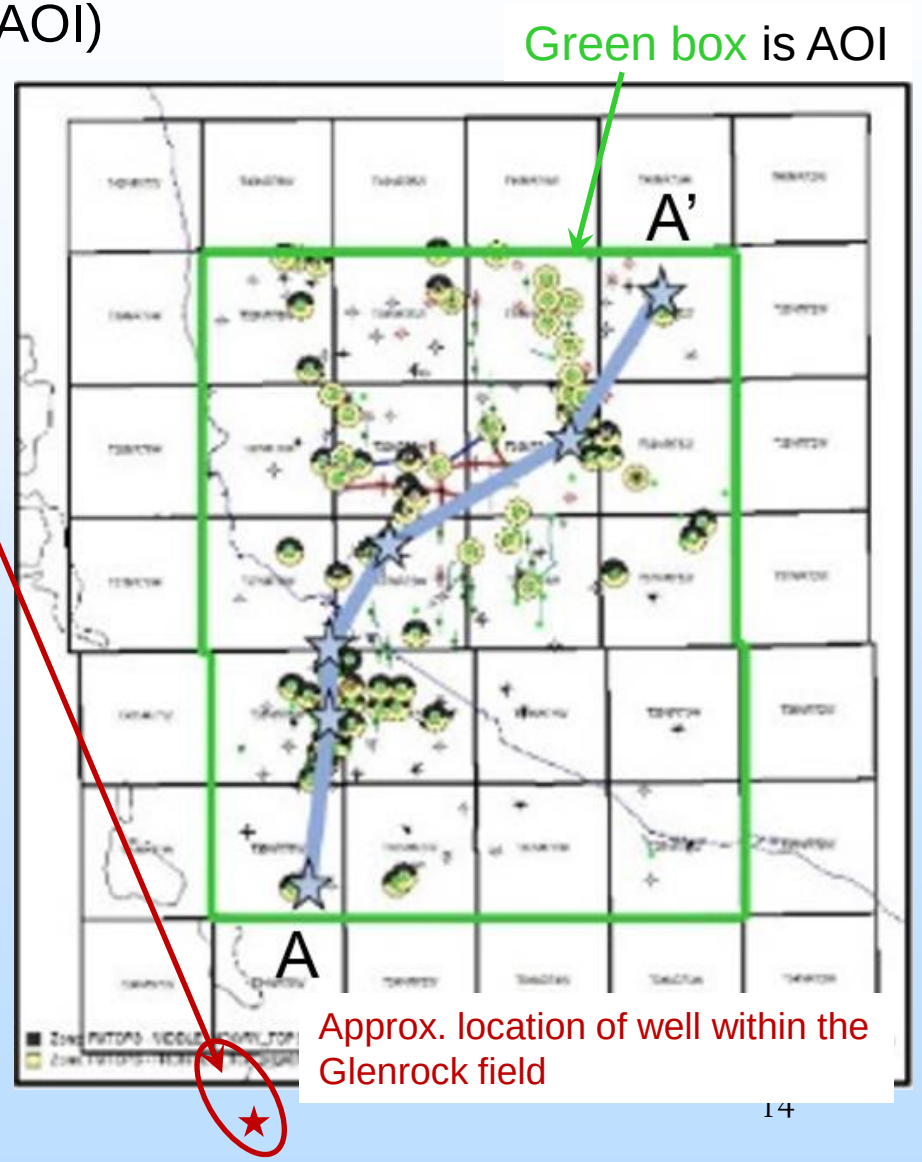
Source: Chesapeake Energy, 2017.

Concerns

- Collect core from pilot hole or other appropriate location(s) has been delayed
  - Causing critical lab work to be delayed as well
  - Originally planned to drill and collect core for characterization in 2020
  - Drilling of pilot hole postponed due to oil price collapse & COVID

Current Plans to Obtain Suitable Core

- Working with additional operators active in area of interest (AOI)
- Work with nearby Glenrock field operator to obtain core drilled through Mowry and Belle Fourche shales in November/December 2020
  - Well location is roughly 8 miles from AOI and less mature
  - Geomechanics and fracture characteristics will be similar
  - Belle Fourche logs indicate possibly higher TOC than in AOI
  - Mowry logs appear very similar between Glenrock and AOI
  - Obtaining Bell Fourche and Mowry core will allow:
    - establishment of facies relationships
    - better understanding of TOC and organic distribution
    - calibration of core to logs
    - understanding of how the bentonites affect these horizontal plays
  - Core data are always helpful in some way
- Core from well to be drilled through Mowry at Dry Fork Station (CarbonSAFE Phase III) in June 2021 (65 mi north of AOI)



Future Plans

- Complete multi-variate analysis of completion designs to determine critical variables and optimize design
- Characterize rock
  - Collect core from pilot hole or other appropriate location(s)
  - Pore-scale visualization of fluid movement
  - Geomechanical studies: mineralogy, stress, permeability, fracture mechanics
- Drill and complete new horizontal well (field laboratory)
  - Incorporate latest technology to monitor completion and production in real time
- Refine completion design as informed by feedback from field laboratory
- Share development strategy with stakeholders
  - Developmental benefits, impacts, and challenges
  - Technical and economic viability for proposed strategy
  - Project risks and mitigation strategies
- Add additional operators/consortium members if possible

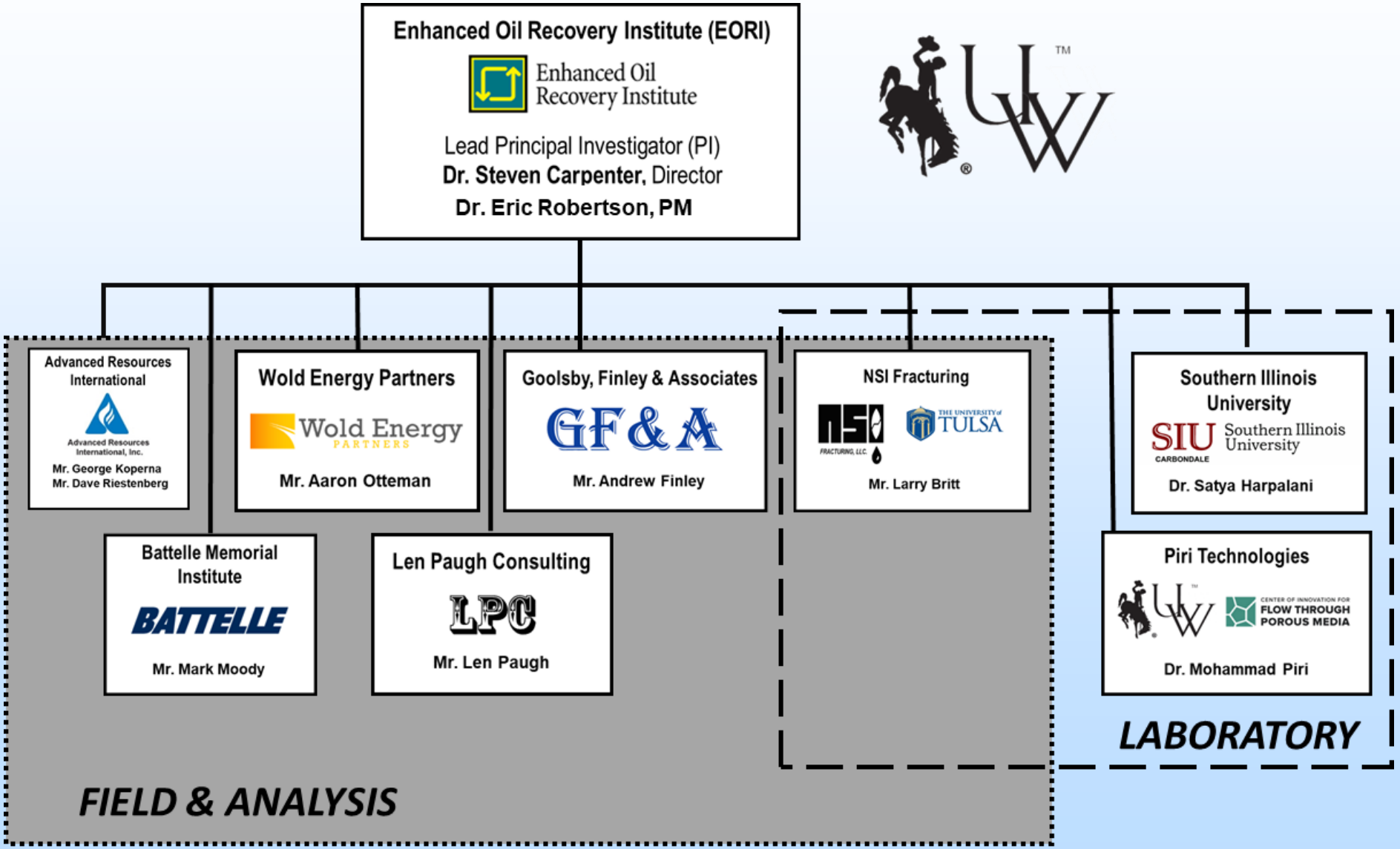
Summary

- Project will significantly aid the development of a key emerging unconventional oil play in Wyoming's Powder River Basin
  - A young project (< 1 yr) with delays (COVID-19, very low oil prices)
  - Expected to achieve outlined goals
- Key findings include better understanding of Mowry and completion practices
  - Pervasive, continuous, uniform thickness, and has at lease three main zones of higher TOC rock
  - Small number of wells, but operators are beginning to focus in on a standard completion
- Future plans include:
  - Continue with work to promote further exploitation of the Mowry resource
  - Partner with additional operators to grow the impact of its results

Appendix

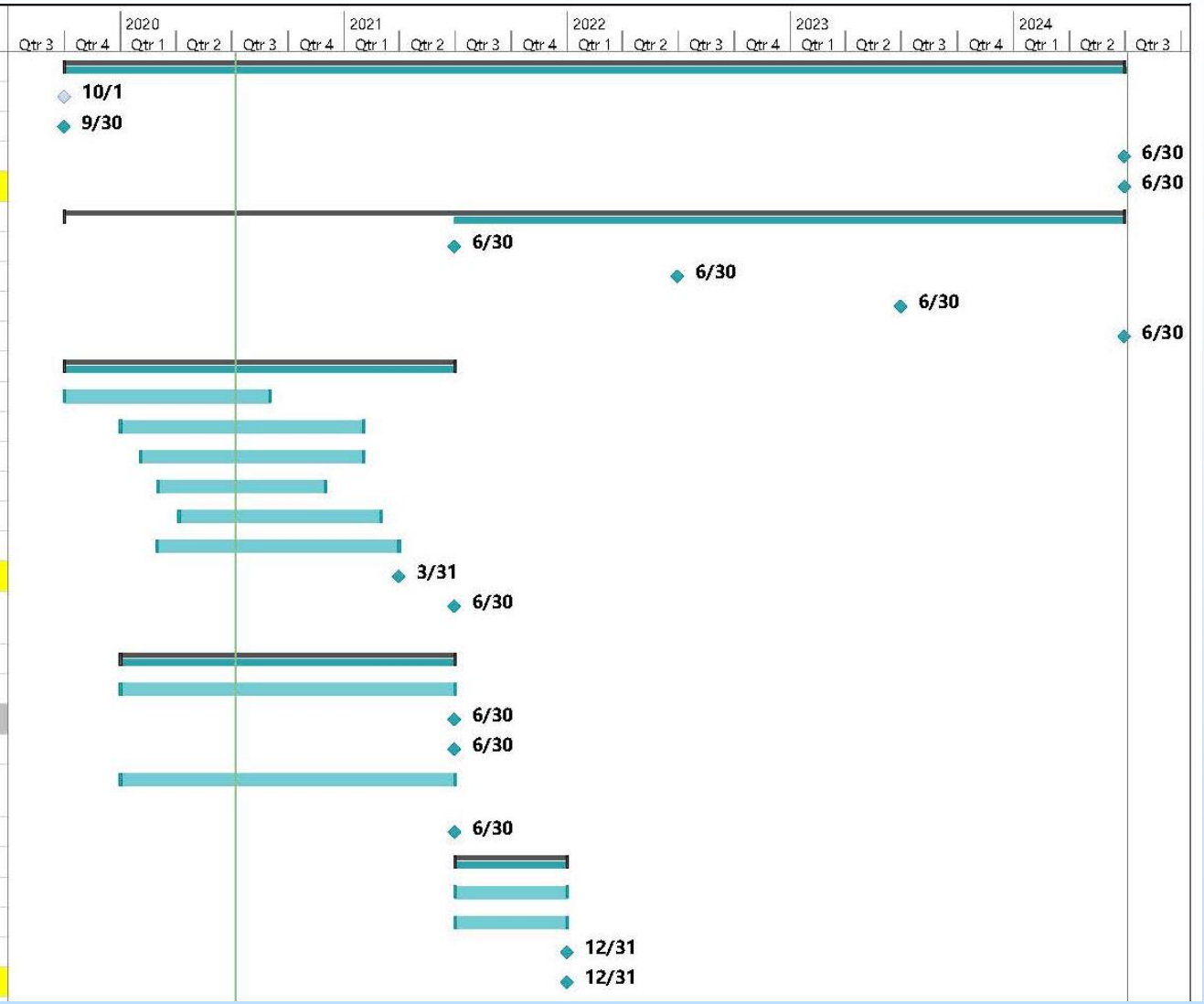
- Organizational Chart
- Gantt Chart

Organization Chart

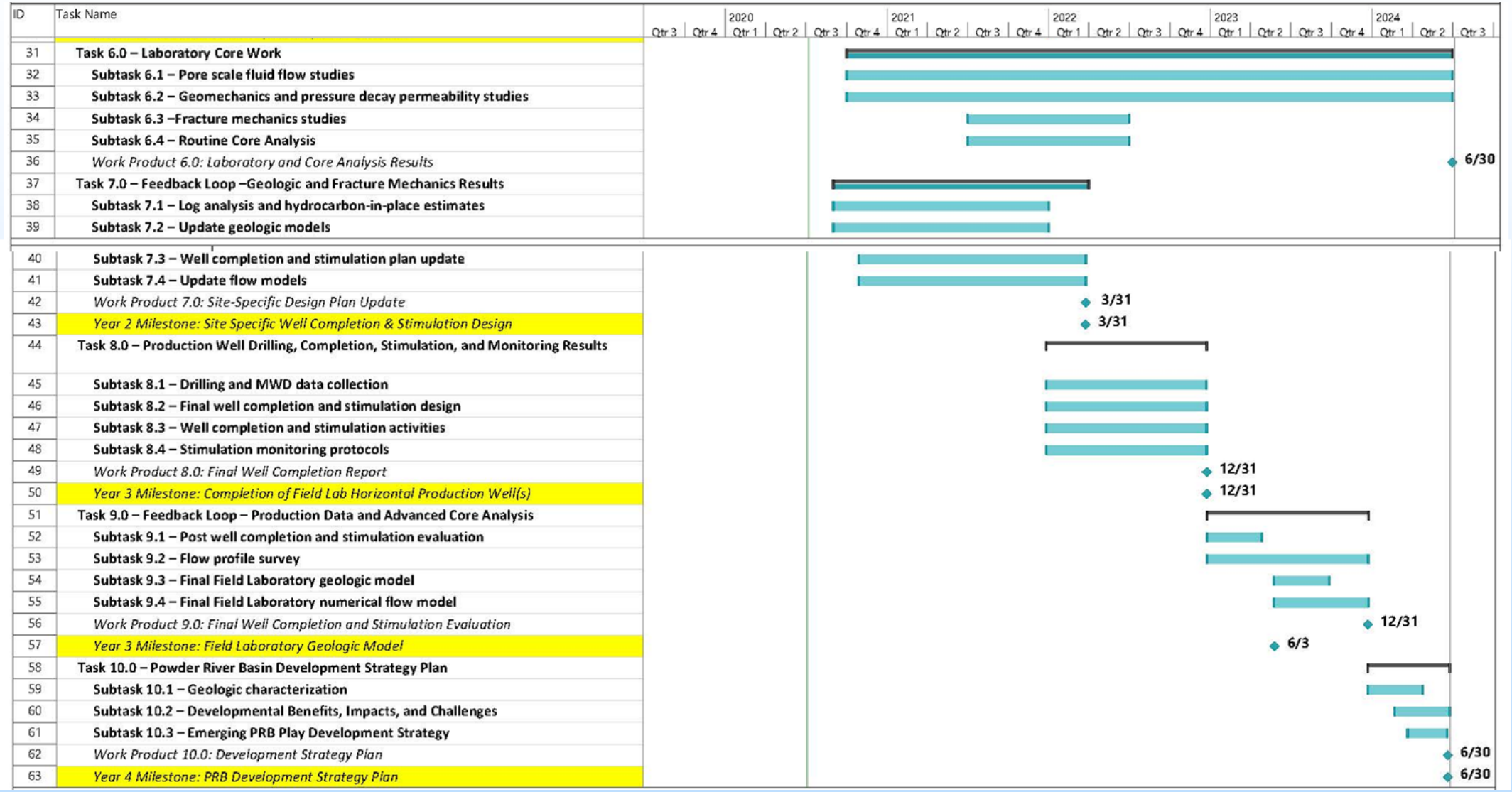


Gantt Chart

ID	Task Name
1	**Task 1.0 Project Management & Planning**
2	*Work Product 1.1: Revised Project Management Plan*
3	*Work Product 1.2: Data Management Plan*
4	*Work Product 1.4: Data Submitted to NETL-EDX*
5	*Year 4 Milestone: Upload data to EDX*
6	**Task 2.0 – Workforce Readiness Plan**
7	*Work Product 2.0a: Workforce Readiness Plan*
8	*Work Product 2.0b: Workforce Readiness Plan Update 1*
9	*Work Product 2.0c: Workforce Readiness Plan Update 2*
10	*Work Product 2.0d: Workforce Readiness Plan Update 3*
11	**Task 3.0 – Baseline Data Gathering and Models**
12	**Subtask 3.1 - Gather available data and identify gaps**
13	**Subtask 3.2 – PRB baseline geologic model**
14	**Subtask 3.3 – Develop current SOA for PRB well completion/stimulation**
15	**Subtask 3.4 – PRB baseline numerical flow model**
16	**Subtask 3.5 – PRB baseline economic assessment**
17	**Subtask 3.6 – Siting Field Laboratory**
18	*Year 1 Milestone: Field Laboratory Site Selection*
19	*Work Product 3.0: PRB SOA Development Strategies and Field Laboratory Site Selection*
20	**Task 4.0 – Develop Work Plans for Field Laboratory**
21	**Subtask 4.1 – Pilot hole testing and development plan**
22	*Go/No-Go Decision Point*
23	*Work Product 4.1: Pilot Hole Work Plan*
24	**Subtask 4.2 – Production well testing, development, and monitoring plan (completion and stimulation testing)**
25	*Work Product 4.2: Field Laboratory Work Plan*
26	**Task 5.0 – Pilot Hole Well Drilling and Data Acquisition**
27	**Subtask 5.1 – Pilot hole drilling**
28	**Subtask 5.2 – Coring and logging**
29	*Work Product 5.2: Pilot Hole Data Collection Summary*
30	*Year 2 Milestone: Collect Logs/Core from Pilot Hole*



Gantt Chart


ID
Task Name
2020
2021
2022
2023
2024
Qtr 3 Qtr 4 Qtr 1 Qtr 2 Qtr 3 Qtr 4 Qtr 1 Qtr 2 Qtr 3 Qtr 4 Qtr 1 Qtr 2 Qtr 3 Qtr 4 Qtr 1 Qtr 2 Qtr 3 Qtr 4 Qtr 1 Qtr 2 Qtr 3
31 Task 6.0 – Laboratory Core Work
32 Subtask 6.1 – Pore scale fluid flow studies
33 Subtask 6.2 – Geomechanics and pressure decay permeability studies
34 Subtask 6.3 –Fracture mechanics studies
35 Subtask 6.4 – Routine Core Analysis
36 Work Product 6.0: Laboratory and Core Analysis Results
6/30
37 Task 7.0 – Feedback Loop –Geologic and Fracture Mechanics Results
38 Subtask 7.1 – Log analysis and hydrocarbon-in-place estimates
39 Subtask 7.2 – Update geologic models
40 Subtask 7.3 – Well completion and stimulation plan update
41 Subtask 7.4 – Update flow models
42 Work Product 7.0: Site-Specific Design Plan Update
3/31
43 Year 2 Milestone: Site Specific Well Completion & Stimulation Design
3/31
44 Task 8.0 – Production Well Drilling, Completion, Stimulation, and Monitoring Results
45 Subtask 8.1 – Drilling and MWD data collection
46 Subtask 8.2 – Final well completion and stimulation design
47 Subtask 8.3 – Well completion and stimulation activities
48 Subtask 8.4 – Stimulation monitoring protocols
49 Work Product 8.0: Final Well Completion Report
12/31
50 Year 3 Milestone: Completion of Field Lab Horizontal Production Well(s)
12/31
51 Task 9.0 – Feedback Loop – Production Data and Advanced Core Analysis
52 Subtask 9.1 – Post well completion and stimulation evaluation
53 Subtask 9.2 – Flow profile survey
54 Subtask 9.3 – Final Field Laboratory geologic model
55 Subtask 9.4 – Final Field Laboratory numerical flow model
56 Work Product 9.0: Final Well Completion and Stimulation Evaluation
12/31
57 Year 3 Milestone: Field Laboratory Geologic Model
6/3
58 Task 10.0 – Powder River Basin Development Strategy Plan
59 Subtask 10.1 – Geologic characterization
60 Subtask 10.2 – Developmental Benefits, Impacts, and Challenges
61 Subtask 10.3 – Emerging PRB Play Development Strategy
62 Work Product 10.0: Development Strategy Plan
6/30
63 Year 4 Milestone: PRB Development Strategy Plan
6/30