The Society of Petroleum Evaluation Engineers

Tuesday, February 13, 2024

Dr. Kumar Ramurthy

Chief Technology Officer, Bayswater E&P

Will be speaking on:

<u>Improving Recovery by Effectively Managing the Drawdown in the DJ Basin Unconventional Reservoirs Using an Engineered Choke Management (ECM) Strategy</u>

Speaker Bio.: **Muthukumarappan "Kumar" Ramurthy, PhD,** is the Chief Technology Officer at Bayswater, where he advises the CEO and the Senior Management Team to ensure Bayswater's business activities are underpinned by the rigorous application of "best accepted and demonstrated" engineering technology and practices. He is also responsible for fostering innovation and expanding the technical knowledge base of the various teams within Bayswater. Before joining Bayswater, Dr Ramurthy worked at Halliburton for 21 years; held several positions including as their Director of Technology for North America. He co-authored a chapter on refracs in the recently published SPE Textbook Monograph Series titled "Hydraulic Fracturing: Fundamentals and Advancements"; and also co-authored a CBM Textbook titled "Coalbed Methane: Principles and Practices" in 2008. He was awarded the SPE Regional Completion Optimization Technology Award for the Rockies in 2010.

Dr Ramurthy has authored 16 SPE papers and holds four patents. Along with Dr Bob Barree, he taught the "Unconventional Reservoir Stimulation: CBM and Shales" class in the USA, Canada, Columbia, Australia, Indonesia, and India. Dr Ramurthy received his Bachelor of Engineering in Mechanical Engineering from Annamalai University, India, M.S. in Petroleum Engineering from Mississippi State University, and his doctorate in Petroleum Engineering from the University of Wyoming.

Abstract.: The economic success of an unconventional horizontal well not only depends upon how the well is drilled and completed but also how it is produced. Standard operating practices are often employed to handle production irrespective of the reservoir conditions which can lead to detrimental results that are usually blamed on other factors.

The overall purpose of a horizontal well is to effectively distribute the wellbore drawdown into the reservoir over a larger area than a vertical well completion, thereby improving the recovery and economics. After the well has been completed, choke management plays a critical role in establishing that connection to the reservoir. If the objective is to have the highest IP90, then one would evidently adopt an aggressive choke management strategy. In some cases, this may be the best strategy to maximize rate of return. However, the aggressive choke management strategy must be approached with extreme caution as it could be detrimental to the long-term viability of the well and the project economics. Researchers have proposed many methods for effectively managing an unconventional well's flowback to minimize damage, maximize productivity and thereby recovery and economics. Improving the recovery and the Return on Investment (ROI) is the main objective behind our development criteria. In order to achieve our objectives, an Engineered Choke Management (ECM) strategy and workflow was developed and widely implemented in Niobrara and Codell well completions in our acreage in the Denver-Julesburg (DJ) basin. This paper (URTeC 3724306) presents the field-tested ECM workflow with clear examples before and after the implementation that has been found to improve project economics and recoveries.

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Improving Recovery by Effectively Managing the Drawdown in the DJ Basin Unconventional Reservoirs Using an Engineered Choke Management (ECM) Strategy

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Bio

Dr. "Kumar" Ramurthy is the Chief Technology Officer at Bayswater Exploration & Production, LLC., He has more than 24 years of stimulation and reservoir expertise in North American and other Unconventional plays

At Bayswater, he is responsible for fostering innovation and expanding the technical knowledge base of the operations, engineering and G & G teams to maximize ROI

Dr. Ramurthy, has served in several SPE technical committees and served as a technical editor for the SPE Production & Operations and SPE Reservoir Engineering Journals. He co-authored a chapter on refracs in the recently published SPE Textbook, Monograph Series titled "Hydraulic Fracturing: Fundamentals and Advancements"; and also co-authored a CBM Textbook titled "Coalbed Methane: Principles and Practices" in 2008. Dr Ramurthy has authored several SPE papers and holds 4 patents.

He has a M.S in Petroleum Engineering from Mississippi State University and a doctorate in Petroleum Engineering from the University of Wyoming

Overview

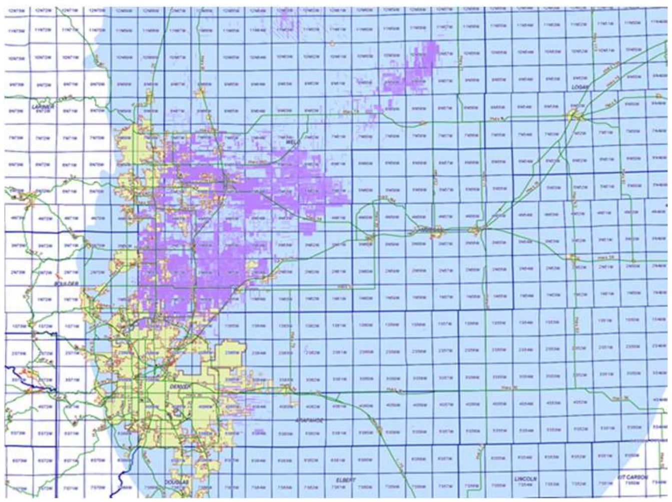
- Unconventional horizontal well: economic success is NOT only dependent upon drilling & completion but also how it is produced
- Blame game: standard operating procedures (SOP) are universally employed to handle flowback and production irrespective of the reservoir conditions which can lead to detrimental results that are usually blamed on other factors
- Overall objective of a horizontal well is to effectively distribute drawdown over a larger area than a vertical well completion thereby improving recovery & economics
- Choke management plays a critical role in establishing that connection to the reservoir
- IP-90

Overview Contd..

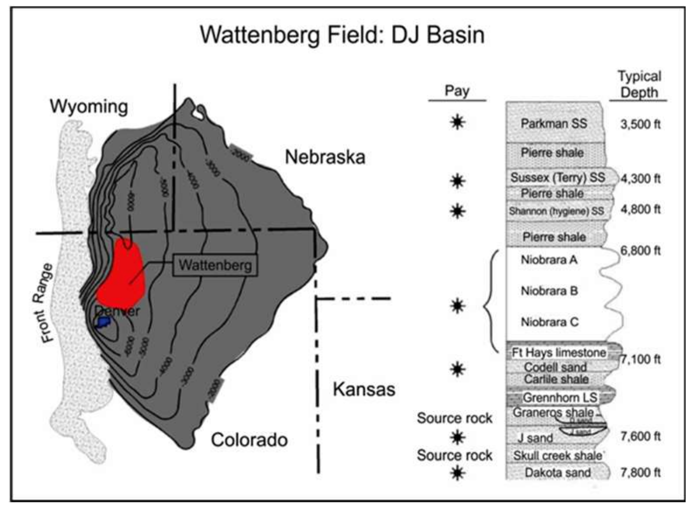
- Aggressive choke management can be detrimental to the long-term viability of the well and project economics (especially in high shrinkage volatile oil reservoirs)
- Managing the flowback is to minimize damage, maximize productivity/recovery and thereby economics.
- Main objective: Improving the recovery and Return on Investment (ROI)
- To achieve the objective an ECM strategy and workflow was developed and implemented in the Niobrara and Codell well completions in the DJ basin
- This work presents the results before and after the implementation that has been found to improve project economics and recoveries

Area of Interest: DJ Basin (7N-64W to 7N-67W)

Map of DJ Basin w/Active Laterals (COGCC)



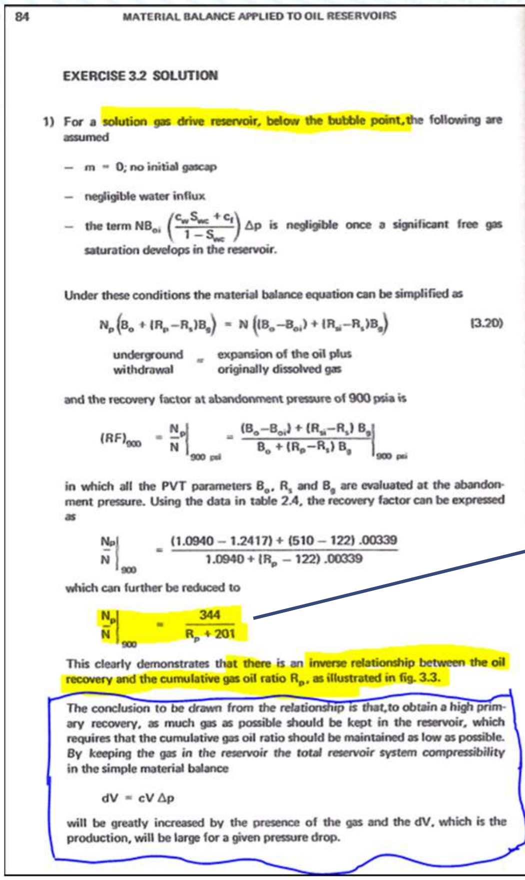
Map of DJ Basin w/Stratigraphic Columns (Sonnenburg 2002)



DJ Basin Area of Interest: Reservoir & Fluid Properties

Reservoir & Fluid Properties								
Formation		Depth (ft)	Thickness (ft)	Reservoir Pressure Gradient (psi/ft)	Effective Porosity (%)	Sw (%)	API (deg)	C7+ (Mol %)
Niobrara-A	Chalk	7011 - 7215	~ 20	~ 0.66	7 - 11	~24	~41.5	27 - 28.5
	Marl		~ 96		5 - 8	~37		
Niobrara-B	Chalk	7097 - 7250	~ 35	~ 0.65	7 - 11	~19	~40.6	29 - 33
	Marl		~ 37		5 - 9	~33		
Niobrara-C	Chalk	7170 - 7340	~ 37	~ 0.68	6 - 9	~26	40 - 42	27 - 29
	Marl		~ 38		3 - 7	~48		
Codell		7282 - 7424	~ 20	0.48 - 0.62	6 - 14	~43	41 - 43	24 - 28

Reference: Fundamentals of Reservoir Eng by L.P. Dake



84 MATERIAL BALANCE APPLIED TO OIL RESERVOIRS

EXERCISE 3.2 SOLUTION

1) For a solution gas drive reservoir, below the bubble point, the following are assumed

- $m = 0$; no initial gascap
- negligible water influx
- the term $NB_{oi}\left(\frac{c_w S_{wc} + c_f}{1 - S_{wc}}\right)\Delta p$ is negligible once a significant free gas saturation develops in the reservoir.

Under these conditions the material balance equation can be simplified as

$$N_p\left(B_o + (R_p - R_s)B_g\right) = N\left((B_o - B_{oi}) + (R_{si} - R_s)B_g\right) \quad (3.20)$$

underground withdrawal = expansion of the oil plus originally dissolved gas

and the recovery factor at abandonment pressure of 900 psia is

$$(RF)_{900} = \left.\frac{N_p}{N}\right|_{900\ psi} = \left.\frac{(B_o - B_{oi}) + (R_{si} - R_s)B_g}{B_o + (R_p - R_s)B_g}\right|_{900\ psi}$$

in which all the PVT parameters B_o, R_s and B_g are evaluated at the abandonment pressure. Using the data in table 2.4, the recovery factor can be expressed as

$$\left.\frac{N_p}{N}\right|_{900} = \frac{(1.0940 - 1.2417) + (510 - 122)\,.00339}{1.0940 + (R_p - 122)\,.00339}$$

which can further be reduced to

$$\left.\frac{N_p}{N}\right|_{900} = \frac{344}{R_p + 201}$$

This clearly demonstrates that there is an inverse relationship between the oil recovery and the cumulative gas oil ratio R_p, as illustrated in fig. 3.3.

The conclusion to be drawn from the relationship is that, to obtain a high primary recovery, as much gas as possible should be kept in the reservoir, which requires that the cumulative gas oil ratio should be maintained as low as possible. By keeping the gas in the reservoir the total reservoir system compressibility in the simple material balance

$$dV = cV\,\Delta p$$

will be greatly increased by the presence of the gas and the dV, which is the production, will be large for a given pressure drop.

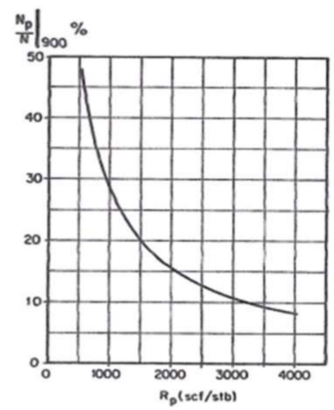


Fig. 3.3 Oil recovery, at 900 psia abandonment pressure (% STOIIP), as a function of the cumulative GOR, R_p. (Exercise 3.2).

ECM was developed to address this !!

ECM: The need and objective

- Keep the gas (i.e., energy) in the reservoir longer;

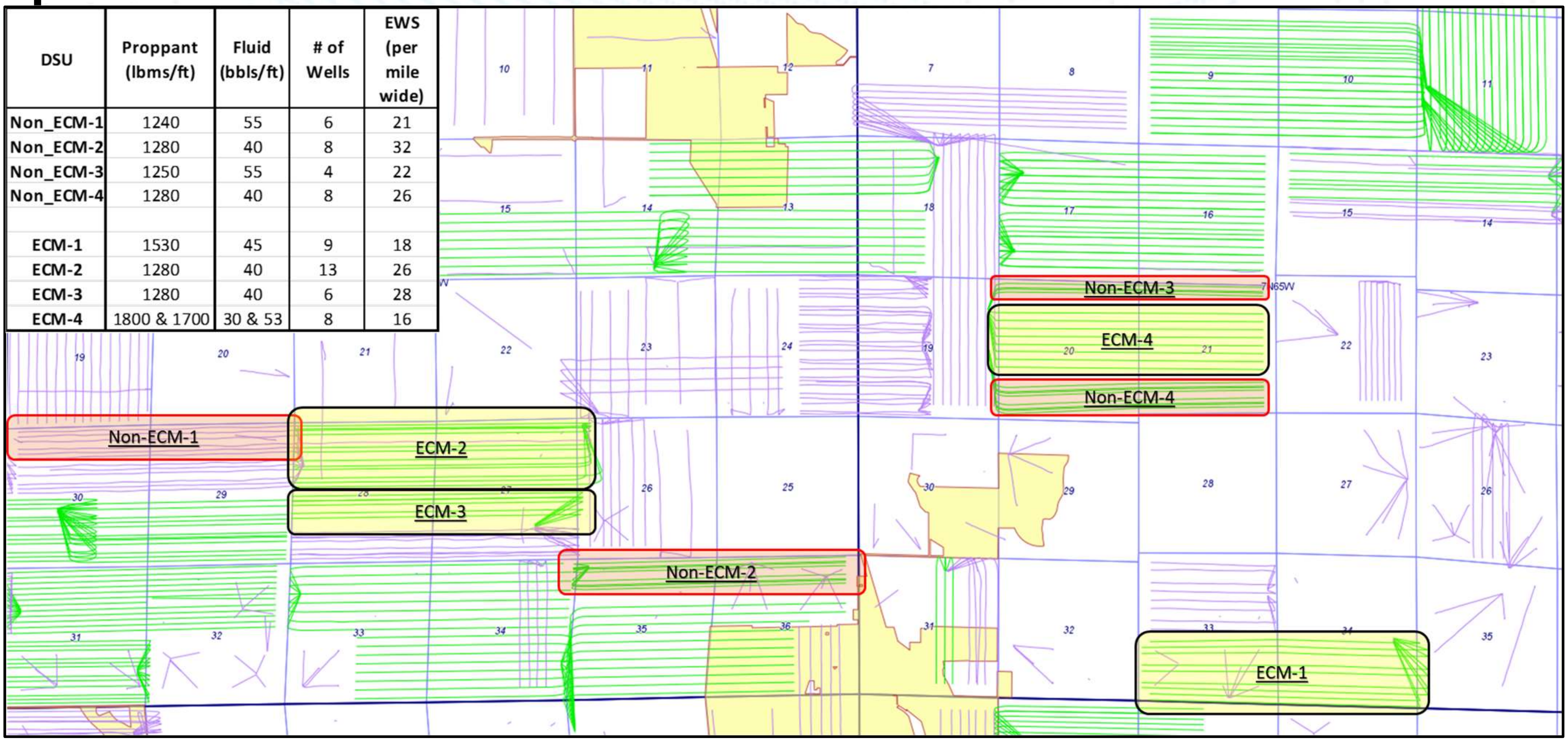
- Address the early onset of higher GOR and promote longer transient production periods

- Extend the time to boundary dominated flow thereby, increased effective drainage area and ultimate recoveries (beyond the initial deferred volumes caused by lower initial production rates)

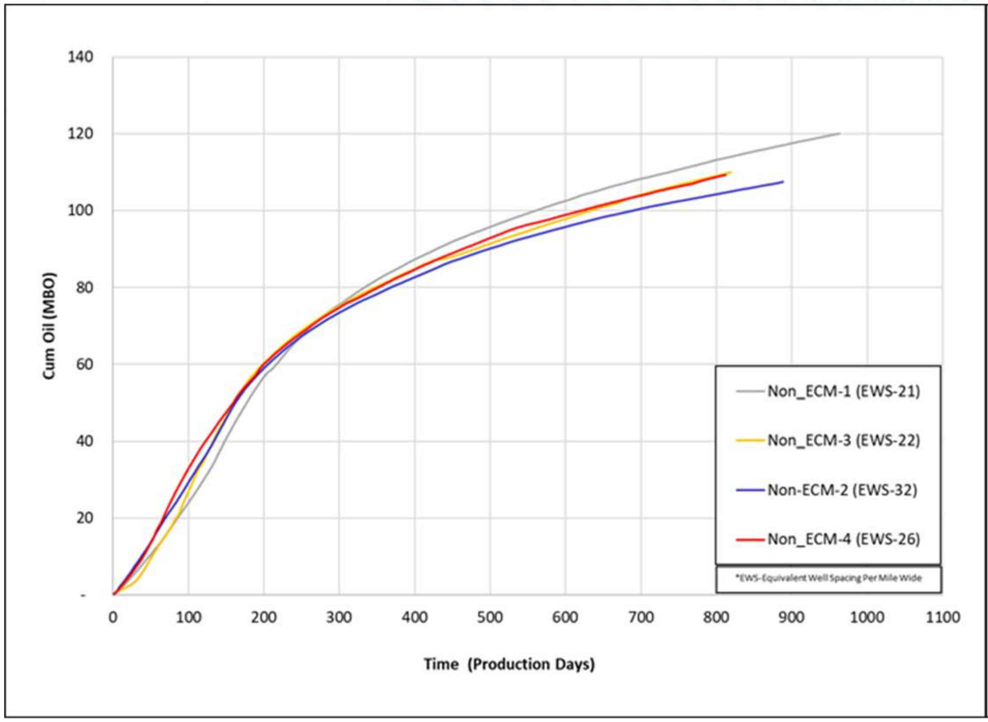
- An attempt has been made to provide clear instructions on when to change the chokes

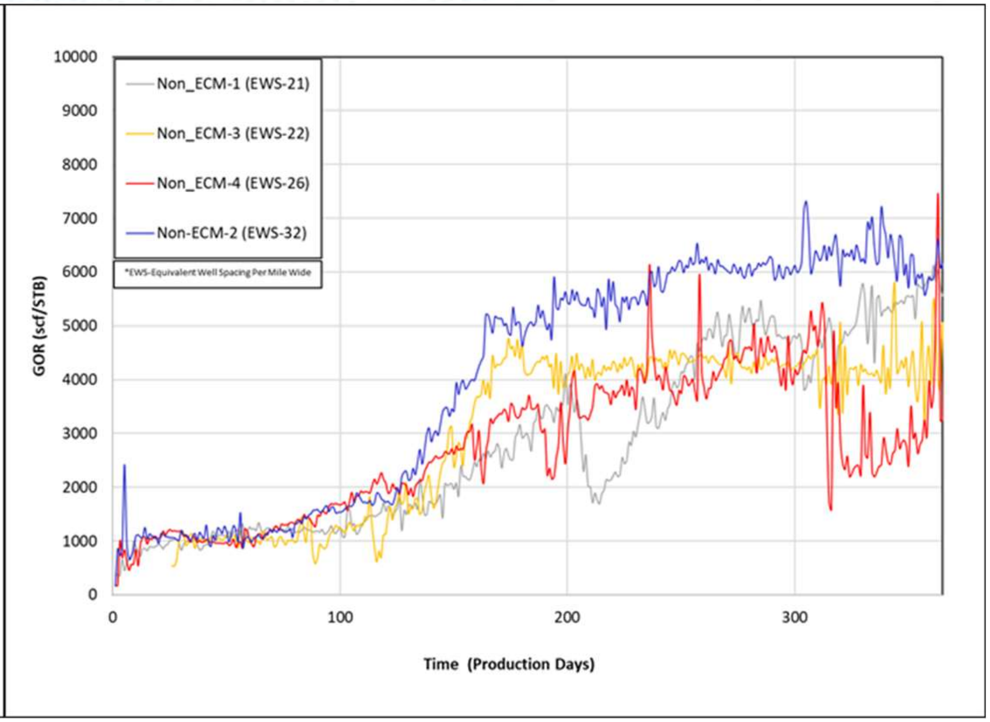
DJ Basin Area of Interest: Drilling Space Unit (DSU) Locations & Completion Metrics

DSU	Proppant (lbms/ft)	Fluid (bbls/ft)	# of Wells	EWS (per mile wide)
Non_ECM-1	1240	55	6	21
Non_ECM-2	1280	40	8	32
Non_ECM-3	1250	55	4	22
Non_ECM-4	1280	40	8	26
ECM-1	1530	45	9	18
ECM-2	1280	40	13	26
ECM-3	1280	40	6	28
ECM-4	1800 & 1700	30 & 53	8	16



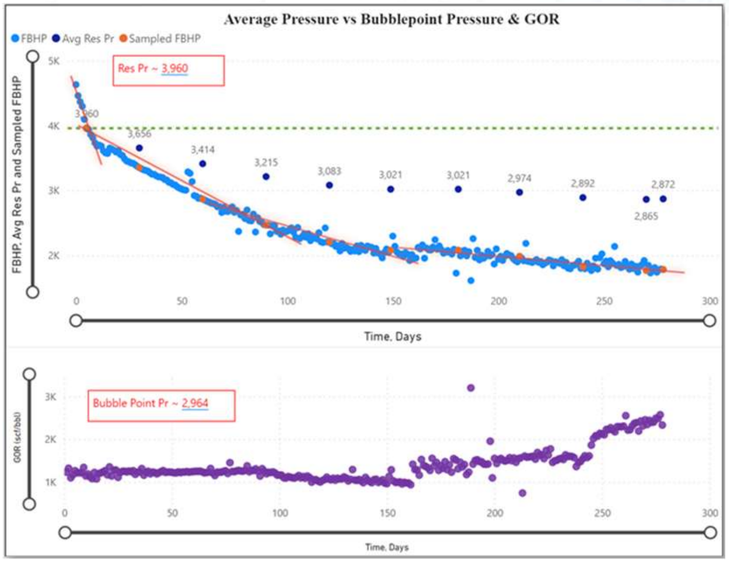
Average DSU Well Cumulative Oil Production & 1st Year Avg Well GOR Before ECM



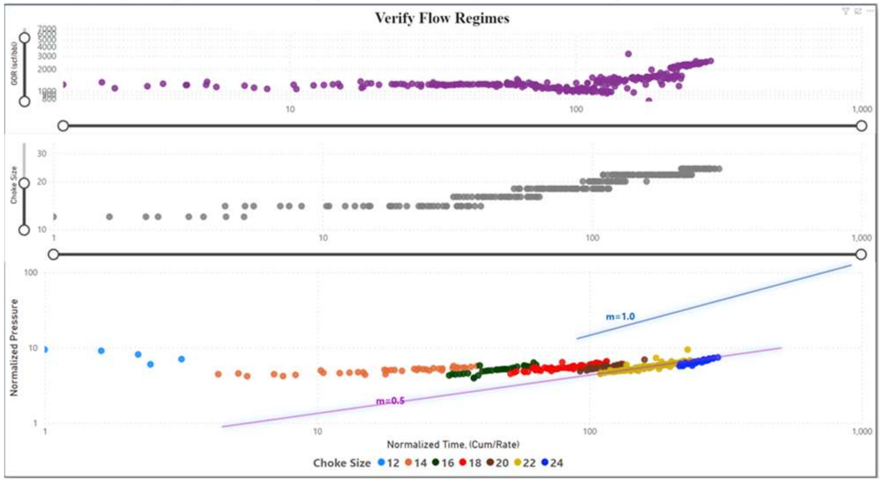


ECM Workflow

Five key diagnostic plots were developed as part of this workflow, and they are discussed below.



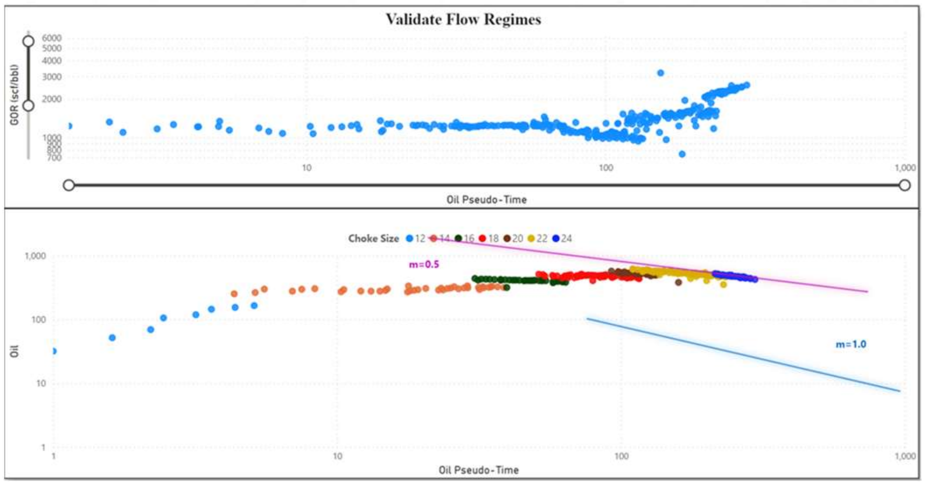
FBHP & GOR vs Time



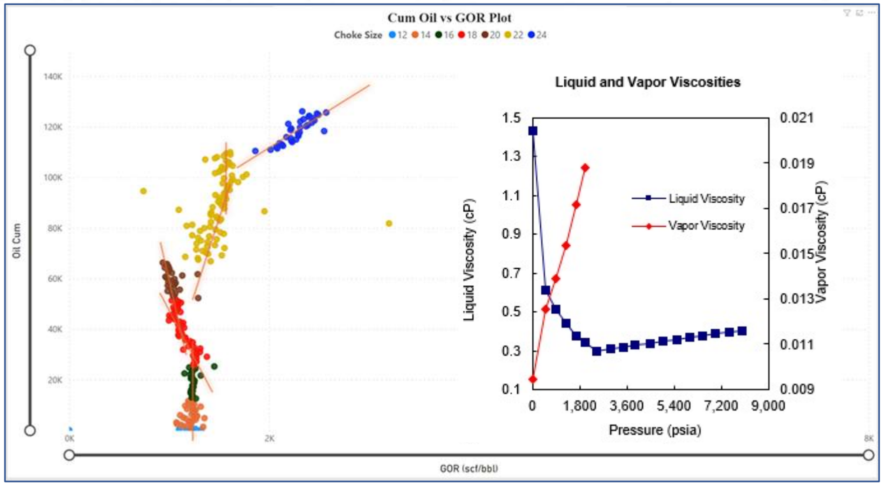
Log-Log Plot of RPI vs Normalized time

ECM Workflow Contd.

Five key diagnostic plots were developed as part of this workflow, and they are discussed below.



Oil Rate & GOR vs Normalized Time

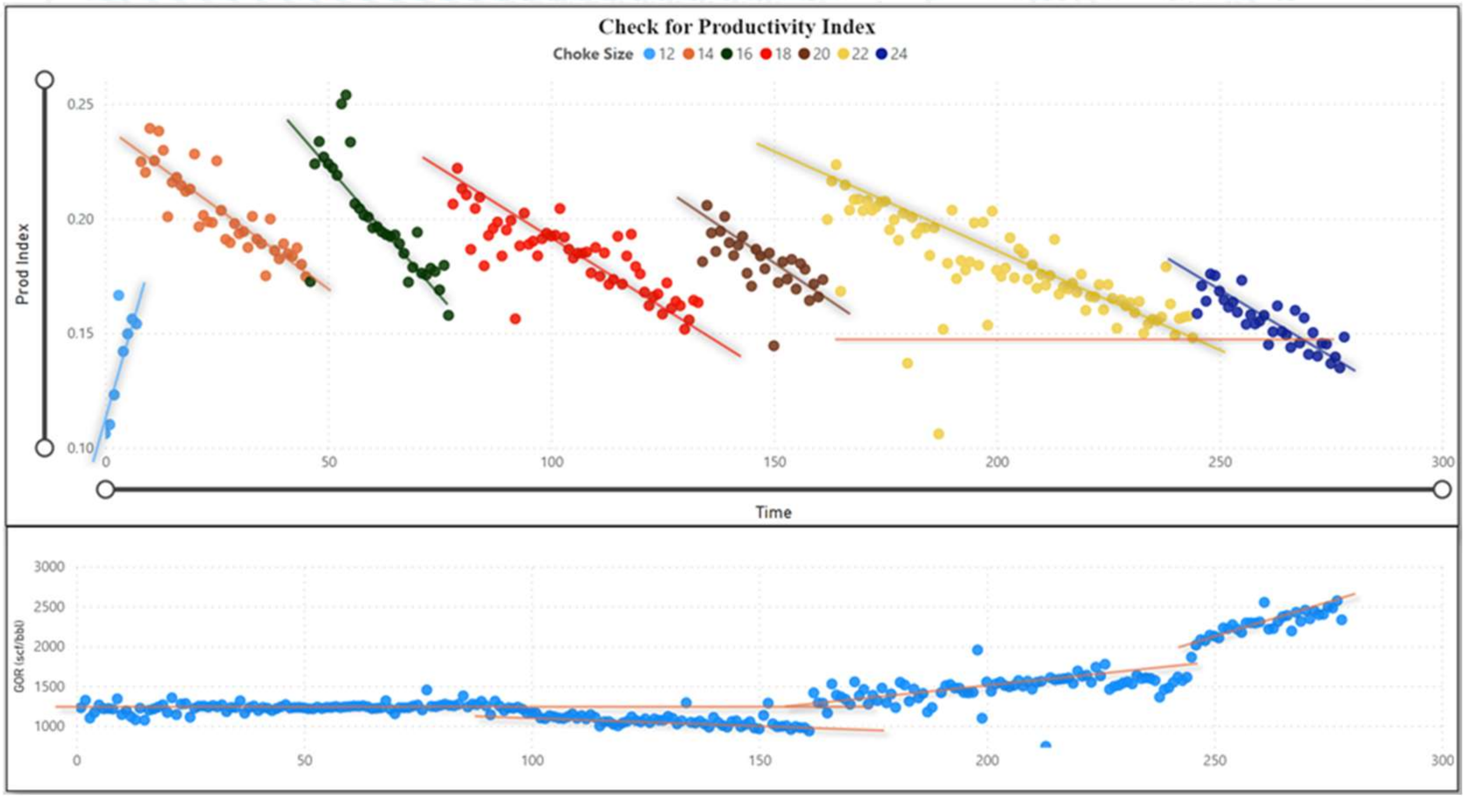


Cum Oil vs GOR Cartesian Plot

- Choke change should NOT be considered for production improvement once the average drainage pressure reaches or goes below bubblepoint.
- Below bubblepoint, maintaining the slope to improve the recovery should be considered unless the well starts to experience unstable flow at a particular choke
- A high shrinkage volatile oil would be very sensitive to a choke change below bubblepoint as opposed to slightly lower shrinkage oil.

ECM Workflow Contd.

Five key diagnostic plots were developed as part of this workflow, and they are discussed below.



Results and Discussion

DSU	Proppant (lbms/ft)	Fluid (bbls/ft)	# of Wells	EWS (per mile wide)
Non_ECM-1	1240	55	6	21
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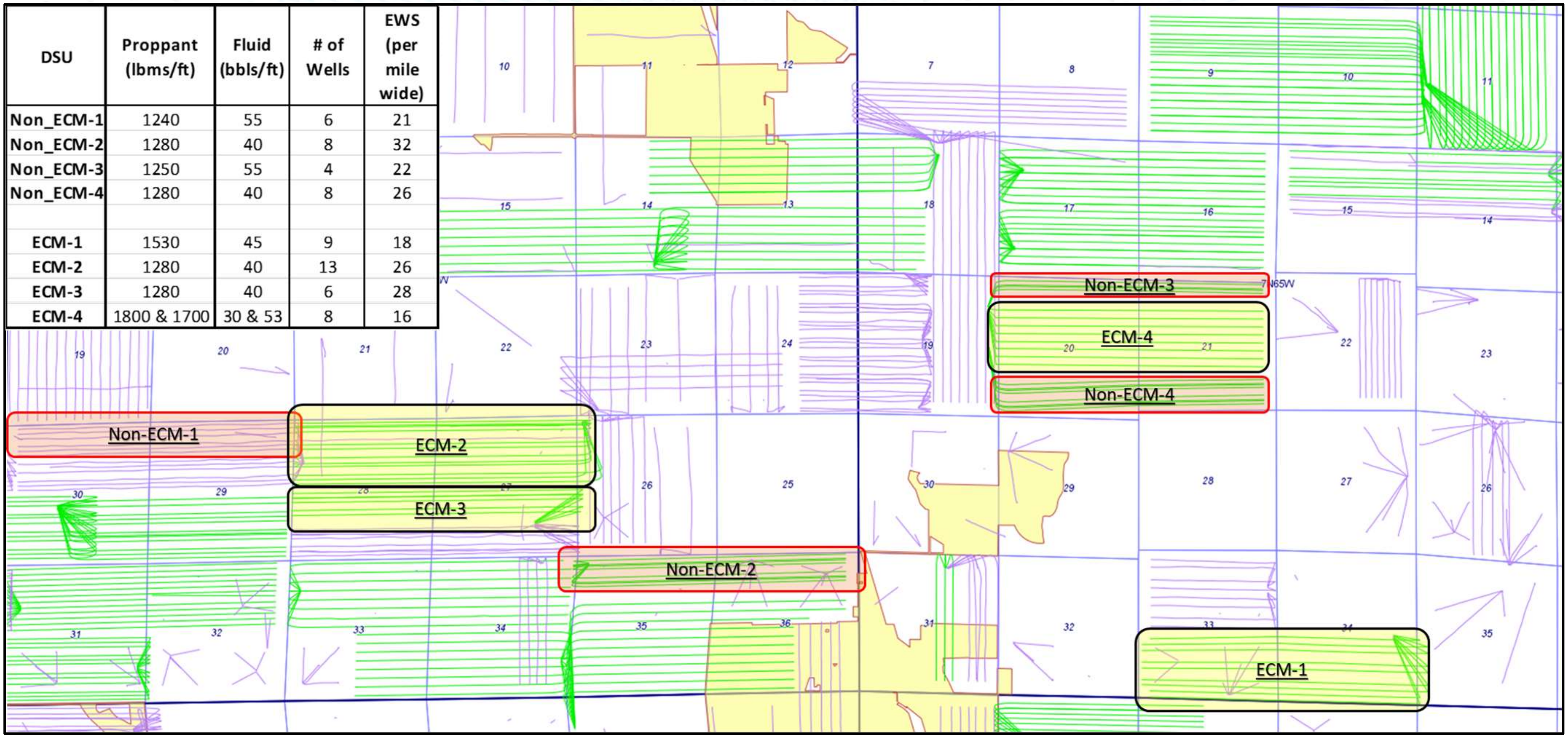
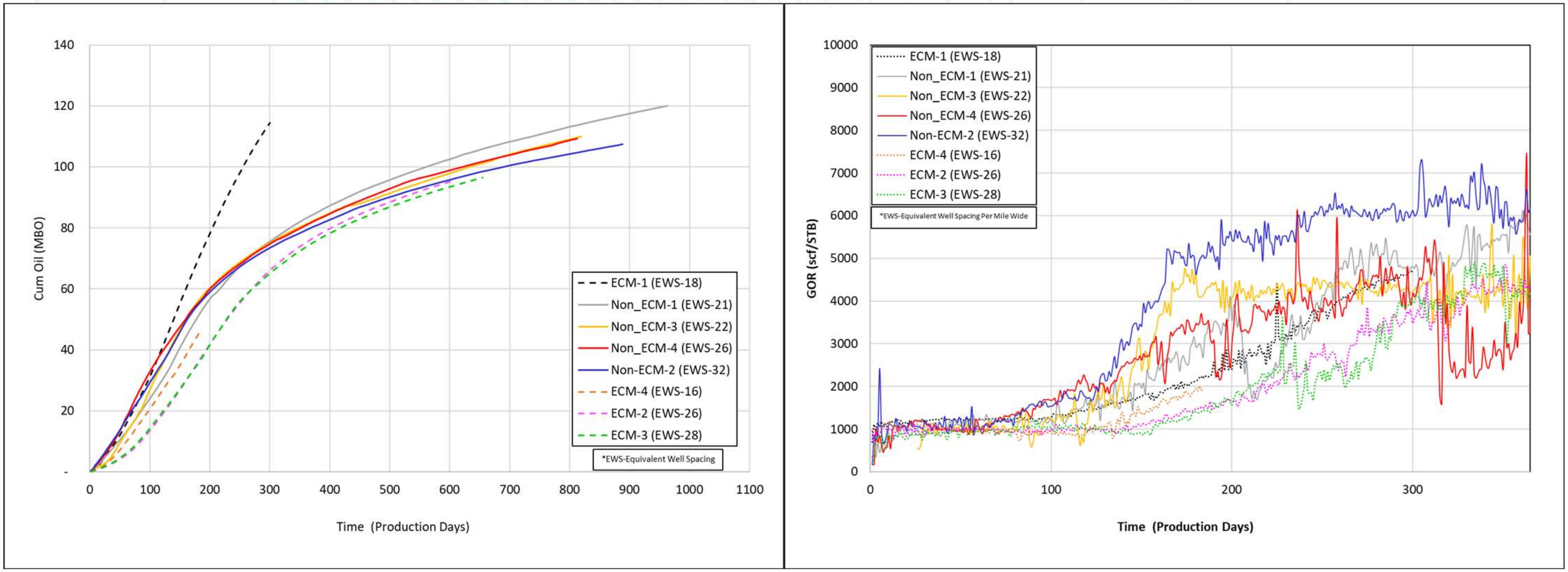


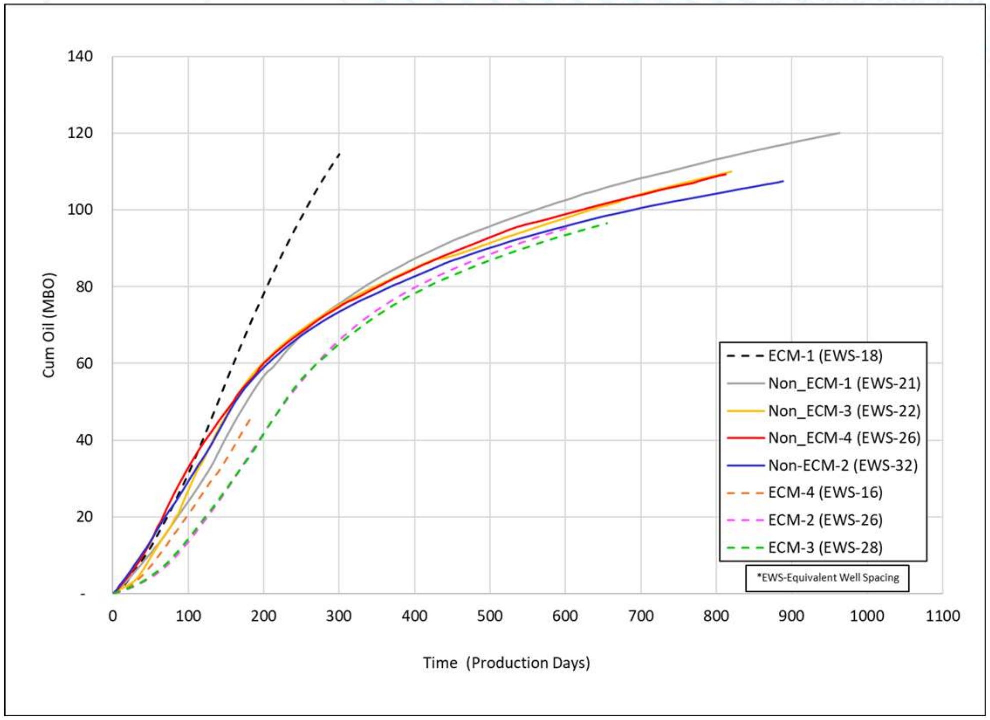
RESULTS and Discussion

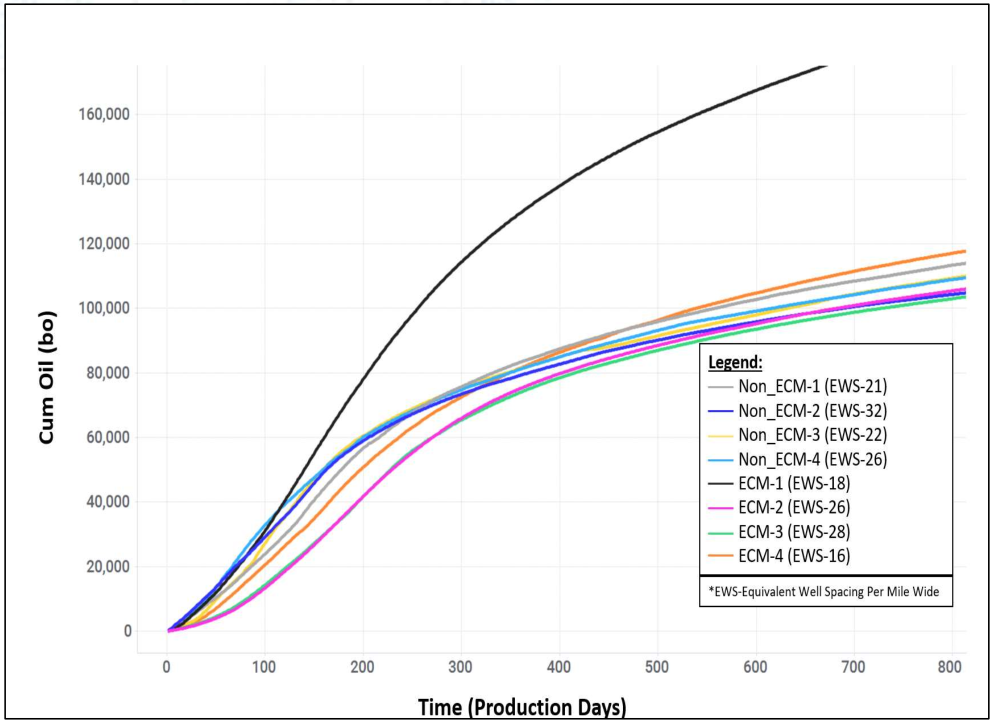


ECM vs Non-ECM DSU Comparison Plot (Left: Cum Oil vs Time; Right: GOR vs Time)

The time to reach BDF in the ECM DSU's are consistently longer than the Non-ECM DSU's thereby improving the potential recovery and the ROI of these wells

RESULTS and Discussion

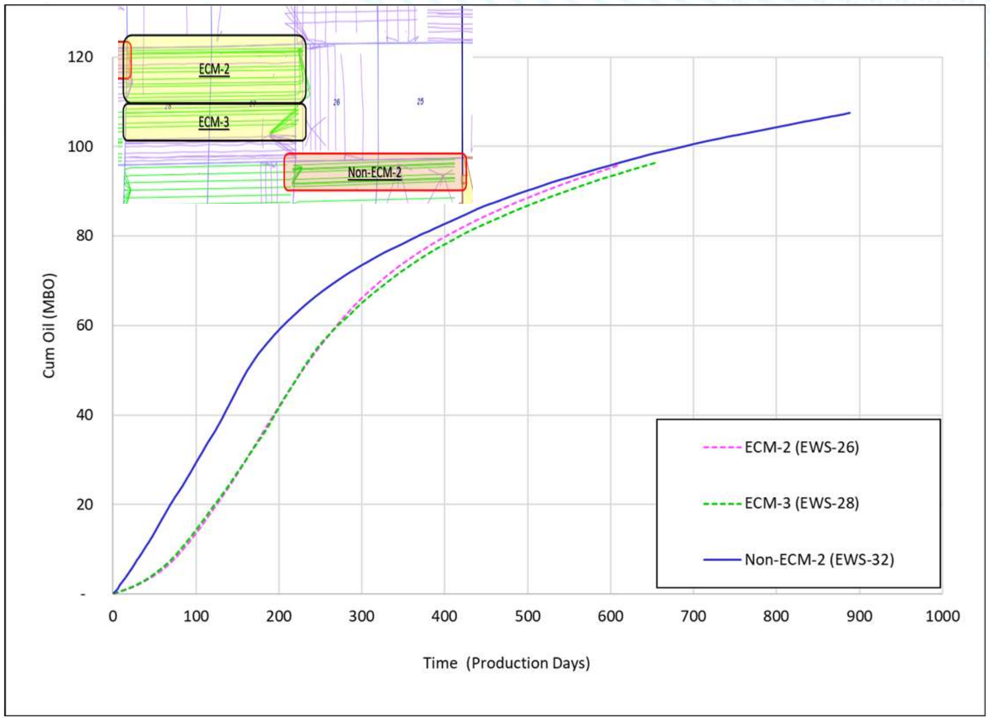




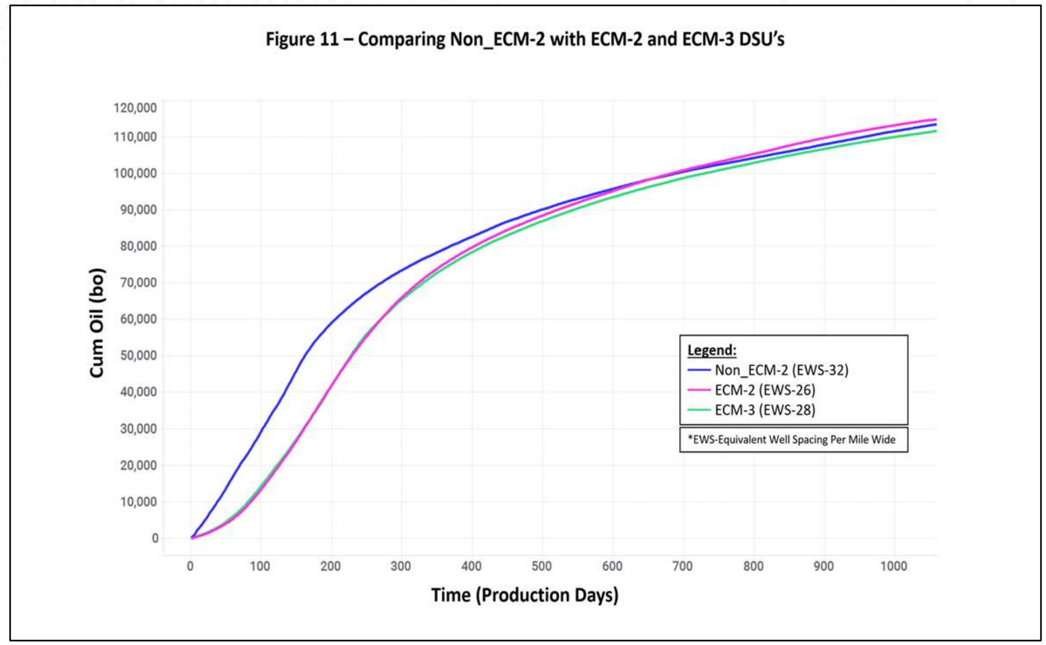
ECM vs Non-ECM DSU Comparison Plot (Left: Cum Oil vs Time; Right: Updated Production)

The time to reach BDF in the ECM DSU's are consistently longer than the Non-ECM DSU's thereby improving the potential recovery and the ROI of these wells

RESULTS and Discussion

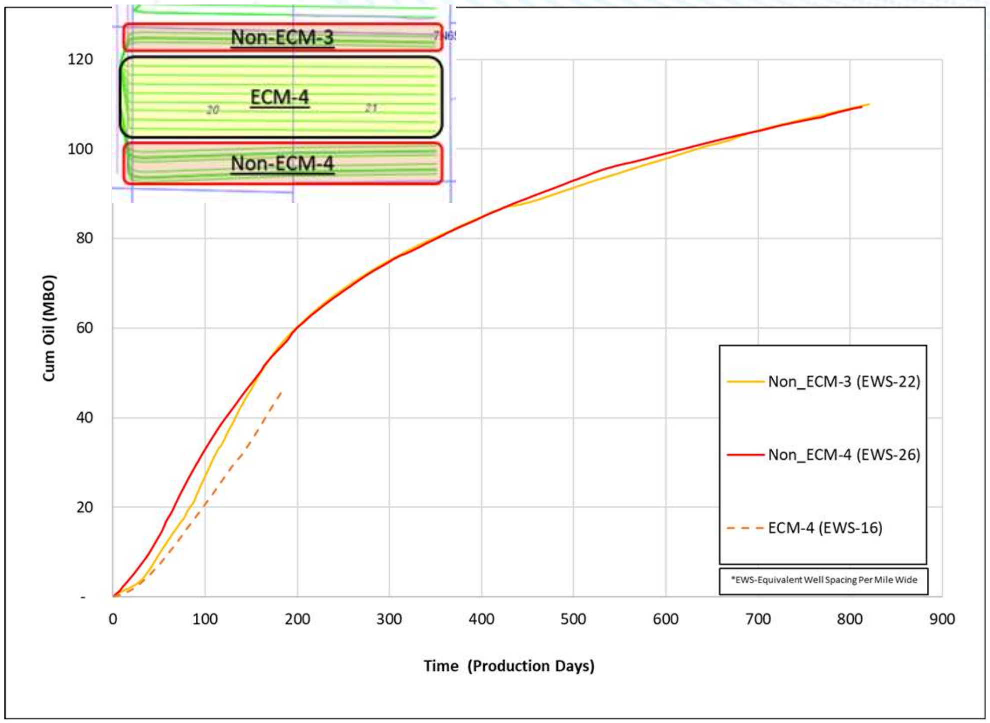


Comparing Non-ECM-2 DSU w/ECM-2 and ECM-3 DSU's;

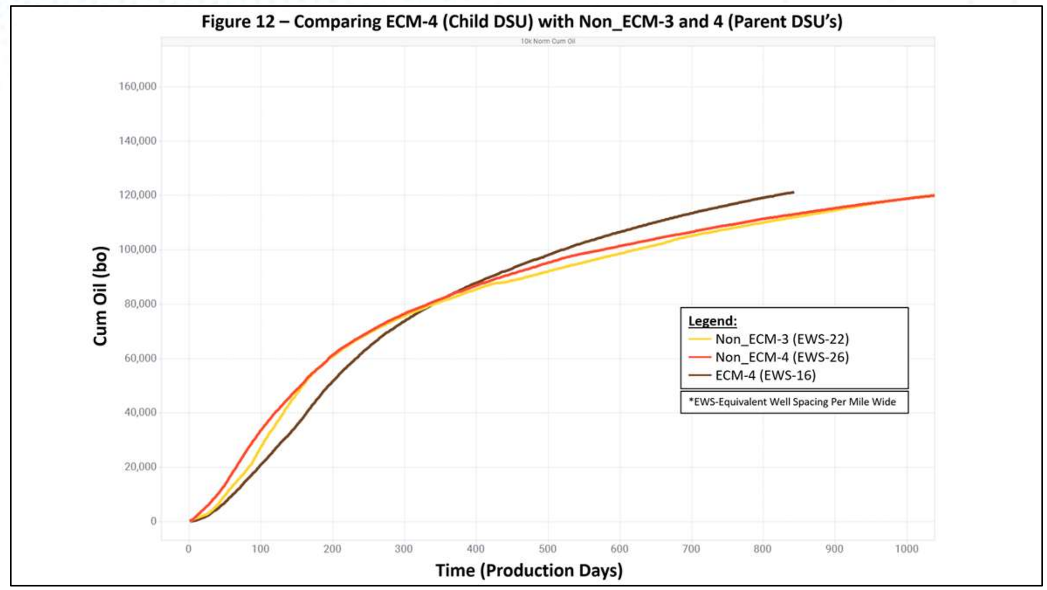


With Updated Production

RESULTS and Discussion



Comparing ECM-4 (Child DSU) w/Non-ECM-3 and 4 (Parent DSU's)



With Updated production

Conclusions

1. The implementation of the ECM workflow has improved well performance in both Codell and Niobrara reservoirs in the study area of the DJ basin.

2. Managing drawdowns during the transient flow period has improved well cleanup and increased drainage area size while also limiting excessive gas production from these reservoirs. It is important to limit excessive gas production during the boundary dominated flow period as well to ensure efficient recovery of these oil resources.

3. Excessive GOR increases have been arrested since the implementation of the ECM workflow. As a result, transient flow periods have been extended thereby improving the potential recovery and the ROI of these wells.

4. The proposed ECM workflow has application in other reservoirs with similar production challenges.

Acknowledgement

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