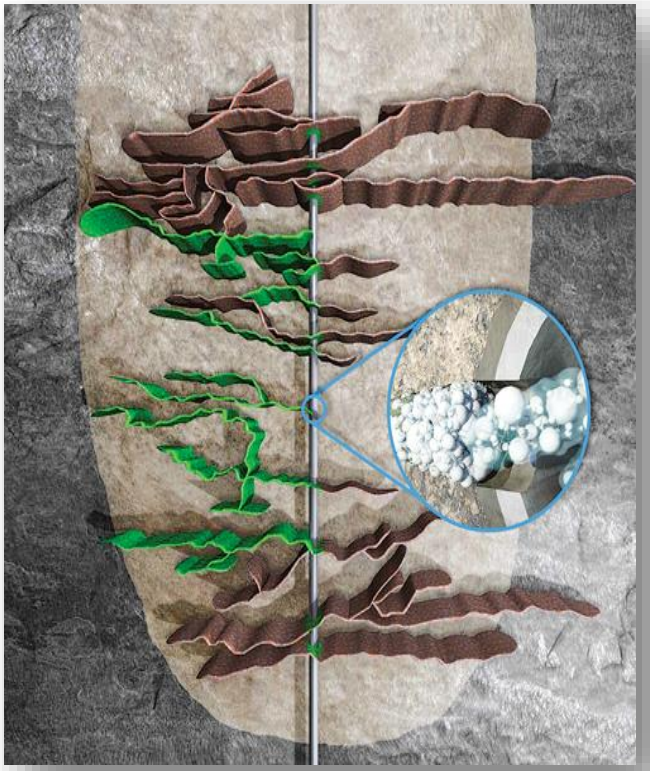
An Integrated Approach to Candidate Selection for Refracturing Success

Jason Baihly – Commercial & Risk Assessment Manager

Schlumberger

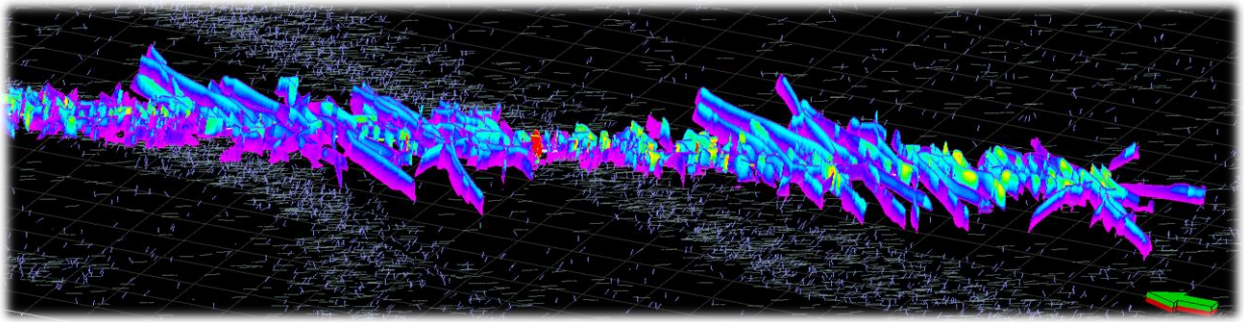
Overview

- Why Refracture
- Selection Methodologies
  - Horizontal Focus
  - Open vs. Specific Candidates
- Candidate Vetting
- Candidate Diagnosis
  - Possible Treatment Types
- Example
- Summary



Why Refracture

- Capital efficiency
  - Contact more hydrocarbons without drilling a new well
- Greater economic return than a new well
  - Less capital exposure
- Add reserves or accelerate reserves
- Extend retention of a lease
- Secondary recovery mechanism/EOR
- Reservoir pressure and stress maintenance
  - Infill wells not achieving the same EUR as Parents
  - Parent wells lose EUR when frac'd into from infill wells



*SPE 174902

Candidate Selection

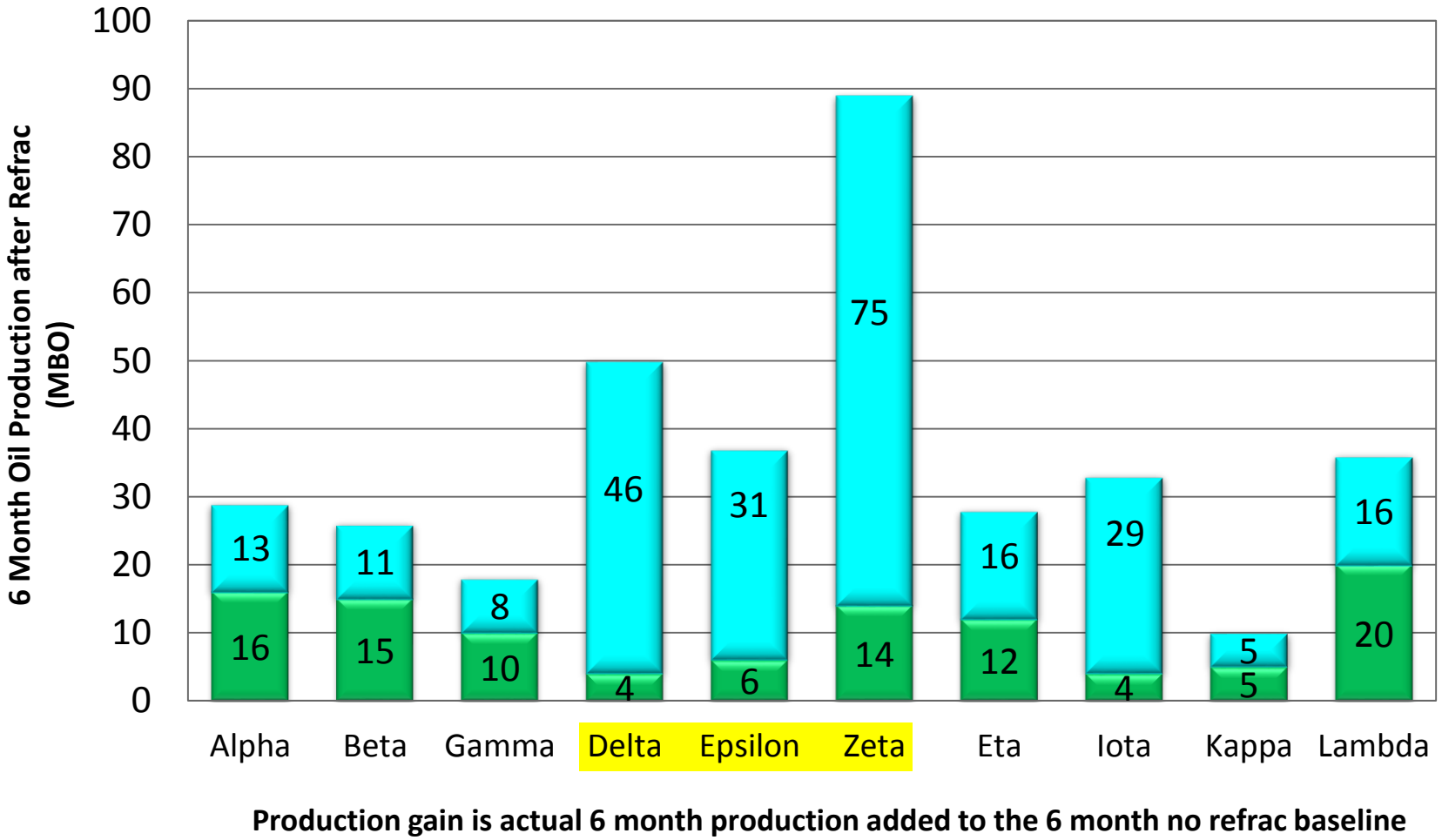
Approaches to Refracturing Candidate Selection

- Open well(s) [Any wells]
  - High level (Candidate Selection) → Well level approach (Candidate Vetting)
- Focused well(s) [Specific wells]
  - Well level approach (Candidate Vetting)
- Some one dimensional methodologies
  - Geologically focused
  - Completion/stimulation focused
  - Production focused
  - Reservoir focused
  - Emotional
  - Financial
- Multidimensional/integrated

Where to Begin

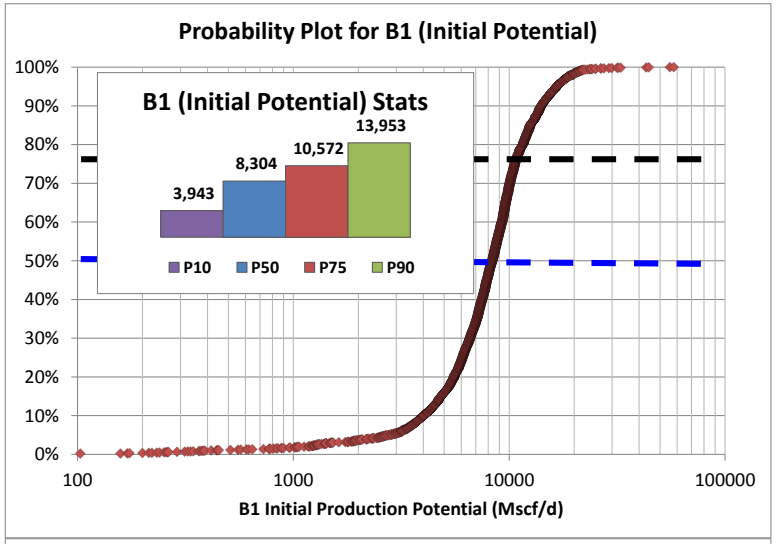
- Lots of wells, lots of data; how to make sense of it all

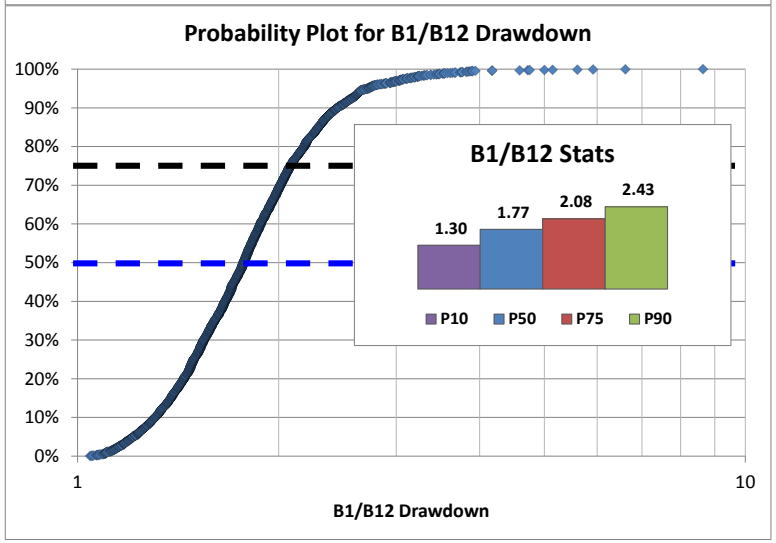
Multivariate 6 Month Production Uplift



URTeC 2461344 Charry et al, 2016

Matrix Approach for Haynesville





B1 Well Count

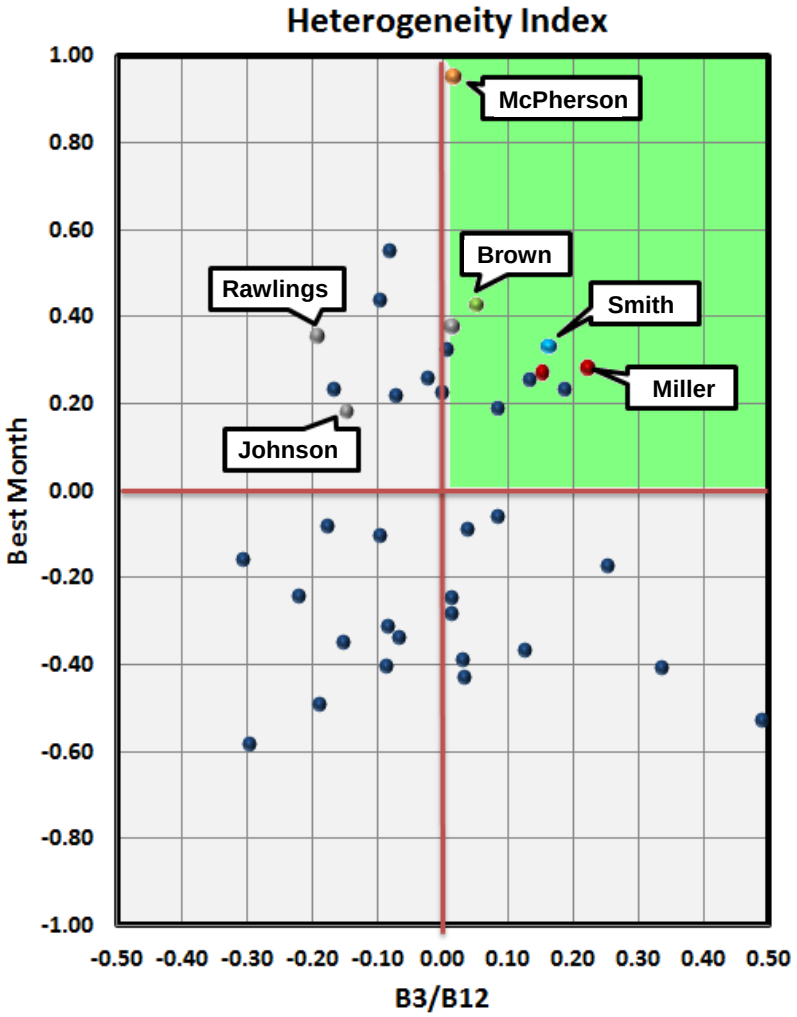
B1/B12 Well Count	>P90	P75-P90	P50-P75	<P50	
>P90	70	50	39	122	281
P75-P90	66	84	89	150	389
P50-P75	92	110	175	289	666
<P50	54	156	357	746	1313
	282	400	660	1307	Totals (2,649)

270 wells with P75 or better on both indicators

775 wells with P50 or better on both indicators

1,342 wells with >P50 B1 Gas

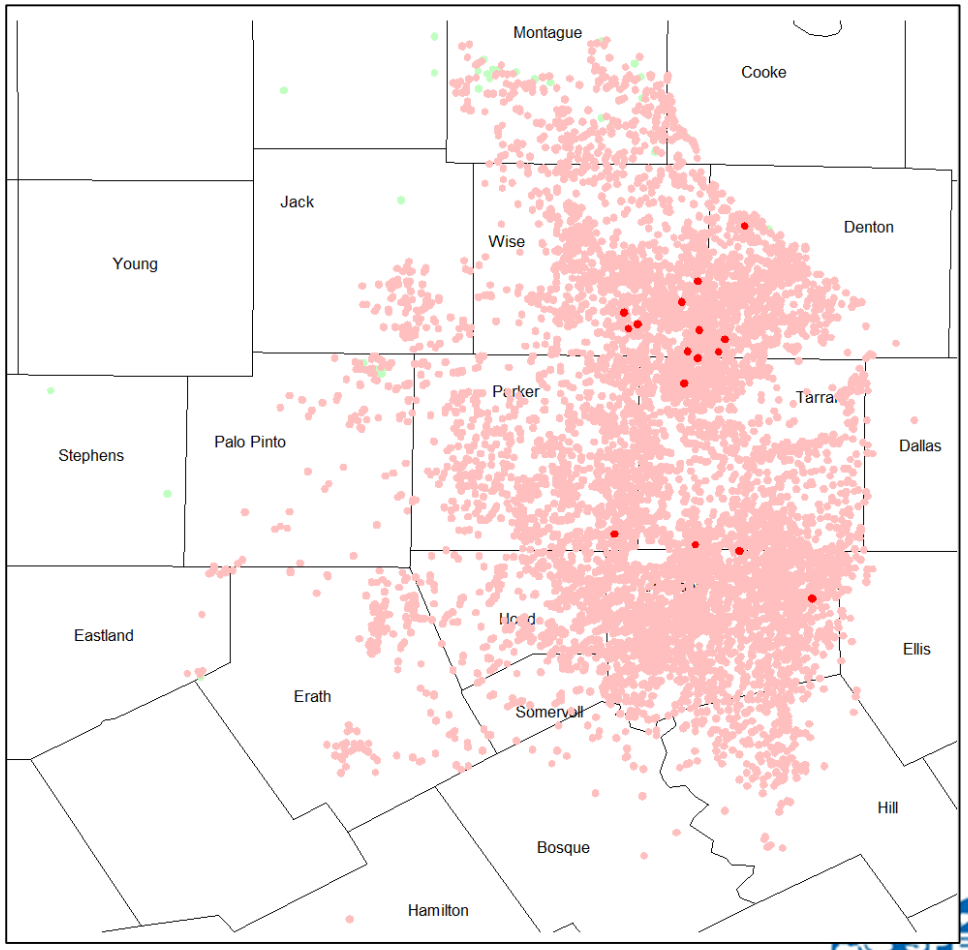
Matrix Approach Alternative Visualization



Identified Barnett Horizontal Refracs H2 2013-H1 2015

Best 3 Month Well Count

Best Month/Best 12-Months Well Count	>P90	P75-P90	P50-P75	<P50	
>P90	87	103	234	999	1,423
P75-P90	193	306	470	1,142	2,111
P50-P75	410	596	962	1,649	3,617
<P50	715	2,136	2,906	3,170	6,915
	1,405	2,135	3,566	6,960	Totals (14,066)



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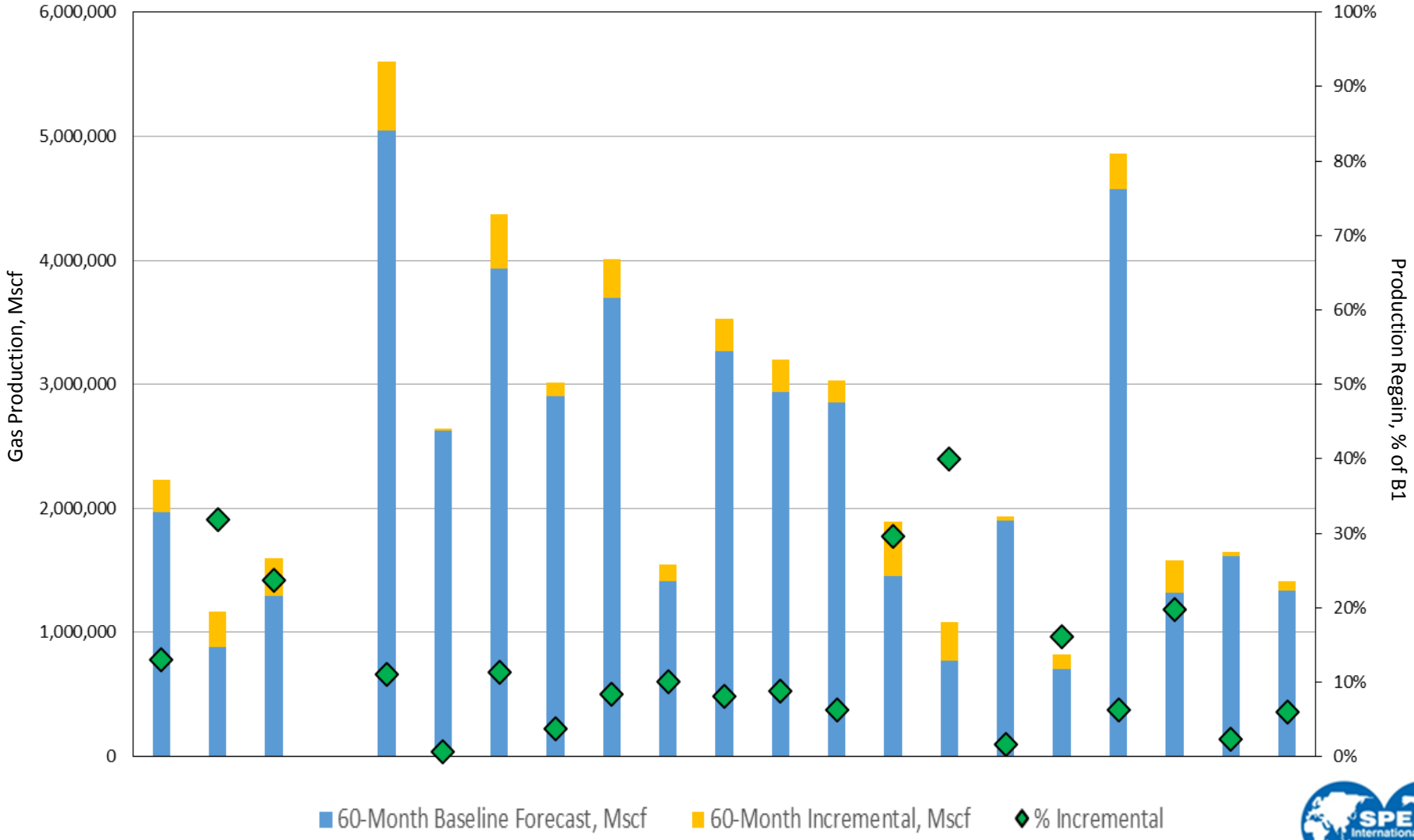
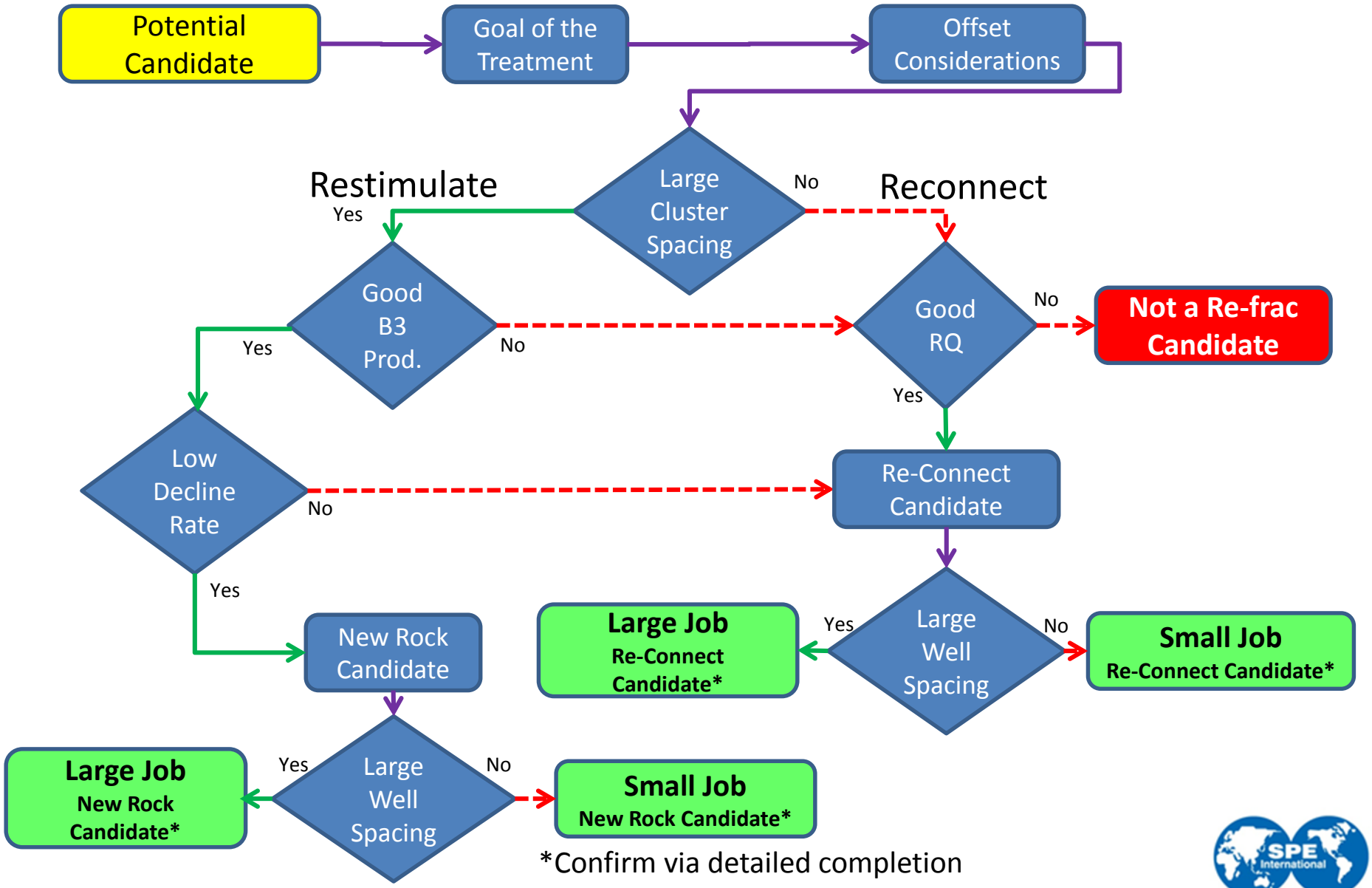


*SPE 179113

Workflow Approach

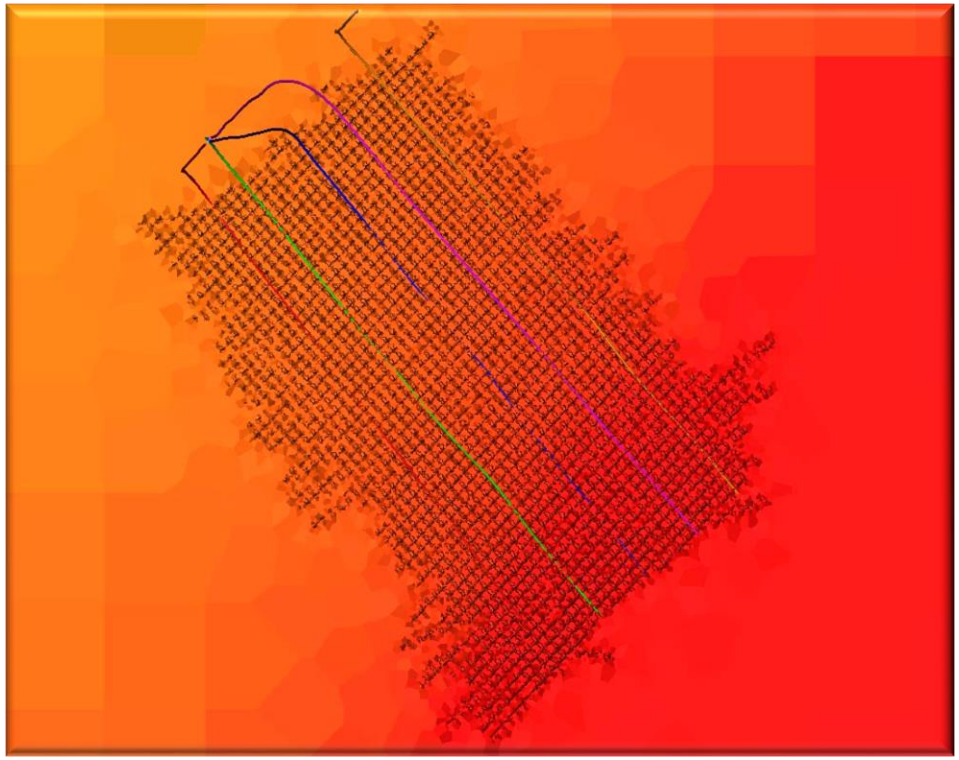


*Confirm via detailed completion and production data review

Candidate Vetting

Reservoir Considerations

- Offset well
  - Spacing
  - Interference/depletion
  - Sequencing
  - Pad vs. single well
- Pressure depletion along lateral
  - Degree, location, and extent
    - Previous fractures
    - Landing zone
- Bypassed pay along lateral
  - Function of
    - Landing
    - Perforation scheme
- GOR
- % of potential EUR* already produced/remaining



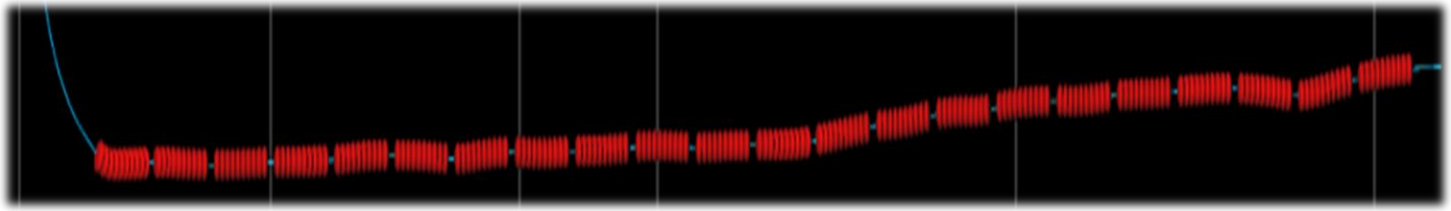
*URTeC: 2172668

Blue font denotes key drivers

*SPE 179113

Well Construction Considerations

- Lateral length and depth
  - Can the entire lateral be effectively stimulated
- Well trajectory
  - Stress variability
  - Lithology variability
  - Sumps
- Treating pressure limitations
  - Wellhead
  - Casing integrity
    - Ballooning/sudden pressure changes
- Frac isolation effectiveness
  - OH vs CH considerations
    - Packers/poor cement
  - Over-flushed balls

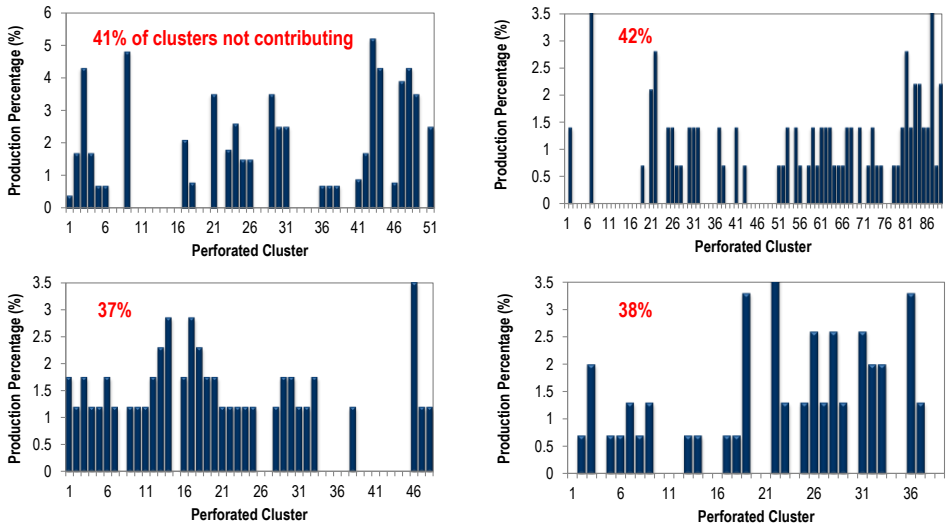


*SPE 179113

Completion Considerations

- Stages
  - Number
  - Spacing
- Perforations
  - Too few
  - Too many
  - Contribution
- Initial fracturing treatment
  - Amount of fluid
  - Type of fluid
  - Proppant amount
  - Size of proppant
  - Rate

- 250+ production logs evaluated in North America
- All well were completed geometrically

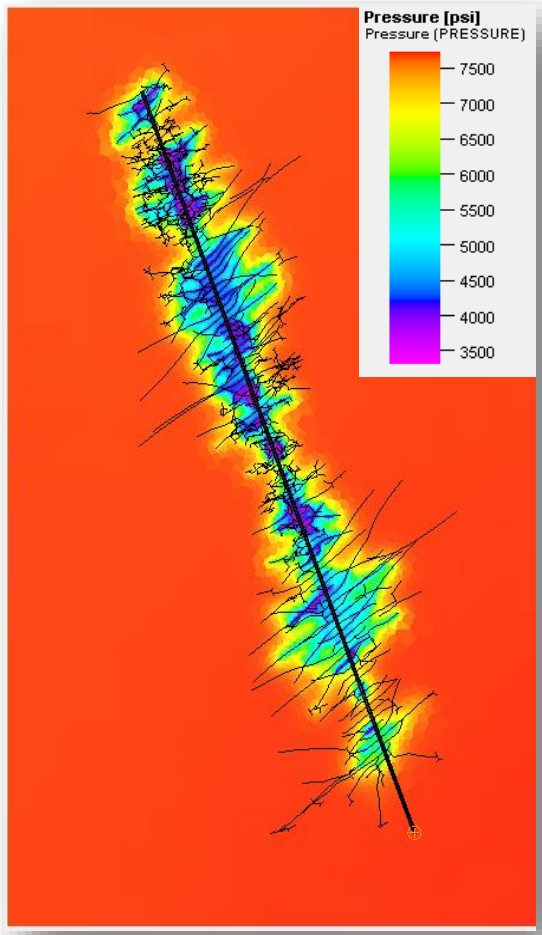


*SPE 144326

*SPE 179113

Other Considerations

- Damage mechanisms
  - Drilling damage - mud losses
  - High drawdown - Migrating clays/Prop embedment
  - Scale damage - paraffins or asphaltenes
  - Future focus of refracturing
- Operational constraints
  - Seasonal issues – winter vs. summer ops
  - Pad resizing
  - Partners
- Rate limitation
  - Pump faster than depleted zones can drink
- Age of the well
- Current production rate



*SPE 174902

*SPE 179113

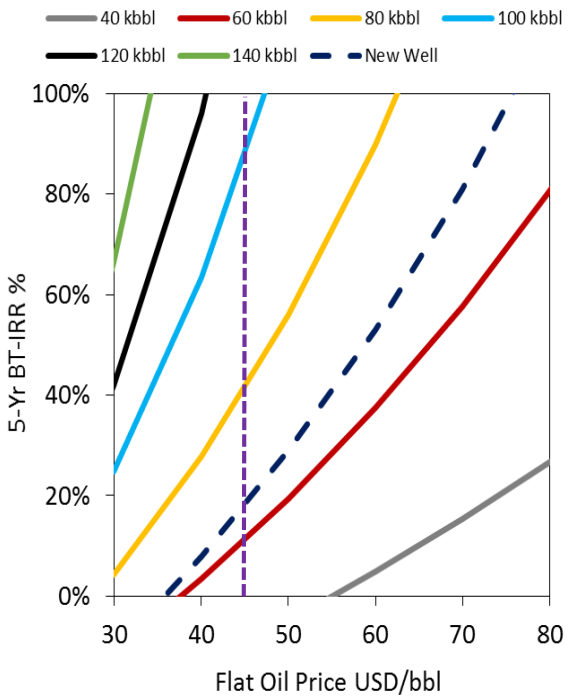
Reservoir Causes for Refrac Failures

- Poor reservoir quality (RQ)
- Landing the well in an undesirable zone
- High depletion
- Little recoverable hydrocarbon remaining

Economic Considerations

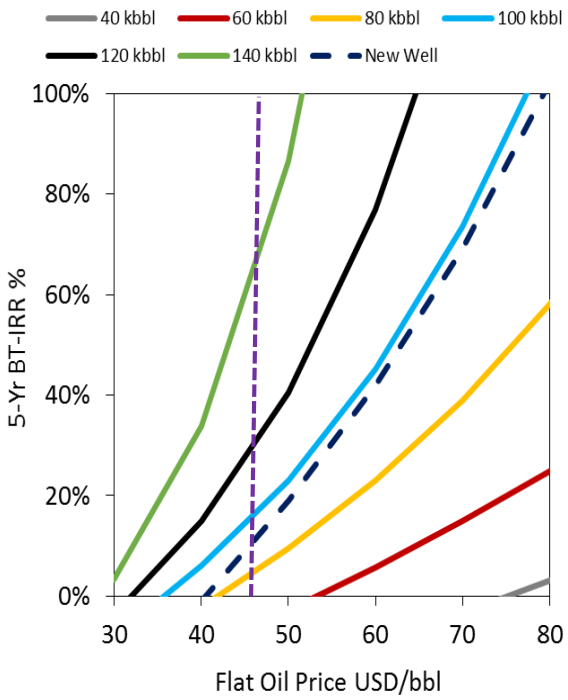
Eagle Ford

Royalty	25%
New well cost	$5.5M
Refrac cost	$1.6M (all-in)



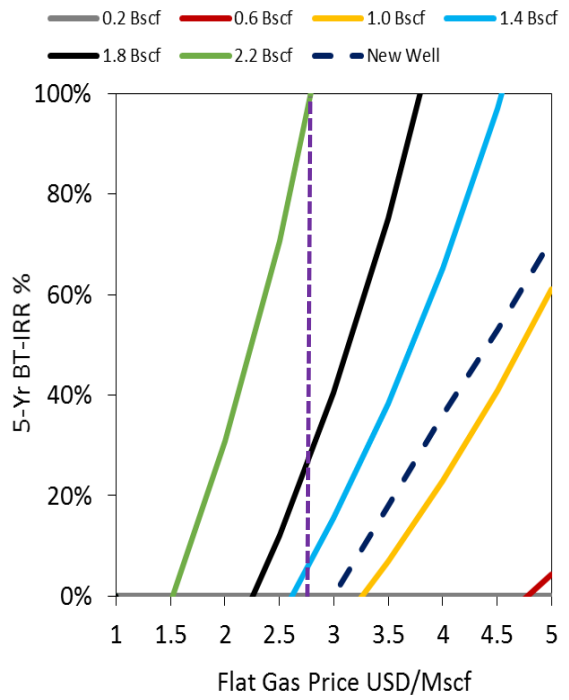
Bakken

Royalty	20%
New well cost	$5.0M
Refrac cost	$1.8M (all-in)



Haynesville

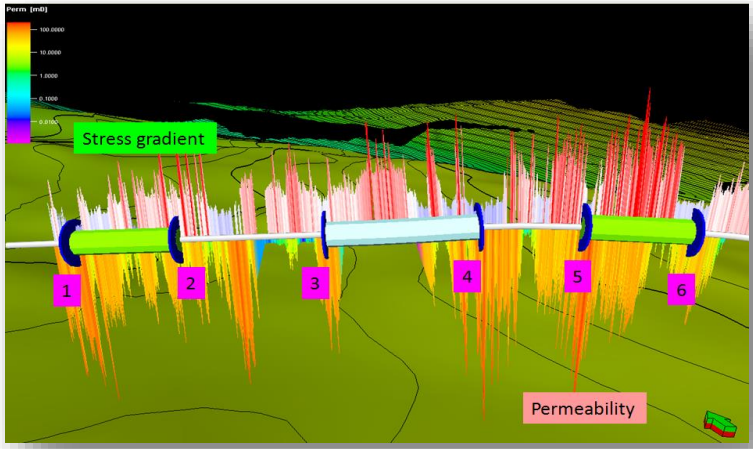
Royalty	25%
New well cost	$6.5M
Refrac cost	$1.7M (all-in)



*Updated from SPE 179113

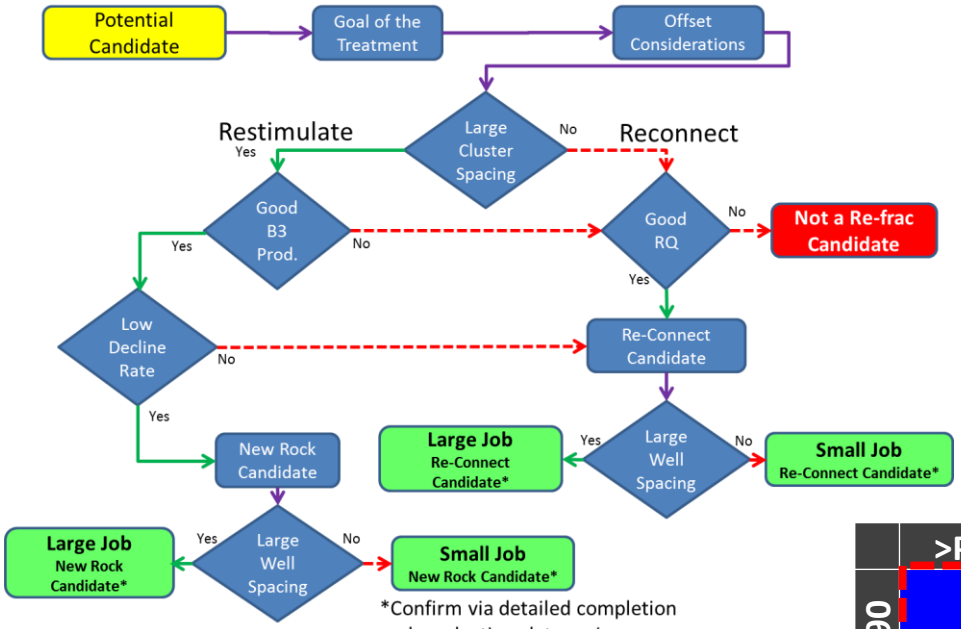
Diagnose the Candidate

- Why should the candidate well be refractured?
- What are the ailments causing the well to need a refracturing treatment
  - Make sure the refrac treatment addresses the ailments/need
- What is the goal of the treatment
- Basic considerations
  - Fair to good reservoir quality
  - Sufficient reservoir pressure
  - Remaining recoverable reserves
  - Under-stimulated wells
  - Economics



Candidate Selection Case Study

Example Candidate Recognition Process



B1 Well Count

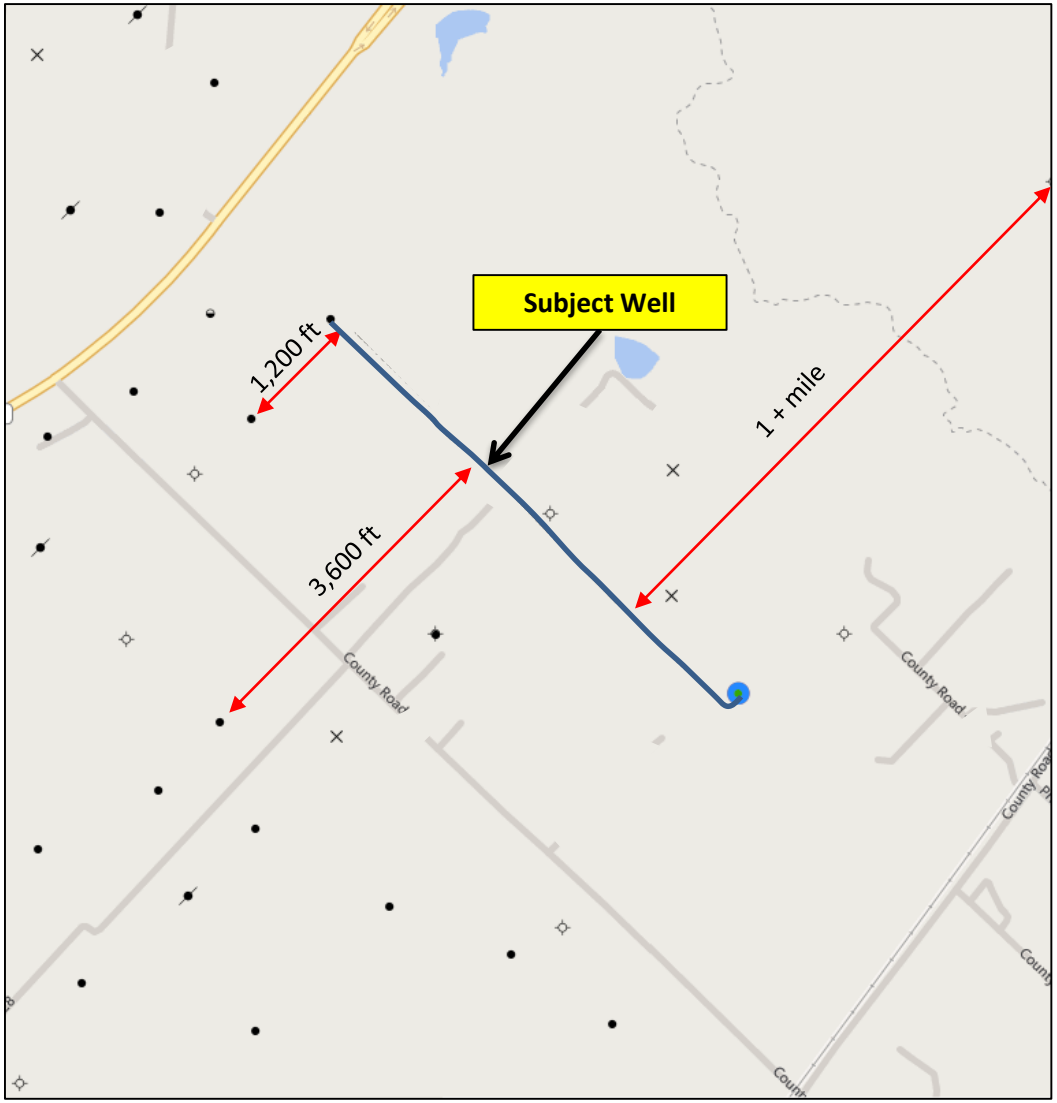
B1/B12 Well Count	>P90	P75-P90	P50-P75	<P50	
>P90	2	5	5	21	33
P75-P90	7	10	12	20	49
P50-P75	9	14	28	29	80
<P50	15	19	36	91	161
	33	48	81	161	Totals (323)

Example Well Spacing Analysis

SE Texas

Nearest horizontal offset well is 1+ mile away

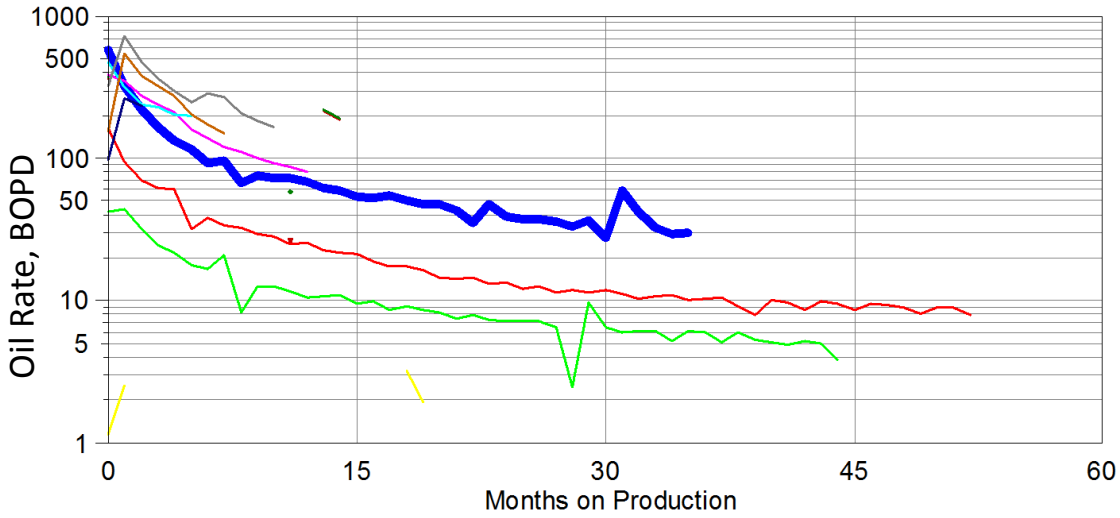
Goal is to test viability of refracs to determine if incremental production is economically viable

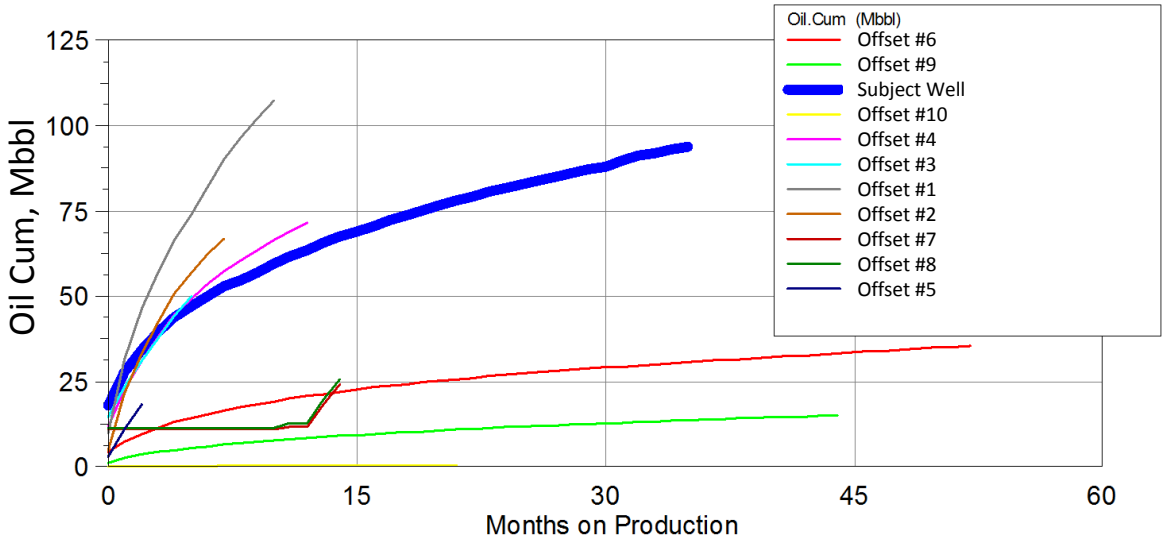


Example Well EB Completion

- ~5K ft lateral length
- 20 stages; 5 clusters/stage; 50 ft cluster spacing
- 250 ft stage interval (plug to plug)
- 738 total perforations
- Total fluid ~4.5 MMgal
- Total proppant ~ 5.1 MMlbs

Offset Production Analysis





- Nearest horizontal offset well ~1+ mile away
- B3 oil production from Operator:
  - **373 BOPD**
- Production welltest IP from IHS:
  - **533 BOPD on 14/64" choke size**
- Last Analyzed Production Rate: 60 BOPD, 21 MSCFD on 06/09/2015

**Compiled from IHS Data*

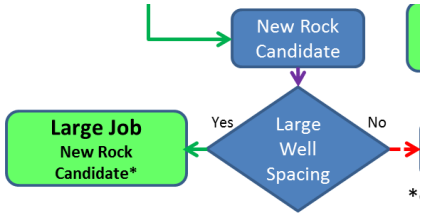
Completion & Production Quality

- Completion/frac data for offset wells from Navport
- Subject Well has good B3 oil normalized by lateral length (**0.07 BOPD/ft**), and decent proppant vol/ft **(1,018 lb/ft)** compared to offsets

Well Name	Operator	Date of First Production	B3 Oil (BOPD)	Lateral Length, ft	B3 Oil Normalized by Lateral Length (BOPD/ft)	Number of Stages	Total Fluid (Mgal)	Total Proppant (Mlb)	Average Prop/Stage (Mlb)	Average Prop Vol/ft (lb/ft)
Offset 1	A		519	5,909	0.09	15	4,741	5,242	350	887
Example Well	**A**		**373**	**4,995**	**0.07**	**20**	**4,445**	**5,085**	**254**	**1,018**
Offset 2	A		415	6,300	0.07	20	4,760	4,928	246	782
Offset 3	A		338	6,056	0.06	18	4,824	5,182	288	856
Offset 4	B		342	6,987	0.05	30	7,009	11,268	376	1,613
Offset 5	B		198	8,115	0.02	30	8,175	12,014	400	1,480
Offset 6	A		108	4,766	0.02	5	1,552	686	137	144
Offset 7	B		138	6,383	0.02	16	6,004	9,160	573	1,435
Offset 8	B		134	6,317	0.02	17	5,837	9,162	539	1,450
Offset 9	A		39	5,023	0.01	2	1,502	327	164	65
Offset 10	C		2	2,915	0.00	2	485	600	300	656

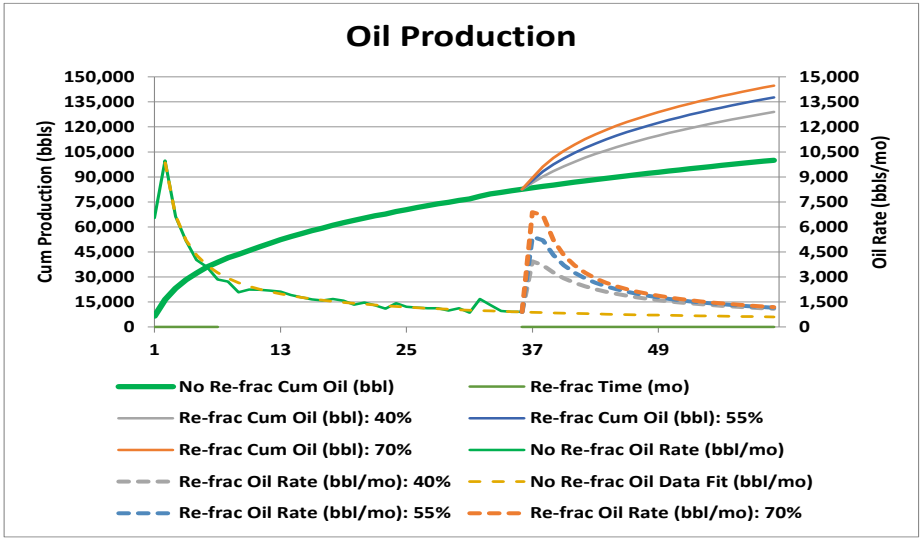
**Compiled from IHS Data*

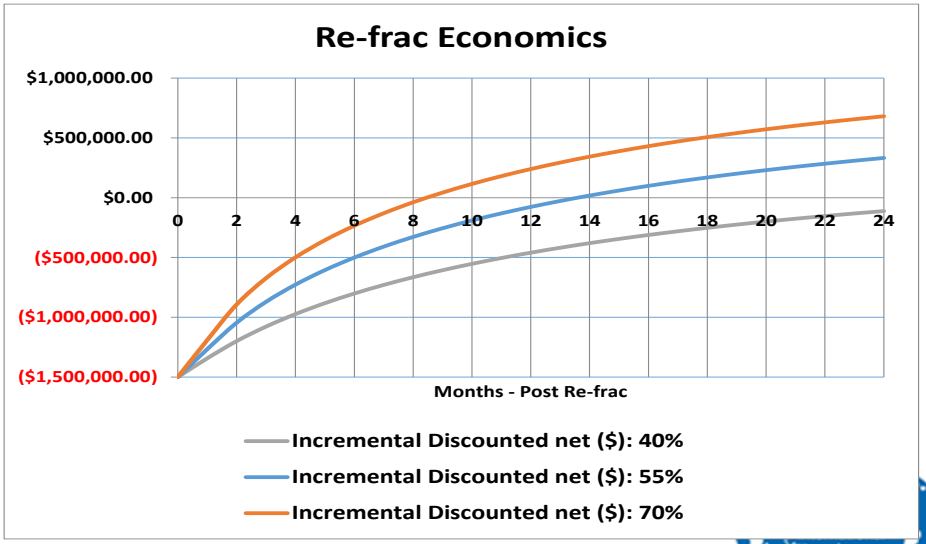
Economics



Assumptions:

- All-in cost of refrac job is $1.5MM
- Fixed Oil Price $60/bbl : Fixed Gas Price $2.9/Mscf
- Royalties ~10%
- Decline after refrac is considered to be the same as the early decline for the first 2 years





Sensitivity for payout in 12 months:

Investment ($)	Production Regain (% of Max Month)
1,800,000	80%
1,500,000	60%
1,200,000	45%

Candidate Selection Process Conclusions and Recommendations

Conclusions:

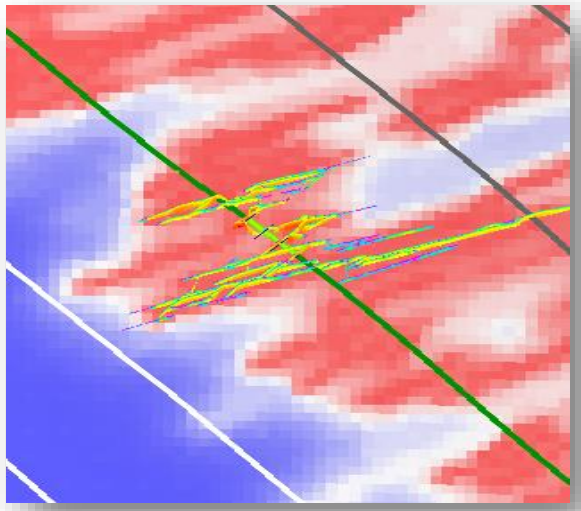
- Good B3 oil production for candidate well (373 BOPD) **(+)**
- Well was down to ~35 BOPD when shut in for refrac **(+)**
- Good initial oil production rate for candidate well (IP – 533 BOPD on 14/64” chokes) **(+)**
- Reservoir and Completion Quality
  - Candidate well lateral is ~5K ft with 5.1 MMlbs of proppant (1,018 lbs/ft – higher end for the area, low for the basin) **(0)**
  - Cluster spacing is tight **(-)**
  - >80% of the lateral was landed in the target zone **(+)**
  - Good reservoir quality for sub-basin **(+)**
  - Nearest EFS horizontal offset well spacing ~1+ mile away **(+)**
  - 55% uplift needed to payout in ~12 months @ estimated completion cost **(+)**

Recommendations:

- Lots of positives, go ahead with a 22 stage 4MMlb refrac treatment with chemical diversion
  - Actual costs lower than the preliminary models

Candidate Selection Summary

- Be open to looking at all wells as possible candidates
- Perform a multidisciplinary integrated analysis
- Diagnose the patient
  - Identifying underperforming wells
  - Understanding the reason for poor performance
- Identify goals and what criteria defines success ahead of field execution
- Vet the finalists
- Perform economic analysis
- Vertical and horizontal wells follow different workflows



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