MAXIMIZING THE RESERVOIR ACCESS WITH COMPLETION OPTIMIZATION AND EFFECTIVENESS

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AGENDA:

- Completion effectiveness
- Intro Case Study
- Completion
- Production analysis
- Completion costs
- Conclusions

Completion Effectiveness

- Challenges to analyze unconventional Shale reservoirs
- Multifracture Horizontal well MFHW - Flow regimes
- Rate Transient Analysis fundamentals
- Diagnostic Plots - Linear flow Specialized plot indicator of completion effectiveness
- SPE references

Challenges to analyze unconventional shale reservoirs

- Flow regimens stay in transient flow for a long period of time
- Difficulties to estimate the ultimate recovery, XF, Permeability, Fracture conductivity and drainage area
- DCA assumptions used for conventional reservoirs not valid
  - Existence of boundary dominated flow
  - Constant flowing bottom-hole pressure

- **Evaluation of** unconventional Shale reservoirs requires rate, pressure and other reservoir parameters to determine the flow capacity in linear flow.

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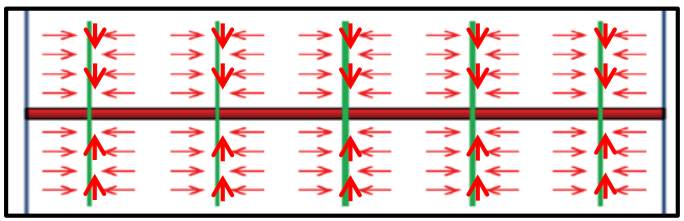
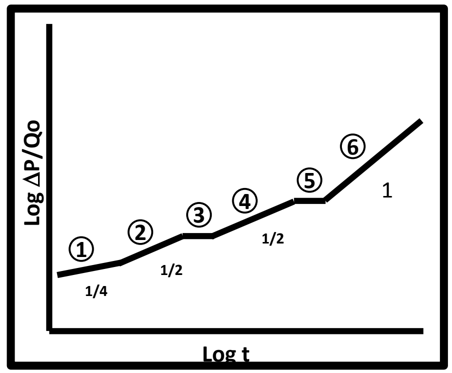
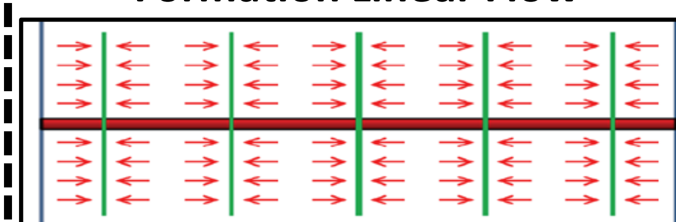
Flow regimes in a MFHW Schematic (SPE 162647)

Bi-Linear Flow

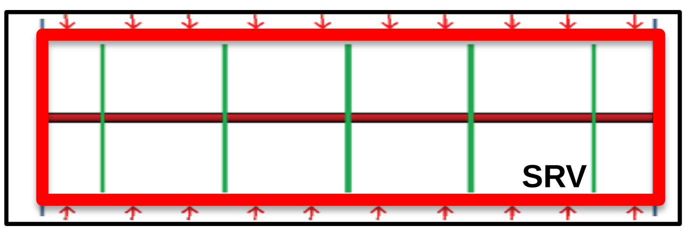




Formation Linear Flow



Compound / SRV Linear Flow

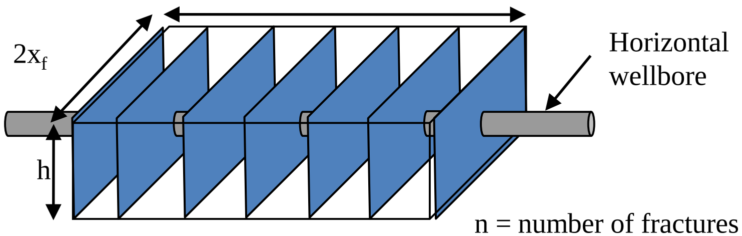


1. Bi-Linear Flow
2. Formation Linear Flow
3. Transition Period
4. Compound / SRV Linear Flow
5. Transition Period
6. Boundary Dominated Flow

Boundary Dominated Flow

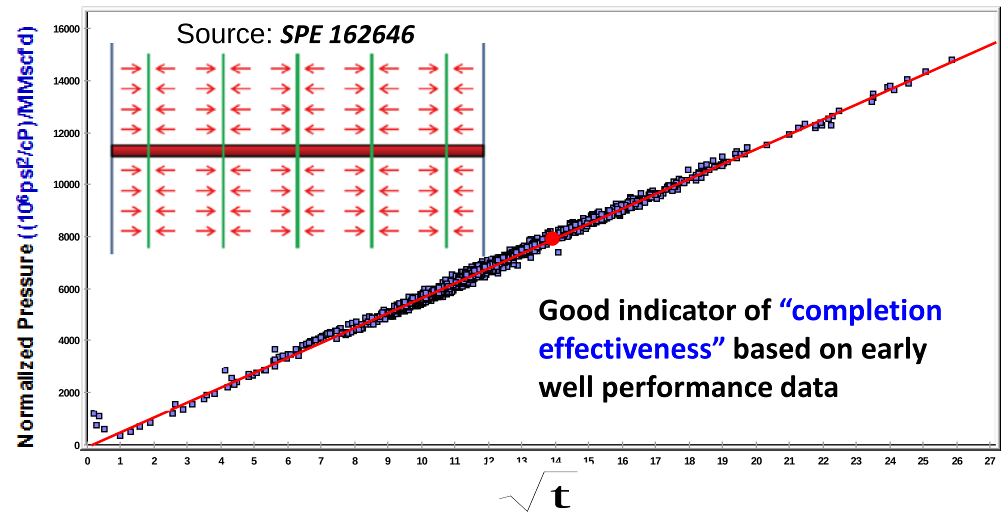
Rate Transient Analysis fundamentals

Multifracture Horizontal well MFHW



$$Af = A_c = 2X_f * h * 2n$$

Diagnostic Plot – Linear flow Specialized plot

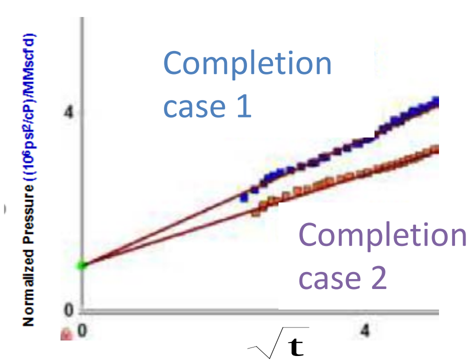


Lineal flow (equation solution)

$$\frac{(Pi - Pwf)}{q} = 16.26 \cdot \frac{B}{Af} \cdot \left(\frac{\mu \cdot t}{k \phi Ct} \right)^{1/2} + 141.3 \cdot \frac{B\mu}{kh} \cdot Sf$$

$$\frac{P_i - P_{wf}}{q_g} = \frac{C * \sqrt{t}}{A_c \sqrt{k}}$$

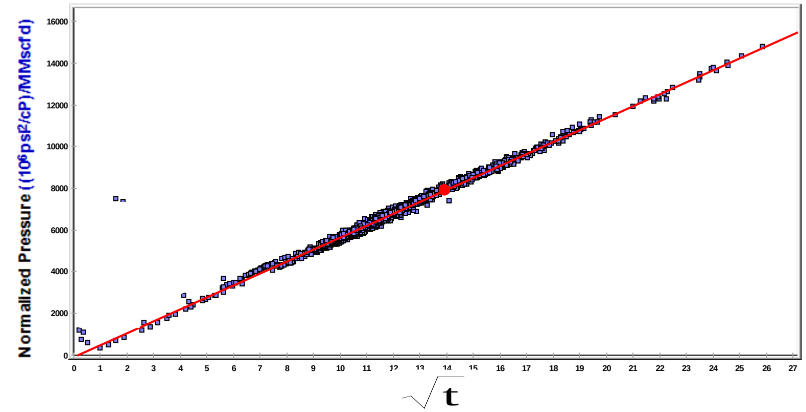
Normalized pressure vs SQR time



Completion case 2 More contacted area than Completion case 1

Diagnostic Plot – Linear flow Specialized plot Normalized pressure vs SQR time

- Can be used as “Completion Effectiveness” tool if limited variation in reservoir properties
- Good indicator of “Completion Effectiveness” based on early well performance data
- Plot identifies transient lineal flow and quantifies total connected fracture area and square root of SRV permeability.



- Use of linear flow tendency over predict EUR……..however, Good correlation between Norm.AQRT vs Norm.EUR

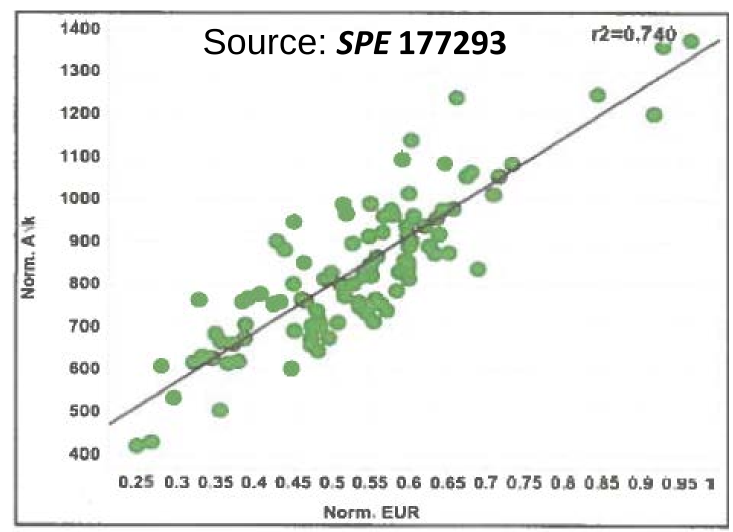


Figure 3—Normalized $A\sqrt{K}$ vs. Normalized EUR

References

- SPE – 162646: Importance of the Transition Period to Compound Linear Flow in Unconventional Reservoirs
- SPE – 162647: What's Positive about Negative Intercepts
- SPE – 177293: Production Analysis using Rate Transient Analysis
- URTeC – 2688694: Timely Understanding Of Unconventional Reserves through Rate Transient Analysis

MAXIMIZING THE RESERVOIR ACCESS WITH COMPLETION OPTIMIZATION: CASE STUDY VACA MUERTA

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INTRODUCTION

- 2 wells in the same PAD
  - Well A => Pinpoint
  - Well B => Plug & Perf

Both wells targeting Vaca Muerta

Comparison of completion methodology, RTA analysis and costs

COMPLETION: *Methodology*

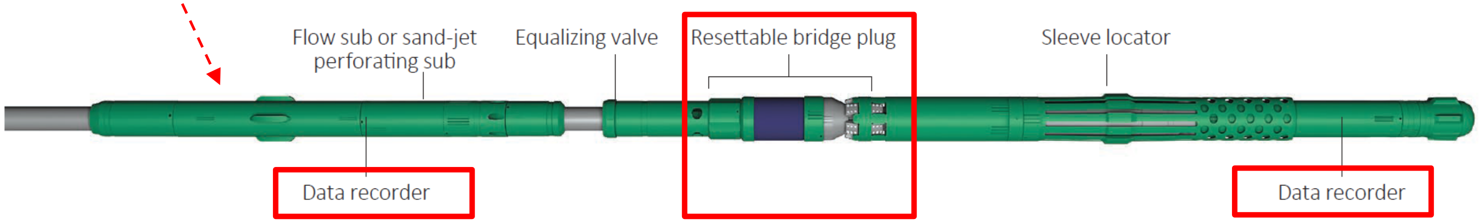
WELL A - **PINPOINT**

- 60 coiled tubing shifted sleeves installed - RECLOSABLE
  - 58 stimulated
- Average spacing ~24.9m between sleeves
- Isolation inside casing with resettable bridge plug on CT BHA
- Annular frac
- No frac plug drillout

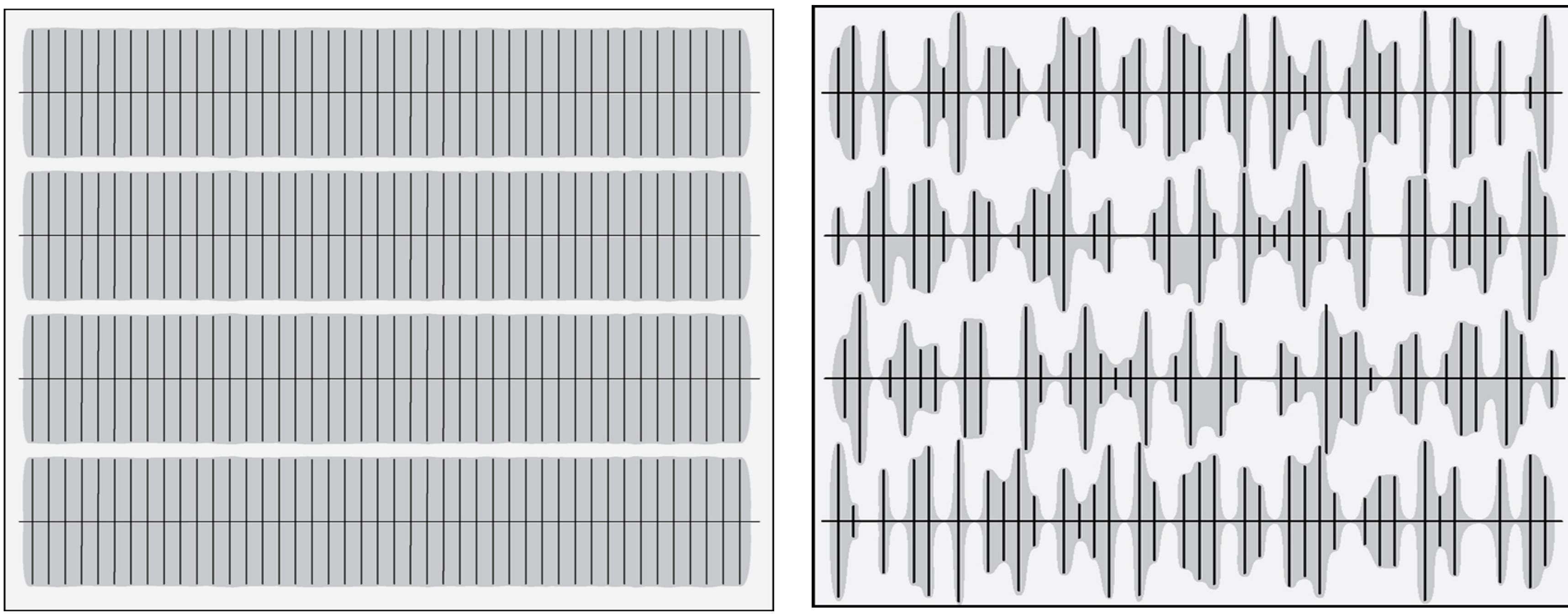
Pinpoint frac isolation tool (see schematic)

WELL B - **PLUG & PERF**

- 18 frac stages / 54 entry points
- 3 perforation clusters per frac stage
  - Isolated by bridge plugs
- 10 perforations per cluster / 0.5 m
- Average spacing ~24.5m between clusters
- Required frac plug drillout



COMPLETION: *Methodology*



COMPLETION: *Frac Design*

Similar treatments

- Hybrid fluid design
- Increasing proppant size 100 mesh to 20/40

Some differences

- Fluid volumes and distribution of fluid type
- Injection Rate
- Proppant size distribution
- Lateral length

Average per entry point

Well	WELL A	WELL B
Entry Point Spacing (m)	**24.9**	**24.5**
Slickwater (bbls)	**1,636**	**1,172**
Gel (bbls)	-	20
Crosslink (bbls)	915	1,210
Total Fluid (bbls)	**2,551**	**2,403**
100 mesh (lbs)	16,144	12,315
40/70 sand (lbs)	45,121	47,220
40/80 Sinterlite (lbs)	40,937	
30/50 sand (lbs)		35,739
30/60 Sinterlite (lbs)	26,418	35,433
20/40 Wanli (lbs)	29,028	29,980
Total (lbs)	**157,648**	**160,687**
Injection Rate (bpm)	**23.3**	**17.3**

-24%

+35%

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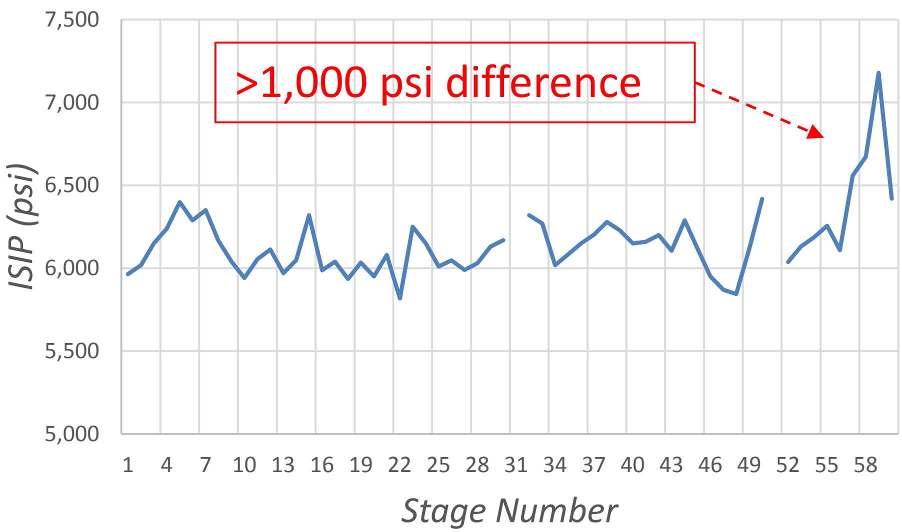
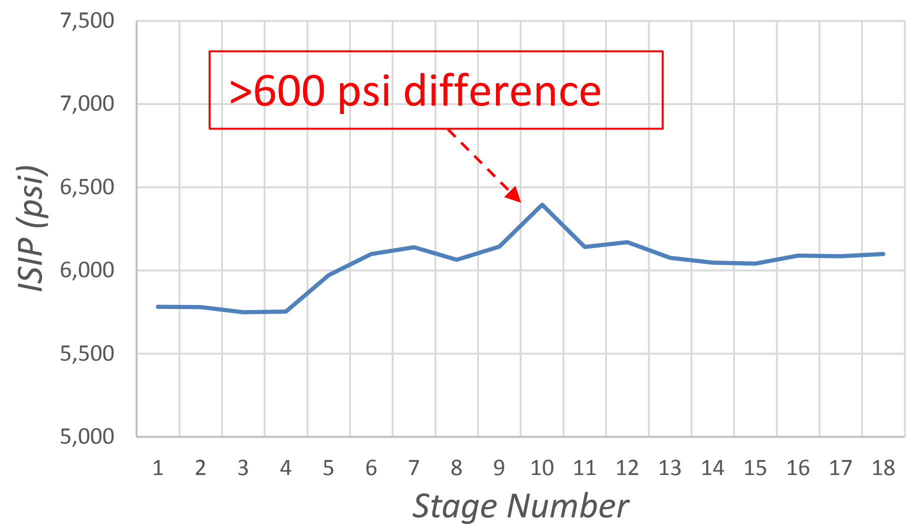
COMPLETION: *Instantaneous Shut-In Pressure*



WELL A

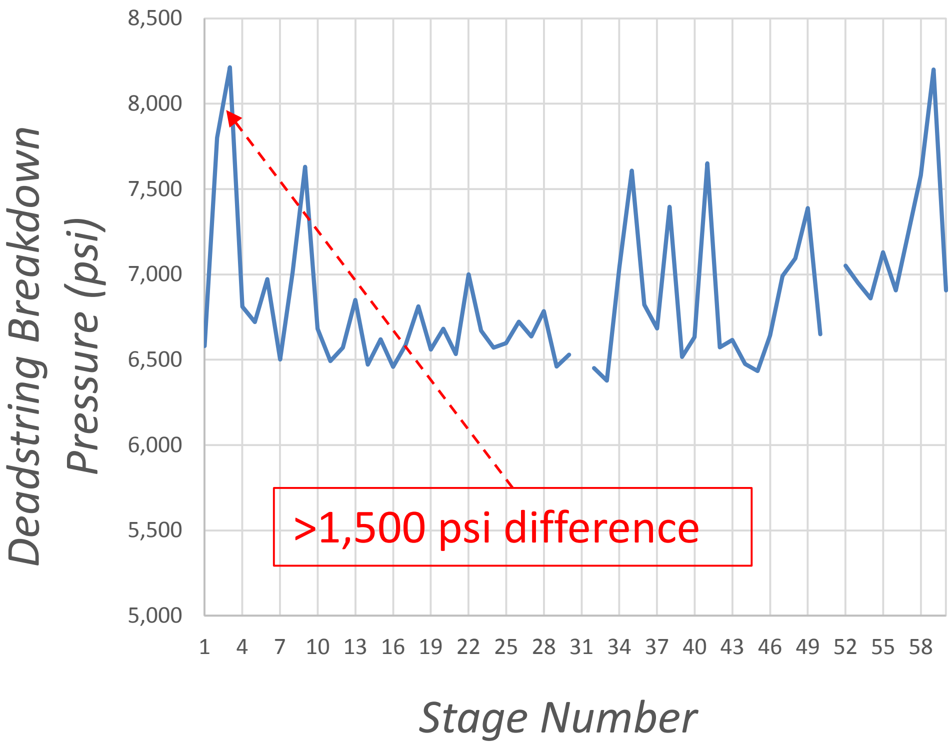
- Individual entry point ISIPs **(BH data)**
- Show end of job pressure variability



WELL B

- Only ISIP data available (surface)
- Shows some variability even with "averaging" effect of 3 clusters

COMPLETION: *Breakdown Pressure (BH gauge)*



WELL A Formation Breakdown Pressure

- Individual entry point breakdown pressures
- Show early job pressure variability
- Deadstring data (BH)
- 58 of 60 zones treated (~96.7%) on WELL A
- **NO DATA ON EFFICIENCY ON WELL B**

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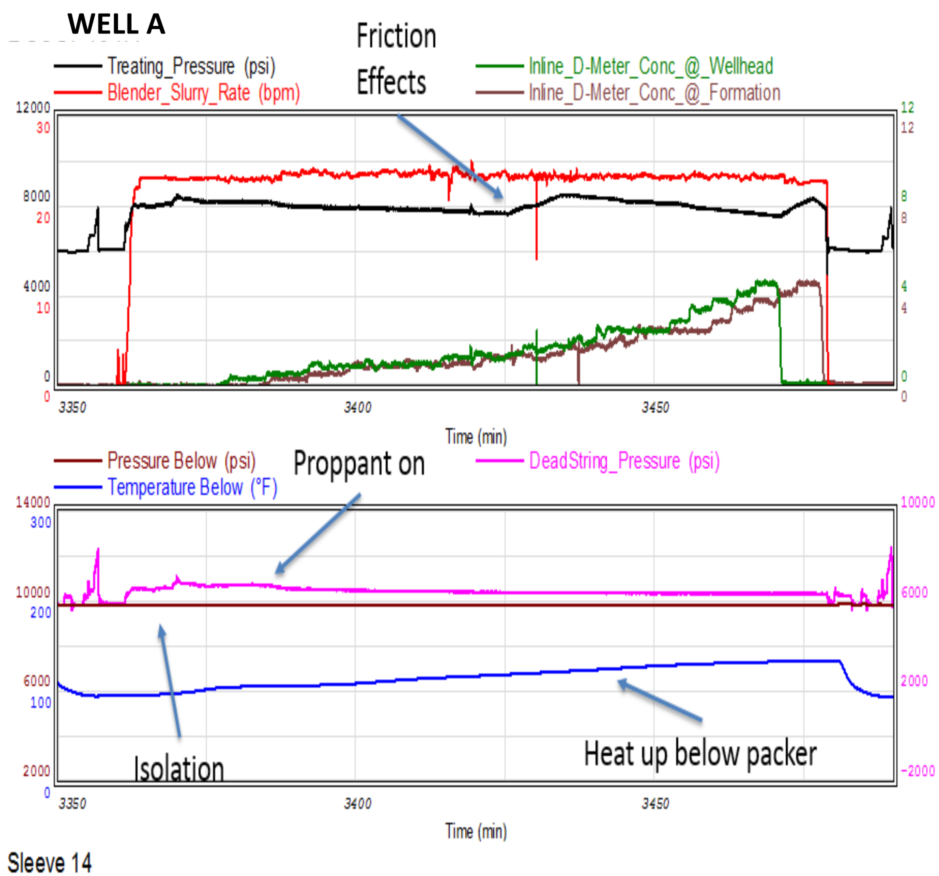
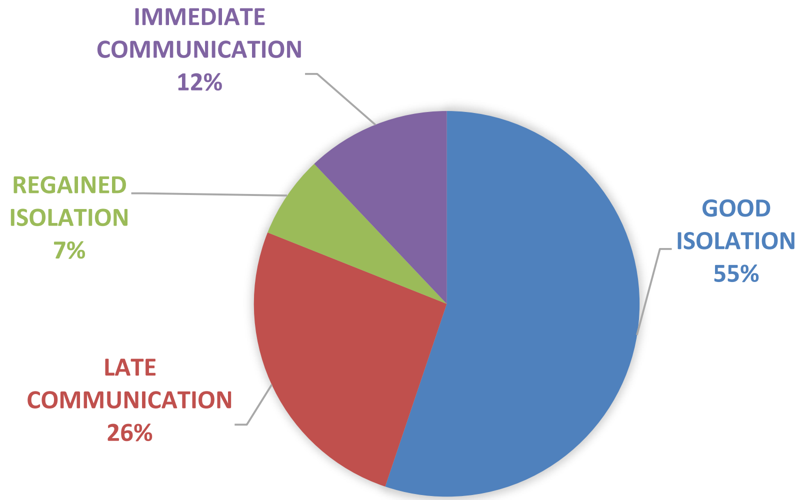
COMPLETION: *Bottom Hole Gauge Data Evaluation*



Only available on WELL A

- **Near wellbore restriction**
  - Indication of fracture complexity
  - Relatively moderate and declines during the treatments
- **Proppant distribution**
  - Interpreted as being good
  - Minimal proppant bridging
- **Real time net pressure indication**
  - CT deadstring
  - Avoid screen out

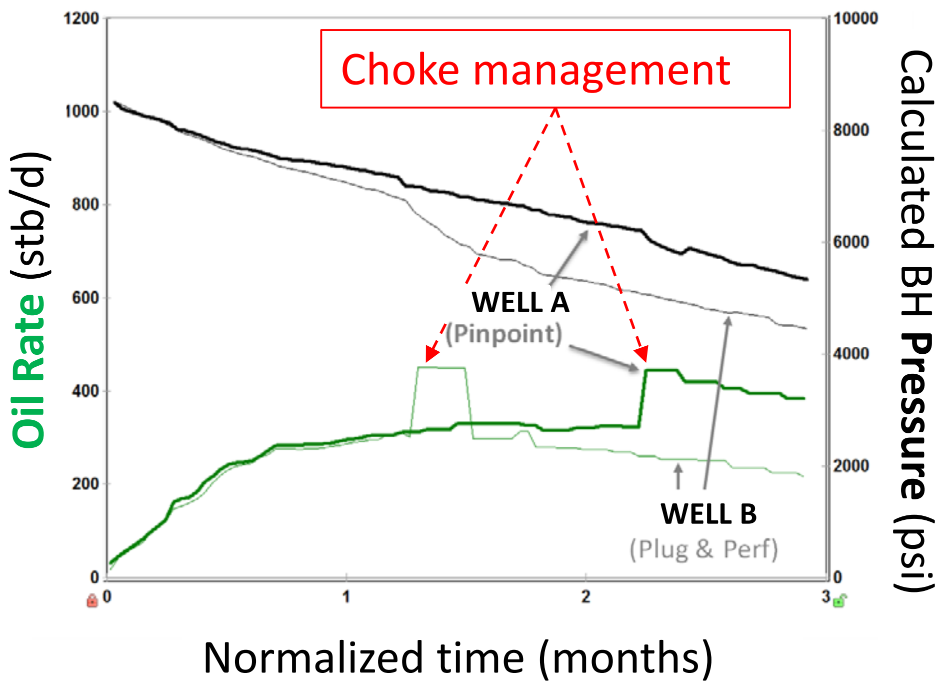
COMPLETION: *Bottom Hole Gauge Data Evaluation*



Communication between stages - Only available on WELL A

- **Zonal pressure isolation evaluation**
  - Reasonable with most communication being slight in nature

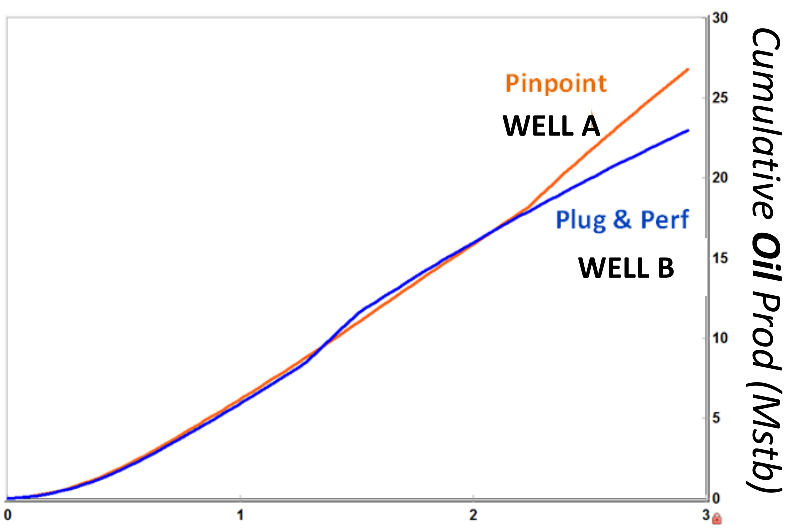
PRODUCTION EVALUATION: *Basic Comparison*



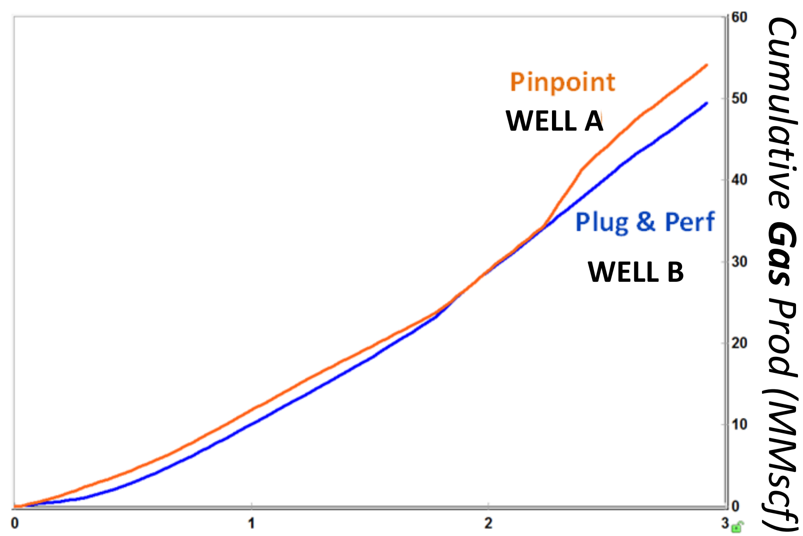
Comparison of production rate and calculated bottomhole flowing pressure

- Similar lateral length (1500 m)
- Both wells navigate in the same section
- Both wells exhibit choke change at different times
- Pressures measured at surface (BH Calc)
- No tubing installed

PRODUCTION ANALYSIS: *Basic Comparison*



Normalized time (months)



Normalized time (months)

Comparison of oil and gas production volumes

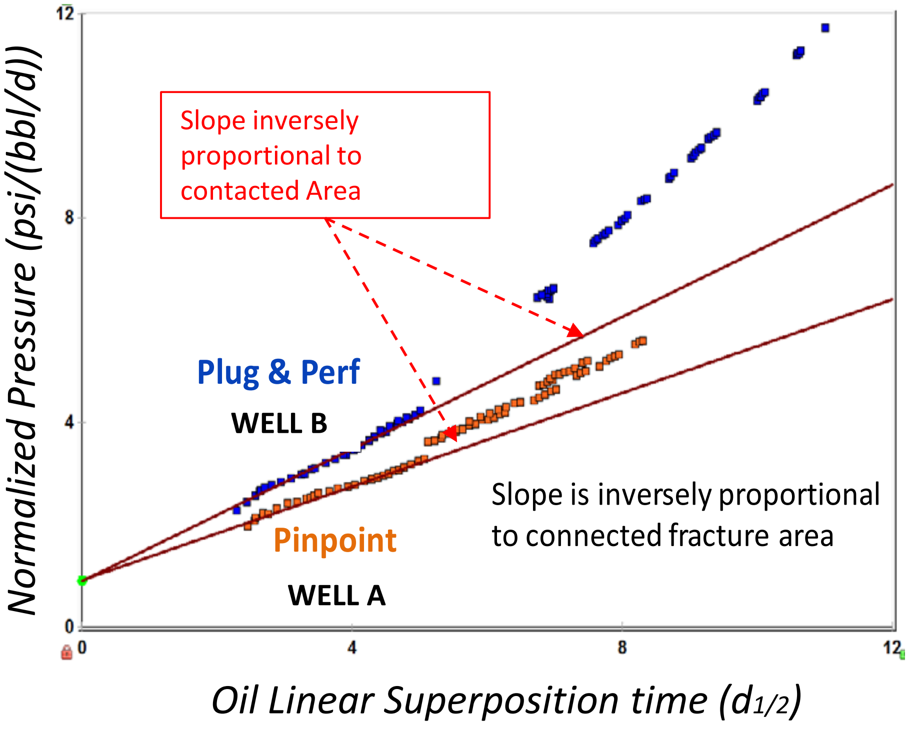
- **Shows similar profiles with the WELL A performing slightly better**

PRODUCTION EVALUATION: *Rate Transient Analysis*

Linear flow specialized plot analysis

- Slope is inversely proportional to connected fracture area (A√k)
- Geomechanical effects with choke changes

WELL A (pinpoint) 40% more connected area

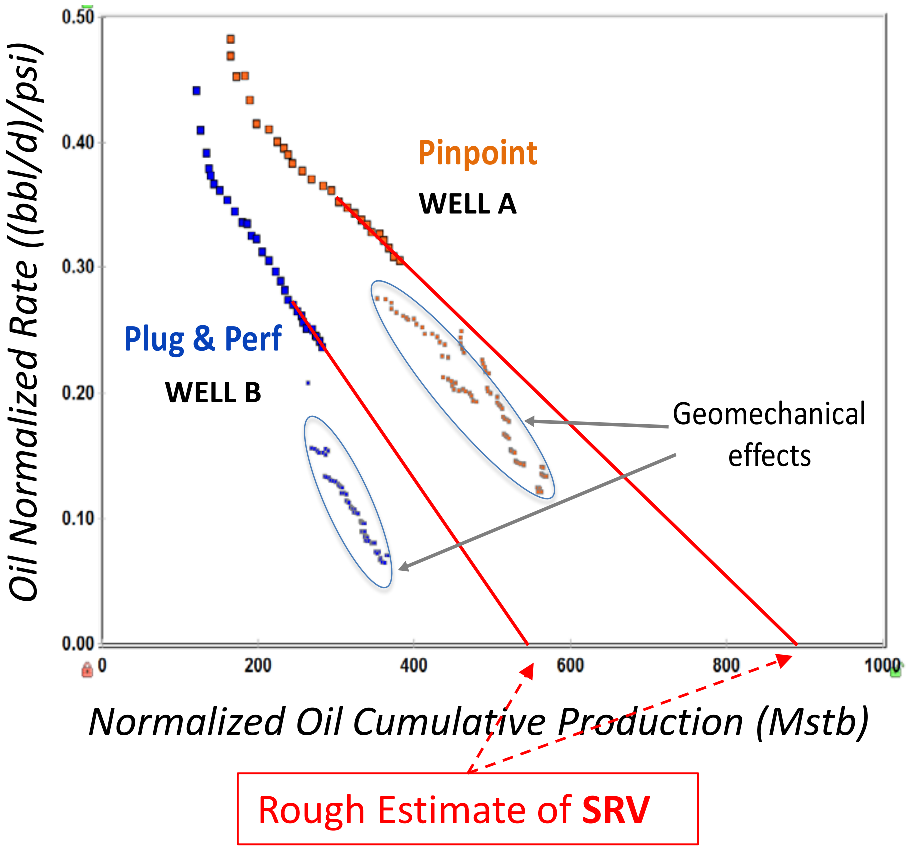


PRODUCTION EVALUATION: *Rate Transient Analysis*

Flowing material balance (FMB)

- Quantifying the contacted Original Oil in Place (OOIP)
- Extrapolation of this plot yields a rough estimate of SRV
- Geomechanical effects with choke changes

WELL A (pinpoint) 60% more SRV



COMPLETION COST: *Comparison*

WELL A (Pinpoint)	WELL A (Plug&Perf)
90.8%	100%

Comparison of bundled completion costs

- Include only those expenditures directly associated with the specific completion methodology employed
- The cost of proppant and other variable costs not associated specifically with the style of completion were not included in the totals

Savings of approximately 9% for the comparable Pinpoint costs vs the Plug&Perf completion costs

CONCLUSIONS

- Cost and production benefits were realized by the application of the pinpoint completion method.

- RTA analysis of well performance suggests a greater stimulated reservoir volume (fracture area) is produced by the pinpoint completion method, and that a larger hydrocarbon volume is contacted by the completion as a result.

- Reclosable sleeves opens up a wide range of comletions design, including refracturing and shuttle frac (non secuential)

QUESTIONS