Expanding the Margins of the Williston Basin

The Impact of Refined Stimulation Design

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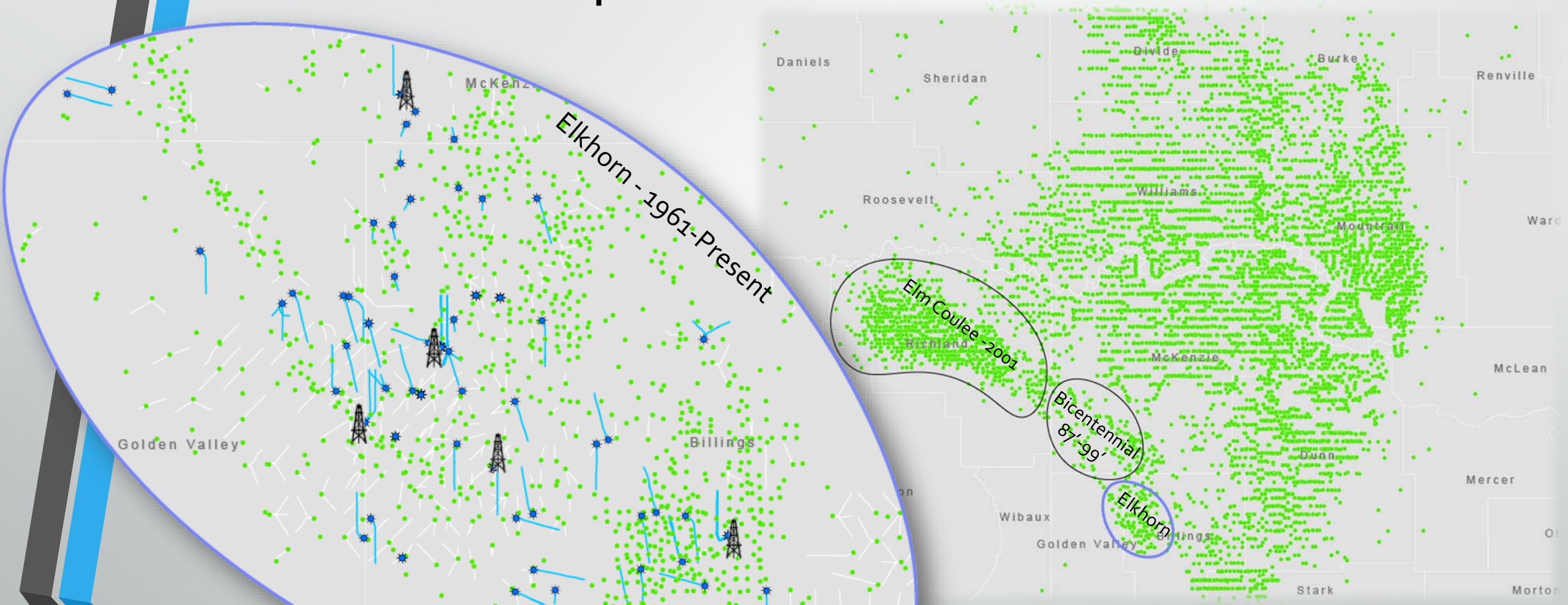
Overview

- Project Overview
  - Locator Map
  - Economic Opportunity
  - Continuous Improvement Cycle
- Design Process
  - Data Evaluation and Integration
  - Oil Potential Variation
  - Perforating and Proppant Diversion
- Results and Conclusions

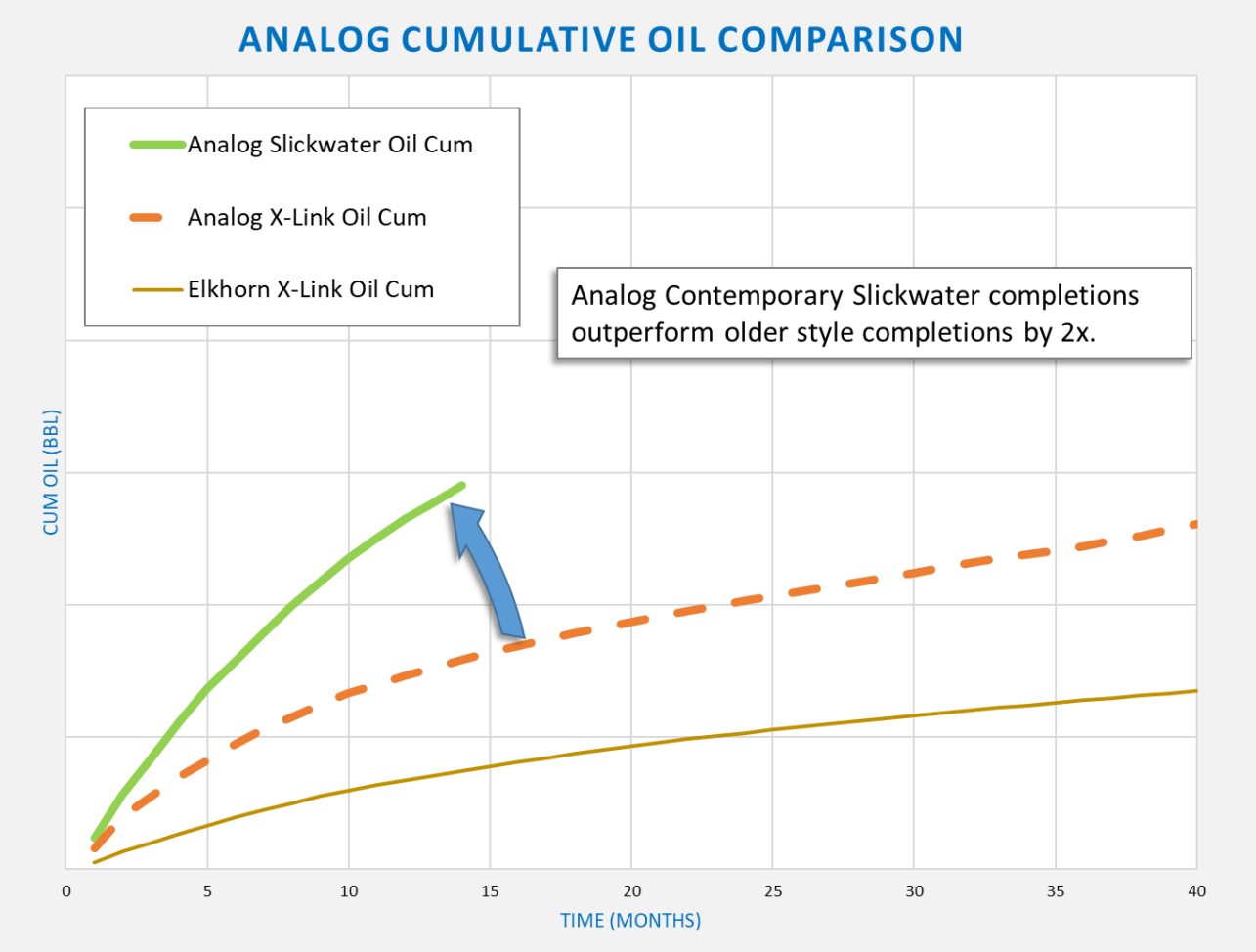
Overview Map – Williston Basin



Elkhorn project, 5 wells D&C 2017+

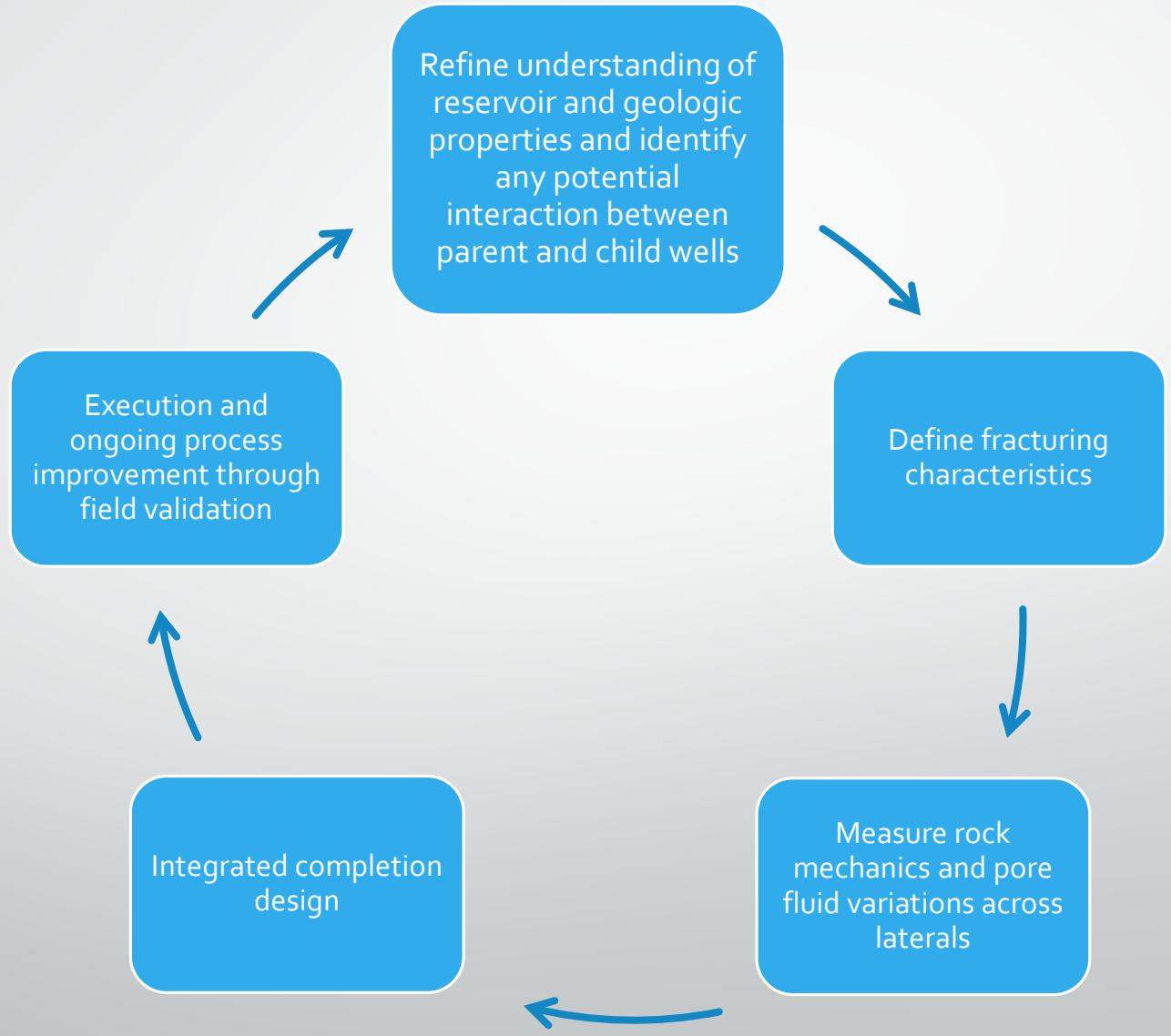
- Engineered completions (mass and placement)
- 4.3 – 7.4 MM lbs proppant
- 33-35 stage slickwater completions
- Limited entry perforating

Economic Opportunity



- Project area was initially delineated by legacy completions:
  - Vertical wells, vintage unstimulated horizontals and early x-link completions.
- Contemporary completions in offset analog field suggested meaningful ROI upside if completions and associated production could be maximized.
- Pilot hole logs and regional geology suggested an opportunity for refinement through engineered completions.

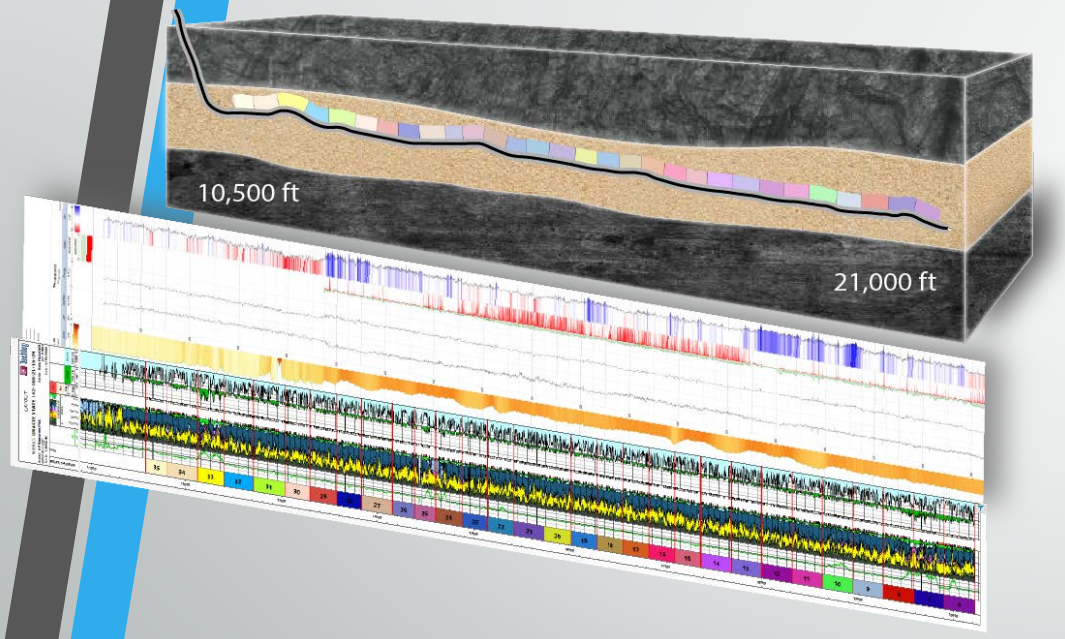
Continuous Improvement Cycle



Data Evaluation – Elkhorn Field

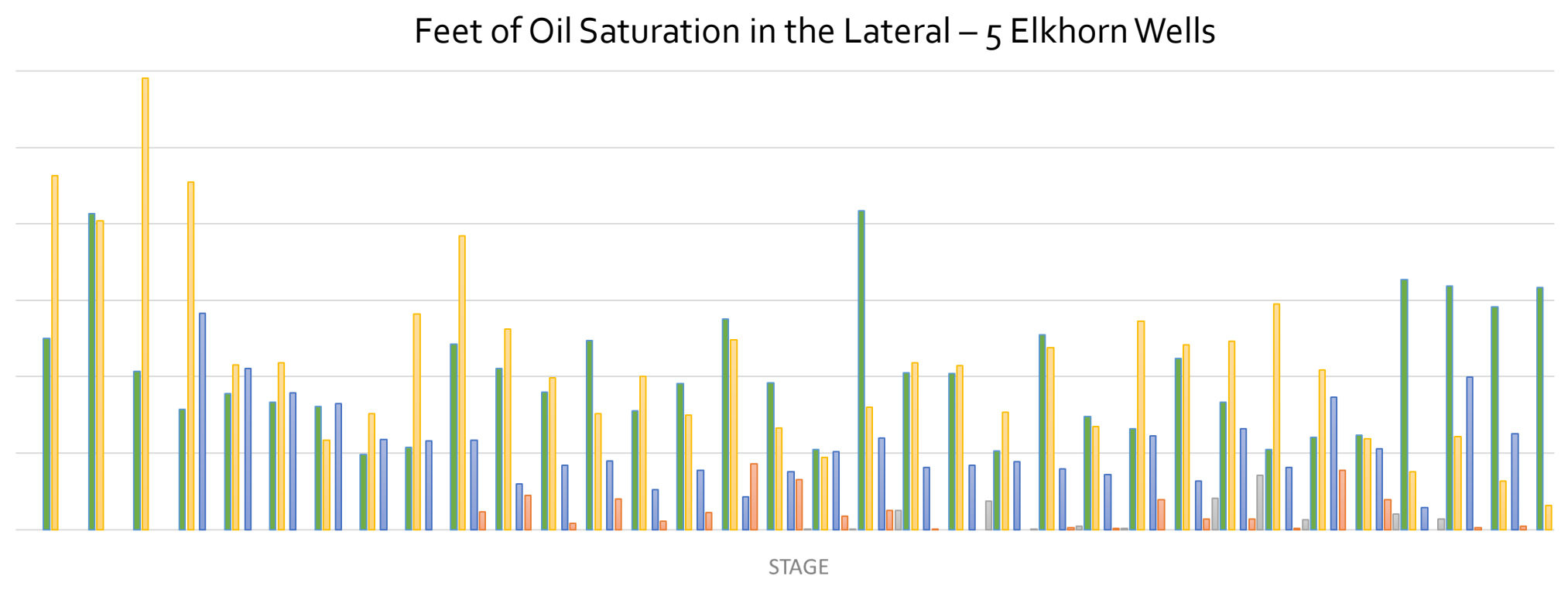
- Completion evaluation suggested poor lateral efficiency from legacy completions.
- The water cut from legacy completions suggested stimulations were communicating with adjacent layers containing higher water saturations.
  - Very high oil cut (90% – 100%) in unstimulated wells
  - Low oil cut from x-link completions (30 – 40%)
- The variation in production responses appeared to be more closely related to variations in stimulation and execution than reservoir quality.

Integrated Design Process



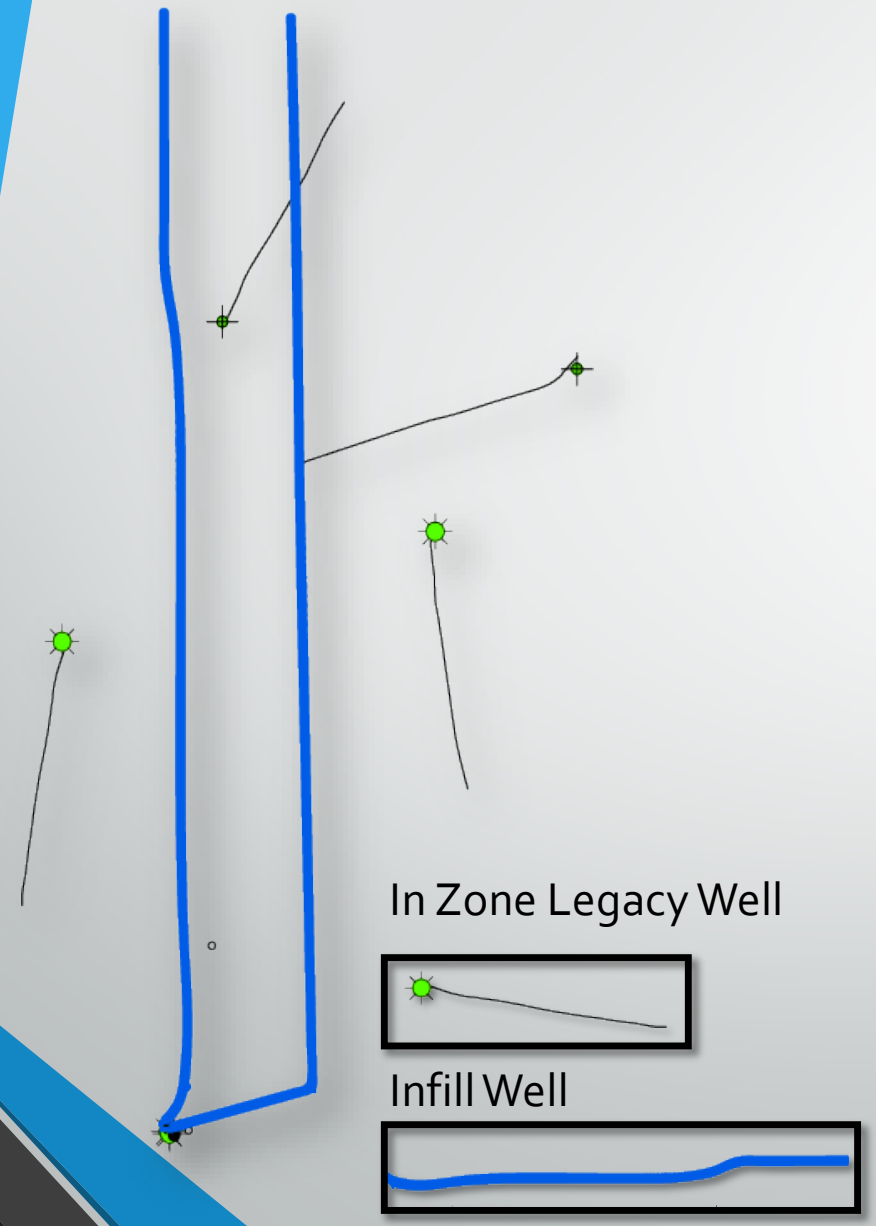
- Completion design must be optimized to accommodate reservoir variability along the lateral.
- Stage length and number of clusters were customized based on variations in mechanical properties.
  - Segments of high or low stress are grouped into stages.
  - Changes in average stress in the lateral dictate required perf friction for limited entry to work.
- Increased investment in larger frac treatments was justified in stages with thicker pay or higher oil saturations
  - Smaller stages were used in stages displaying reduced potential to maximize ROI

Lateral Variability-Feet of Saturation



- Not all wells need the same mass of proppant and volume of fluid, fine tuning the right job mass by stage is key.

Interaction with Legacy Production



- Data gathered in the lateral can be used to infer areas of depletion that effect how a fracture may propagate.
- Portions of the lateral with less favorable fluid saturations, or pore pressure may be left unstimulated.
- Stage mass and volume can be directed to areas in the lateral that will produce a favorable ROI.

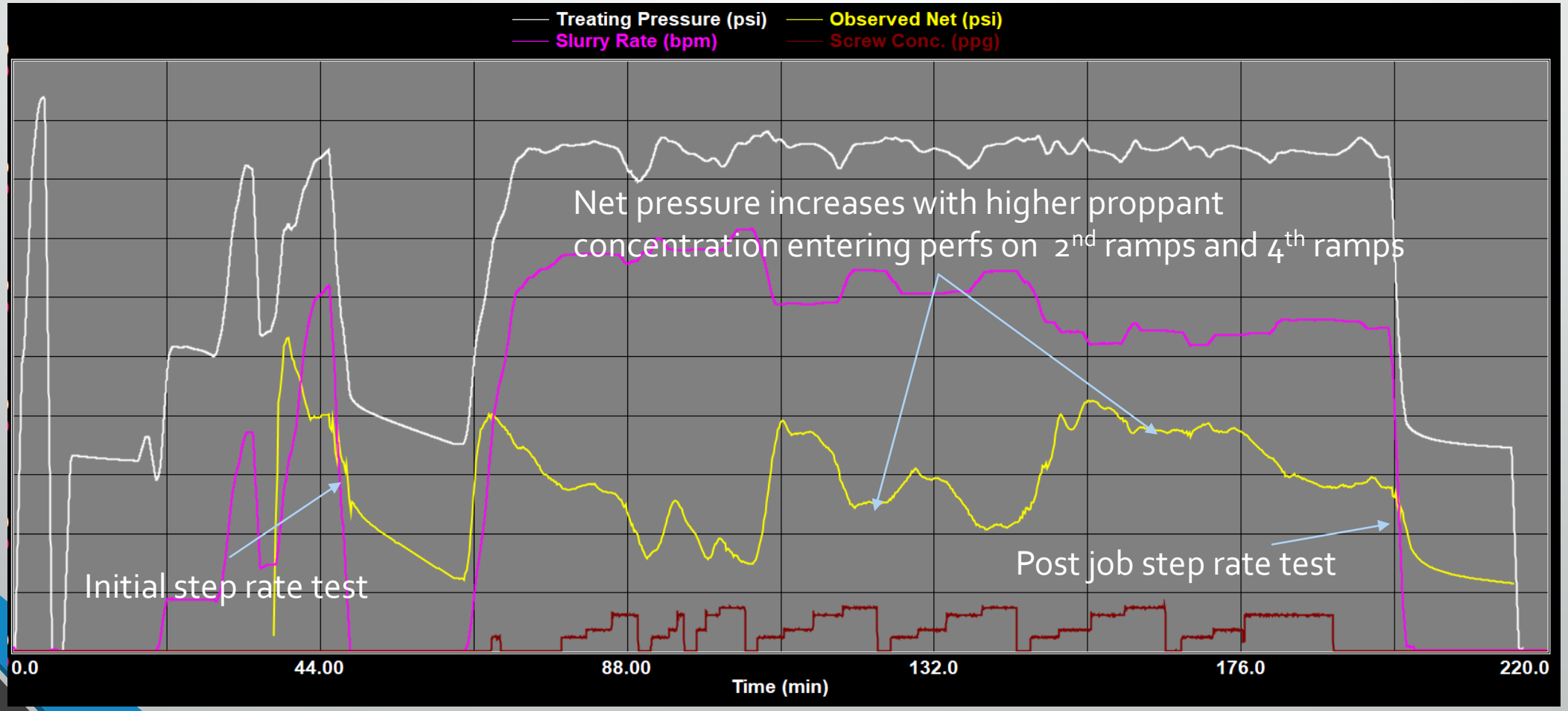
Perforating

- Average cluster efficiencies of >90% per stage can be achieved by:
  - Adapted extreme limited entry as piloted by Liberty Resources
  - Grouping stages by similar stress
  - Matching perf friction to overcome rock stress variations by stage
  - Oriented perforating
  - Equal exit hole diameter charges

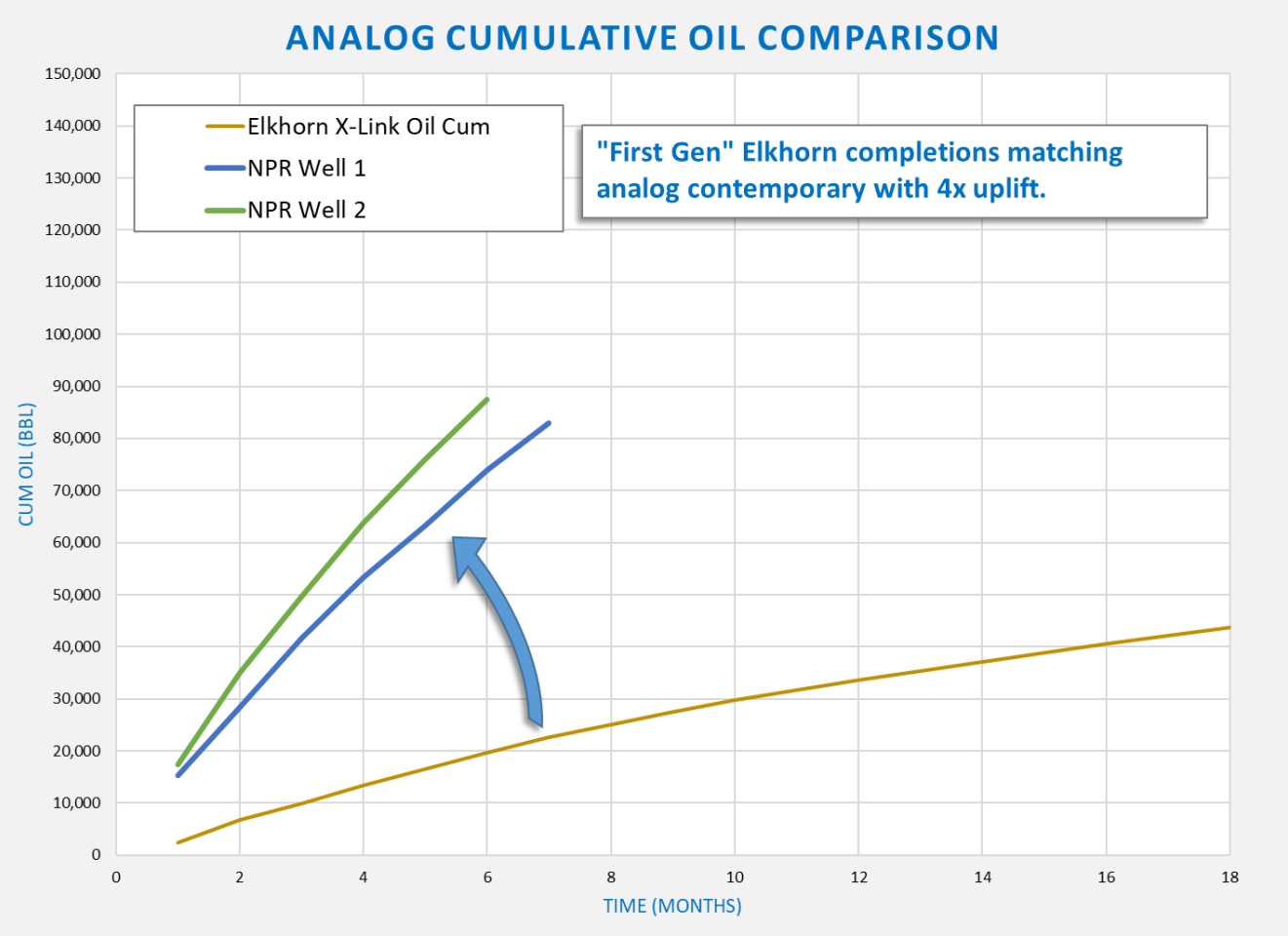
- Perforating efficiencies are gauged by:
  - Initial and final step rate tests
  - Chemical tracers

Proppant Diversion

- High efficiency limited entry can be combined with proppant slugs to produce similar trends in observed net pressure to other diverting agents.
- Post job step rate test confirm a reduction in clusters taking fluid through the course of the stage.



Results – initial program



- Project area wells show 4x uplift from legacy wells.
- Meaningful upside ROI was realized with an engineered completion approach turning a "marginal" field into a development project with robust economics.
- Still in relatively early stages of program (5 wells) with more process improvements planned.

Conclusions

- Cluster efficiencies of >90% were achieved with limited entry.
- Rock mechanics measured in the lateral helped drive stage placement and limited entry design.
- The proppant mass and fluid volume were tied to the fluid saturations in each stage.
- The engineered completion improved the effective stimulation with an increase of ~four times the legacy well baseline production. Measurements of rock stress and pore fluid volume in the lateral were an important part of this design approach.
- Questions?