Society of Petroleum Engineers

IOR/EOR Practices for Enhanced Efficiency in the Evolving Carbon-Conscious Environment

11–12 JUNE 2024 | JAKARTA, INDONESIA

Effect of Proppant Production on Long-Term Recovery in Shale Gas Reservoirs

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Agenda

1. Introduction
2. Methodology
3. Model Development
4. Results and Analyses
5. Conclusions

1. Introduction

➢ Appalachian basin

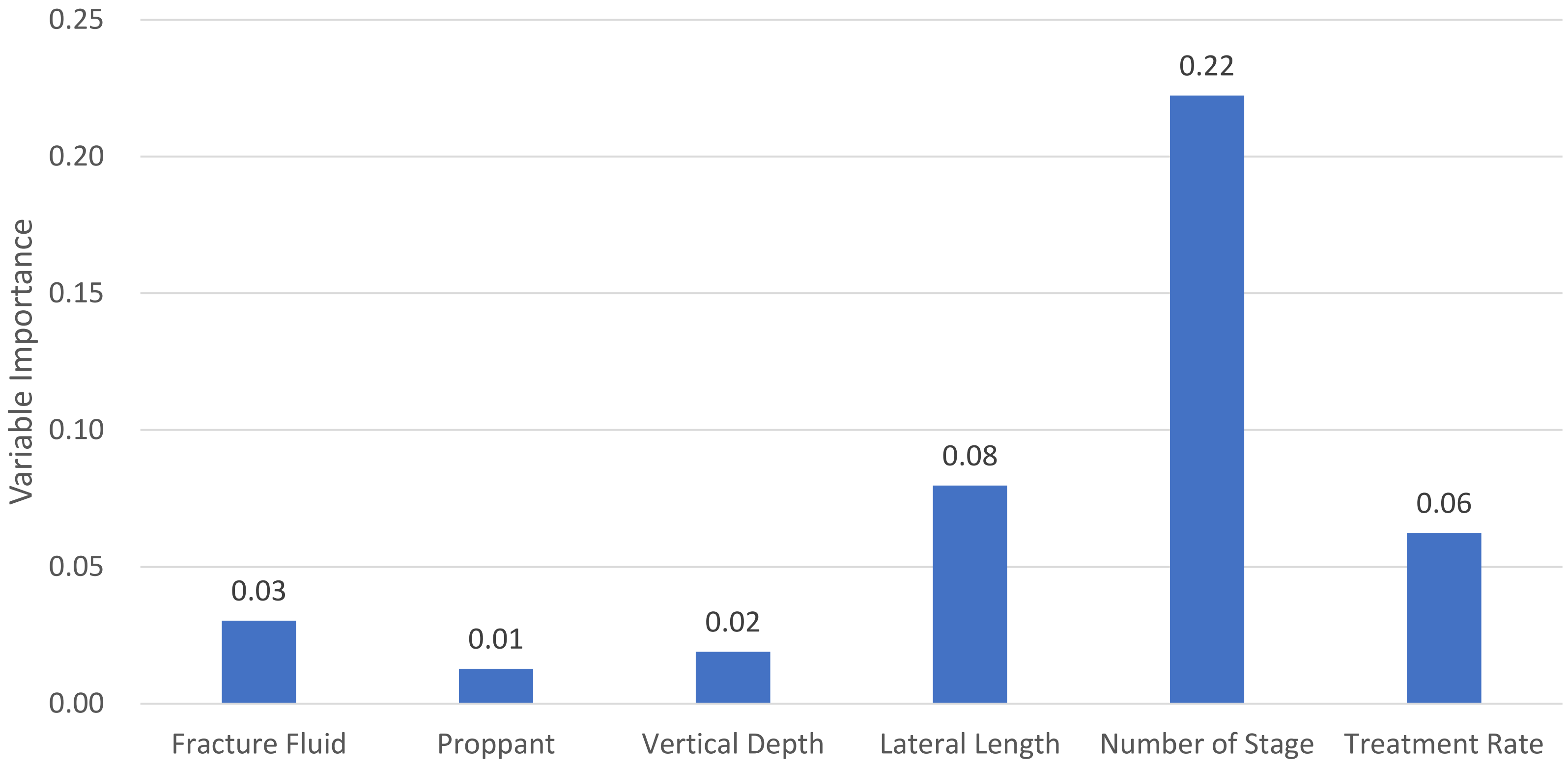
- 1/3 gas production in the U.S.
- Low permeability and porosity
- Nano-scale pores
- Heterogeneous
- Natural fractures

1. Introduction to stimulation treatments

Name of Parameters	Mean	Range
Fracture fluid (million gallon)	4.97	0.03-10.90
Proppant mass (million lbm)	4.46	0.02-10.50
Number of stages	12	5-29
Treatment rate (bpm)	87	62-101
Vertical depth (ft)	7,081	4,483-8,732
Lateral length (ft)	4,690	1,096-10,616
One-year cum gas production (bcf)	0.74	0.09-2.09

- Proppant concentration is close to **1** lbm/gal.
- Data screening processes were done by Mahalanobis distance

1. Introduction to important factors affecting recovery

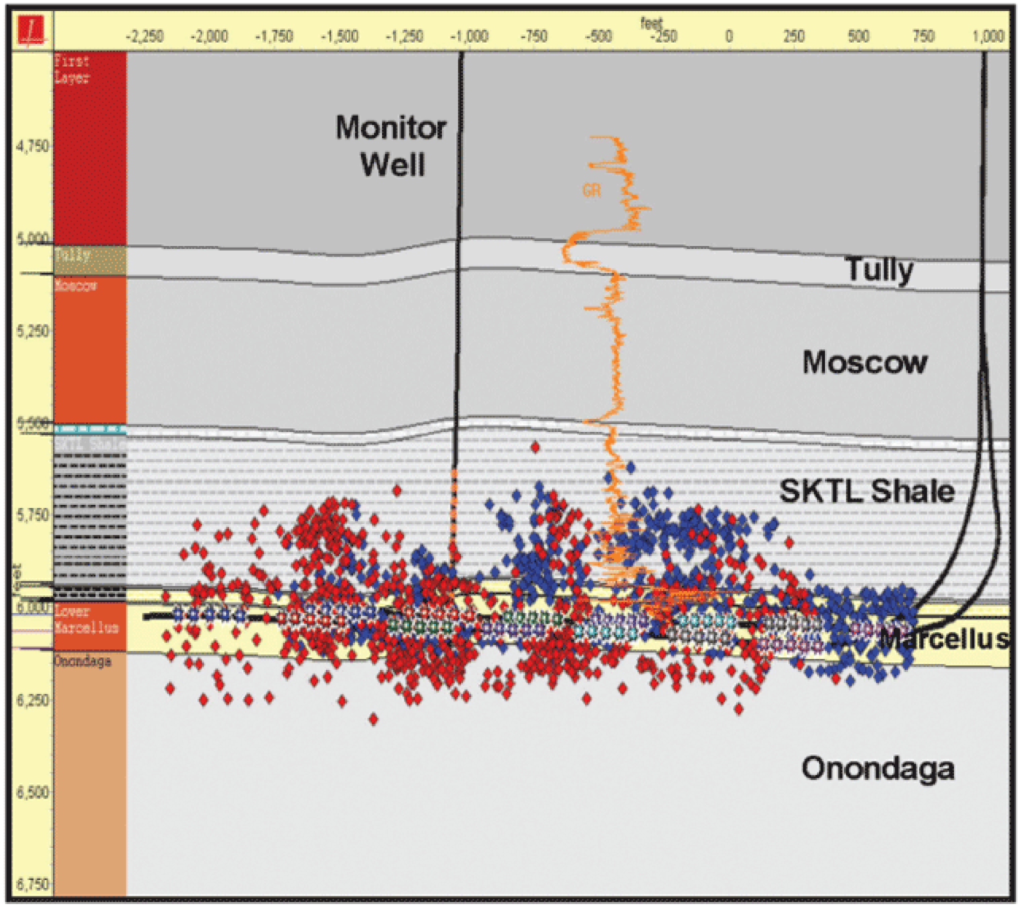


Zhou, Dilmore, Kleit and Wang, 2014

1. Introduction

- ➢ Horizontal well and hydraulic fracture stimulation
  - Create stimulated reservoir volume (SRV)
  - Enable economic recovery
- ➢ Fracture Conductivity
  - Is $k_f \cdot w_f$ (md·ft)
  - Placed proppant to maintain high conductivity

However, proppant production occurs during the production phase



Microseismic imaging of Marcellus shale (Barth, 2012)

➢ Problem statement

- Mechanisms of proppant production are not well understood
- None of the published studies investigated the impact of proppant production on long-term recovery in shale gas reservoirs

Research objective

- To investigate the effect of proppant production on long-term recovery in shale gas reservoirs through numerical simulation

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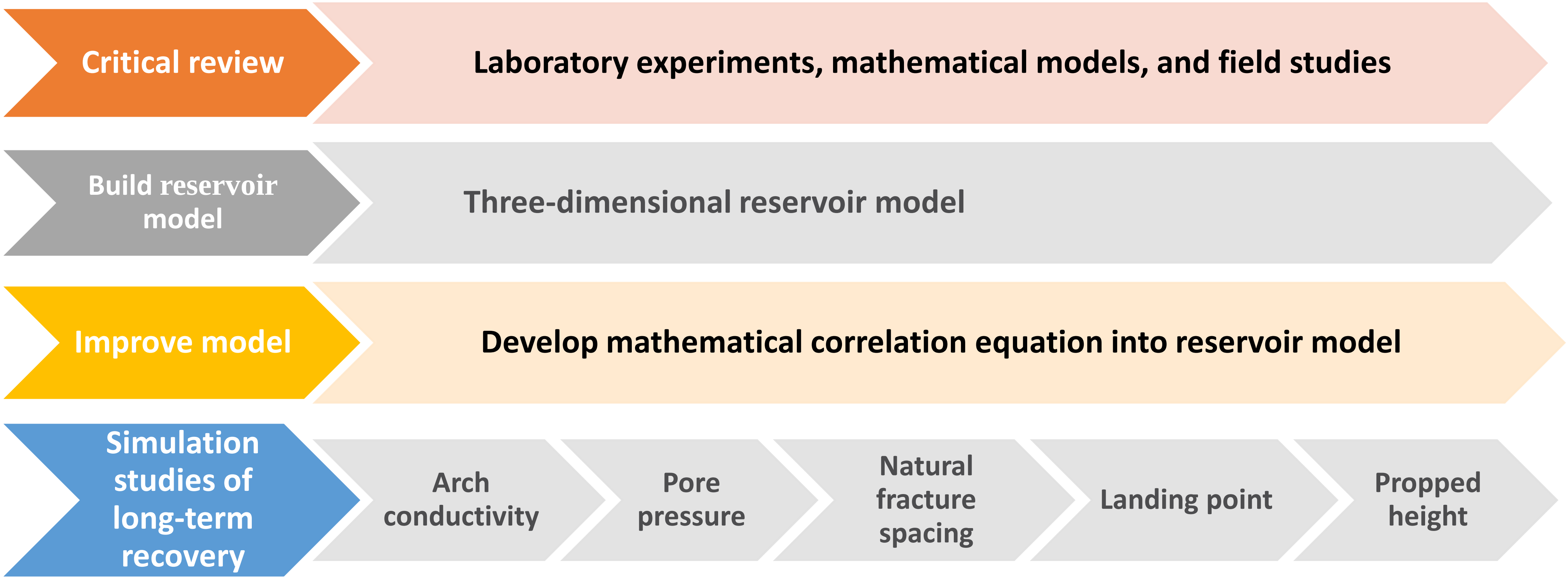
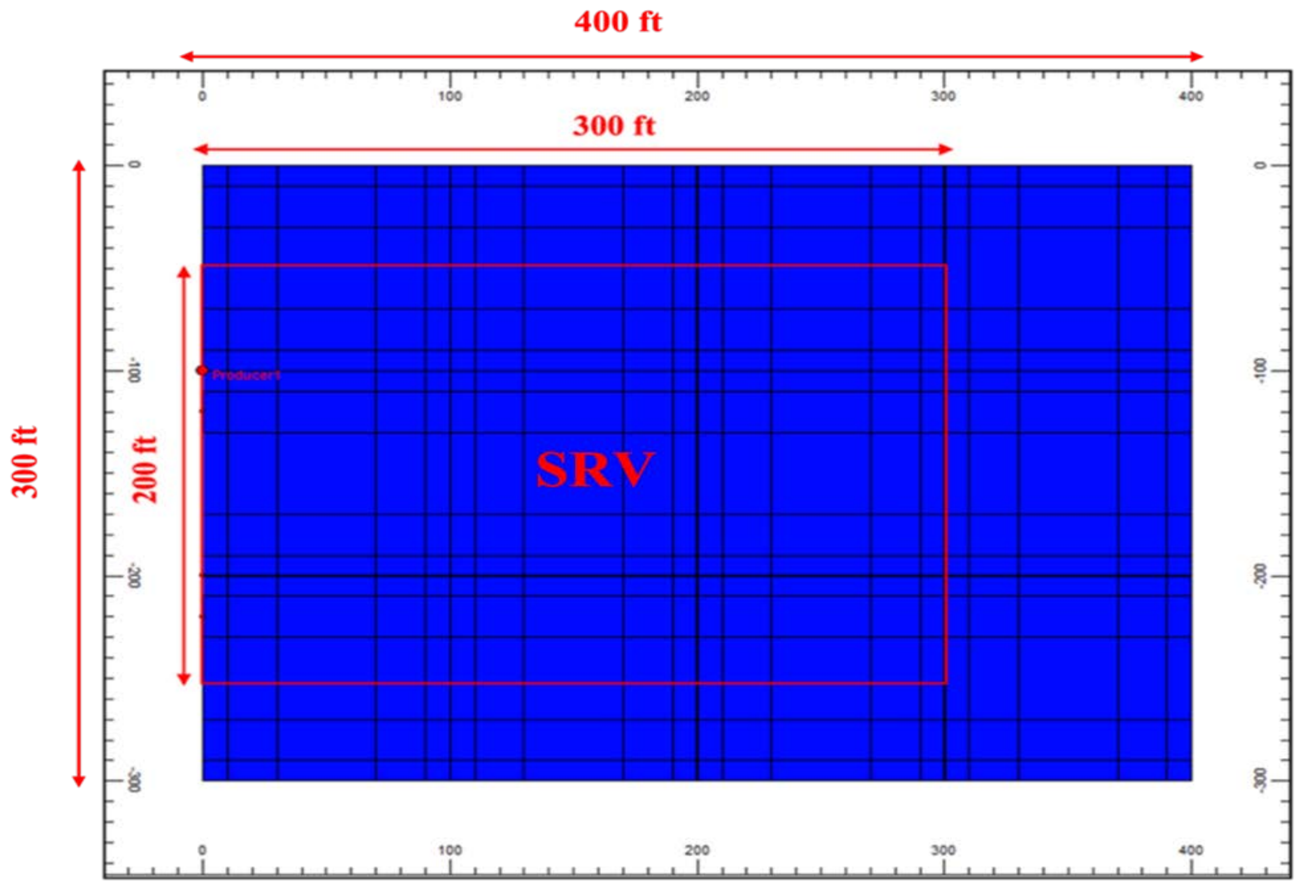
2. Methodology



3. Model development

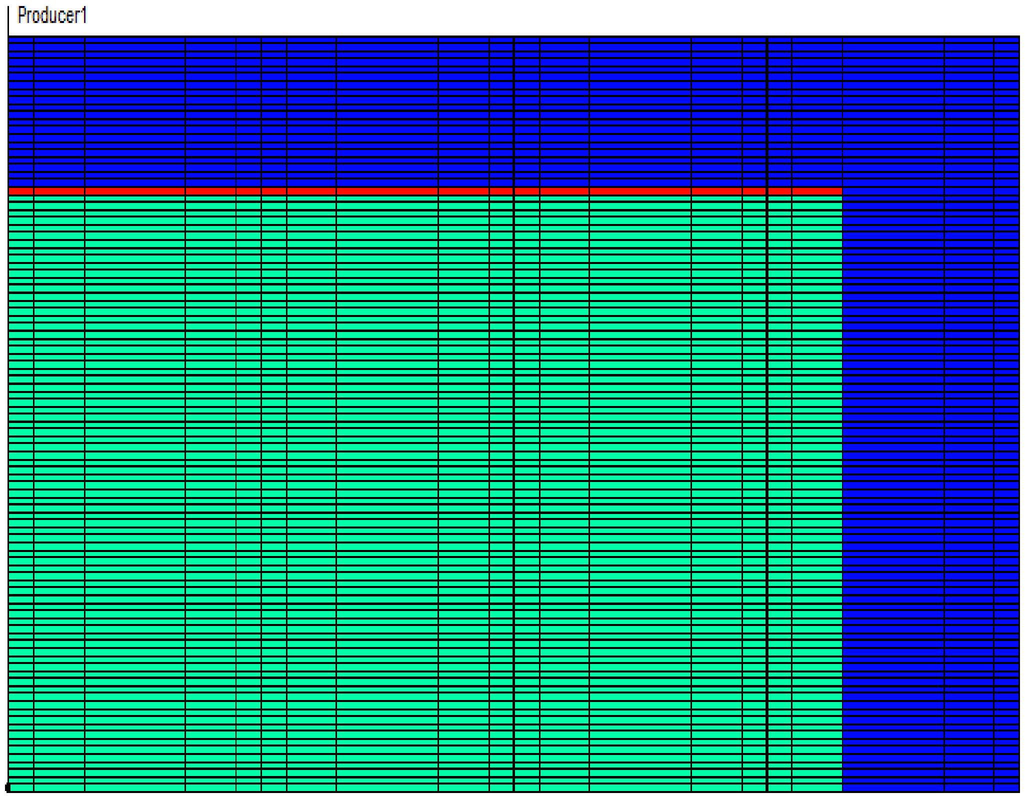


Grid system of matrix and SRV in the reservoir model (cross-sectional views)

Reservoir and fluid properties for base model

Reservoir parameters	Value
Matrix permeability, md	1.0×10^{-5}
Matrix compressibility, psi^{-1}	3.0×10^{-6}
Matrix porosity, fractional	0.09
Fracture conductivity, md·ft	15
Arch conductivity, md·ft	45
Fracture compressibility, psi^{-1}	3.0×10^{-6}
Fracture porosity, fractional	0.09
Reservoir temperature, °F	200
Reservoir pressure, psi	3,600
Thickness, ft	100
Depth, ft	9,000
Initial gas saturation	1
Wellbore radius, ft	0.125

3. Model development



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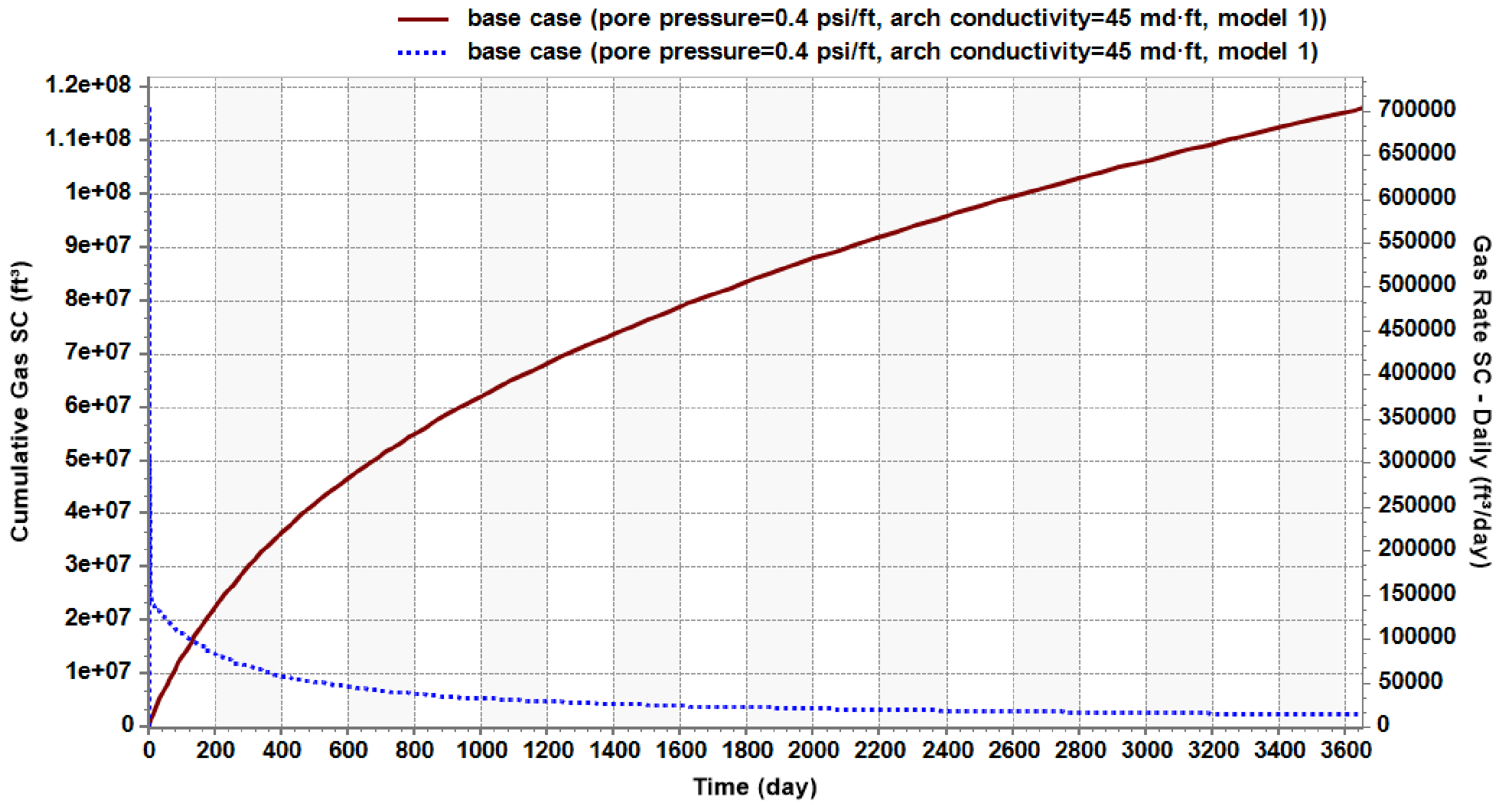
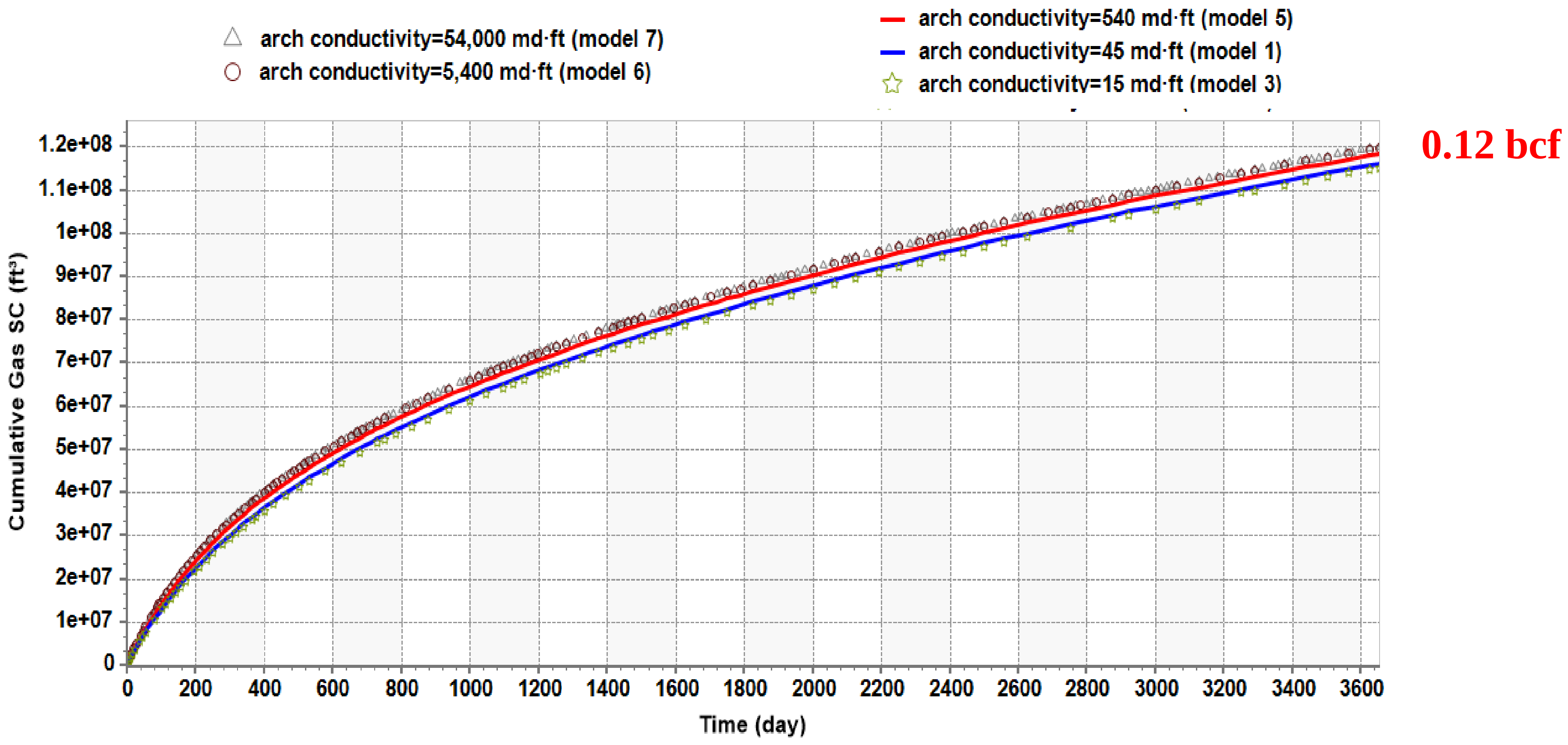
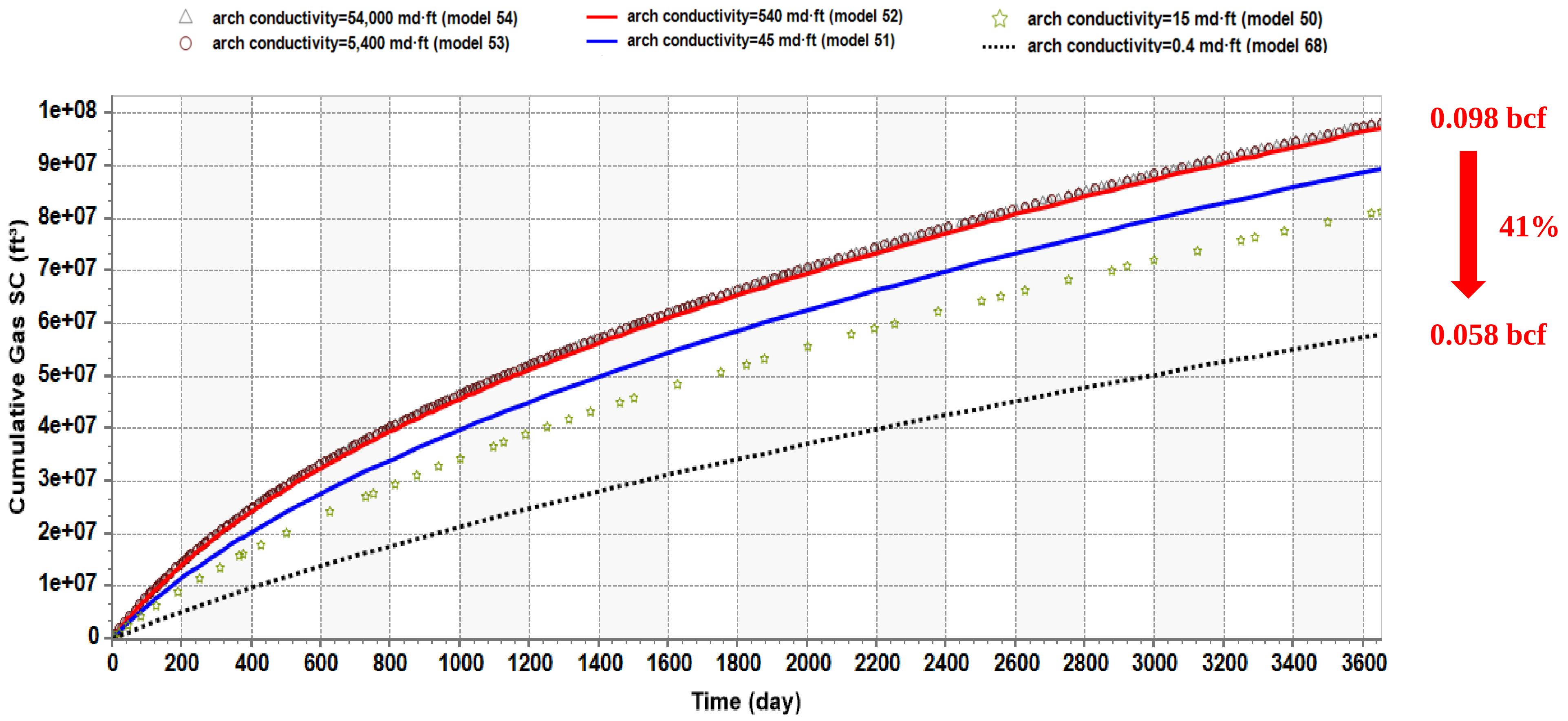
4. Results and analysis



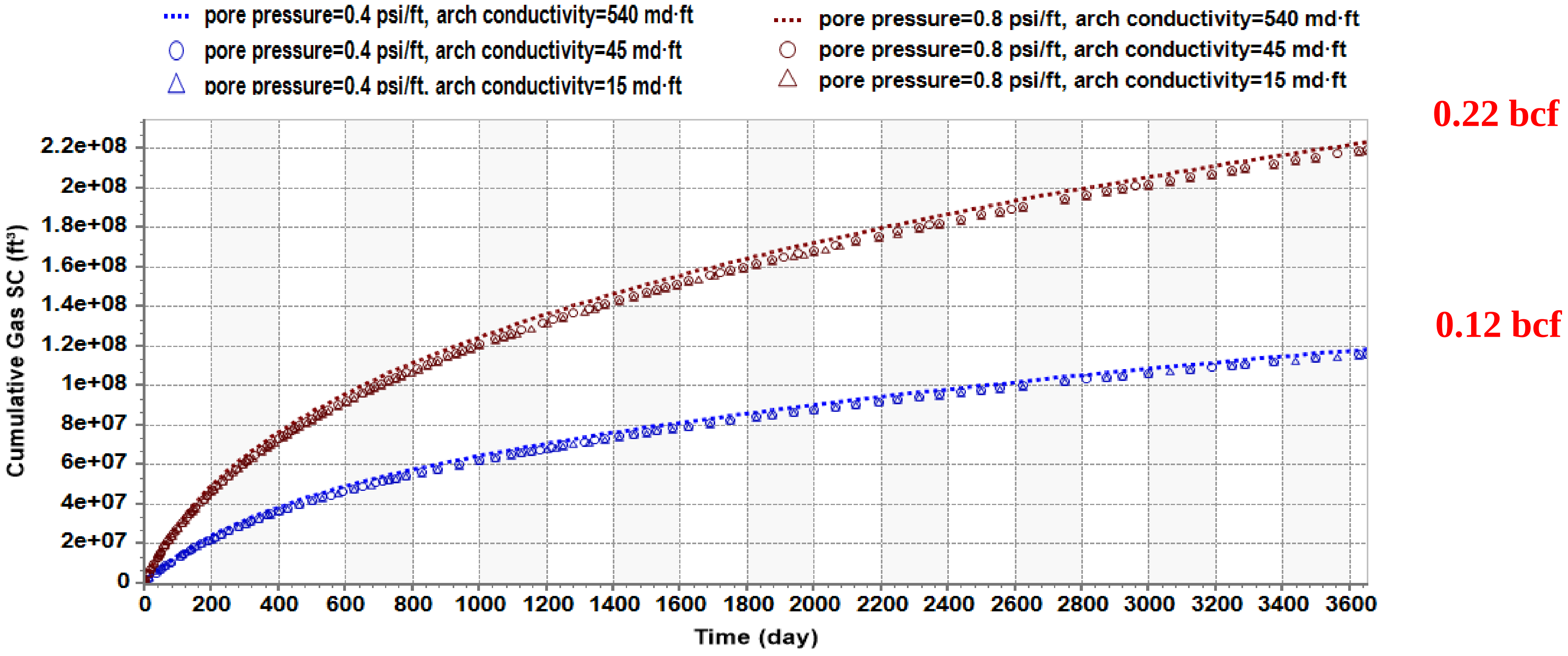
➢ Effect of arch conductivity for $C_{f,SRV}$ = 15 md·ft



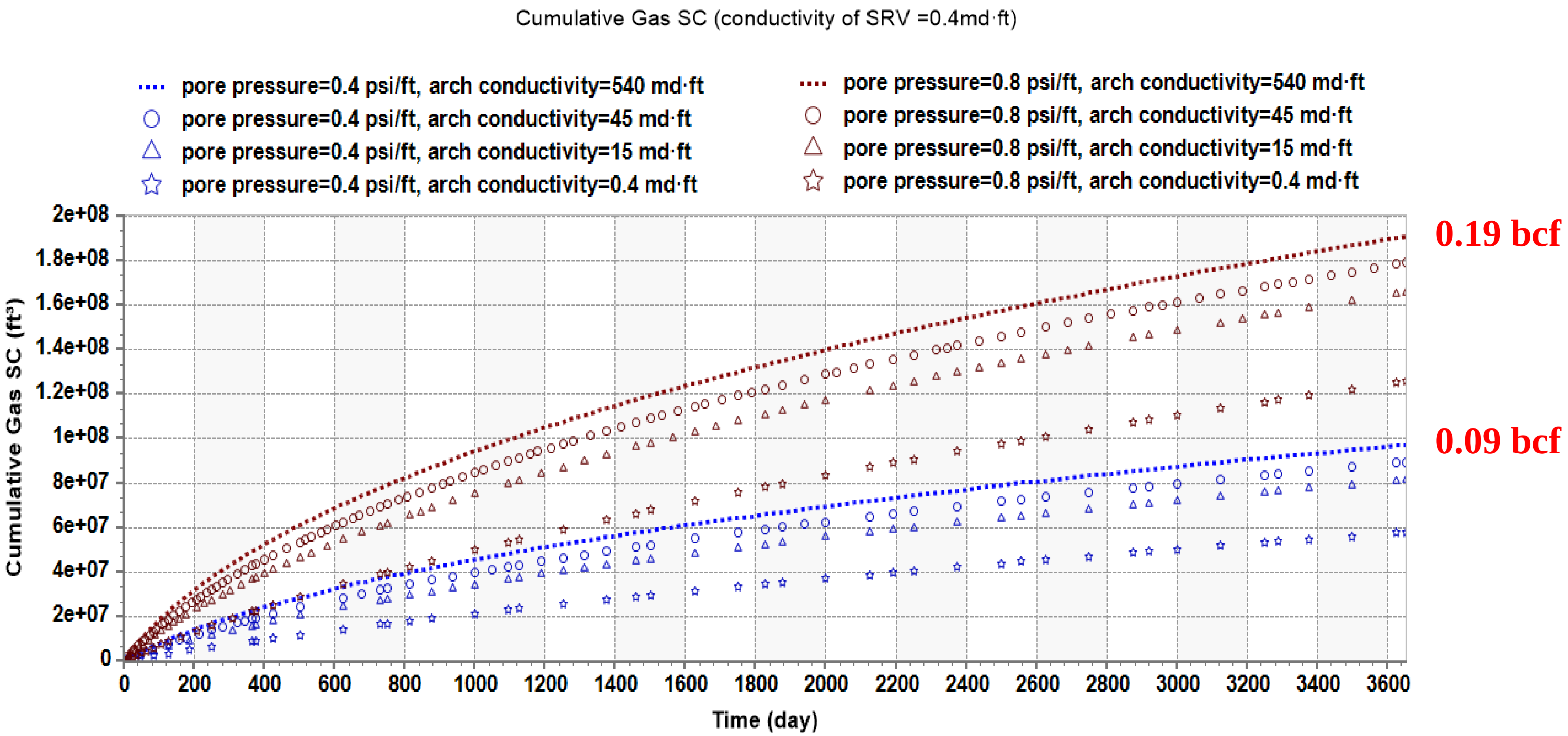
➢ Effect of arch conductivity for $C_{f,SRV}$ = 0.4 md·ft



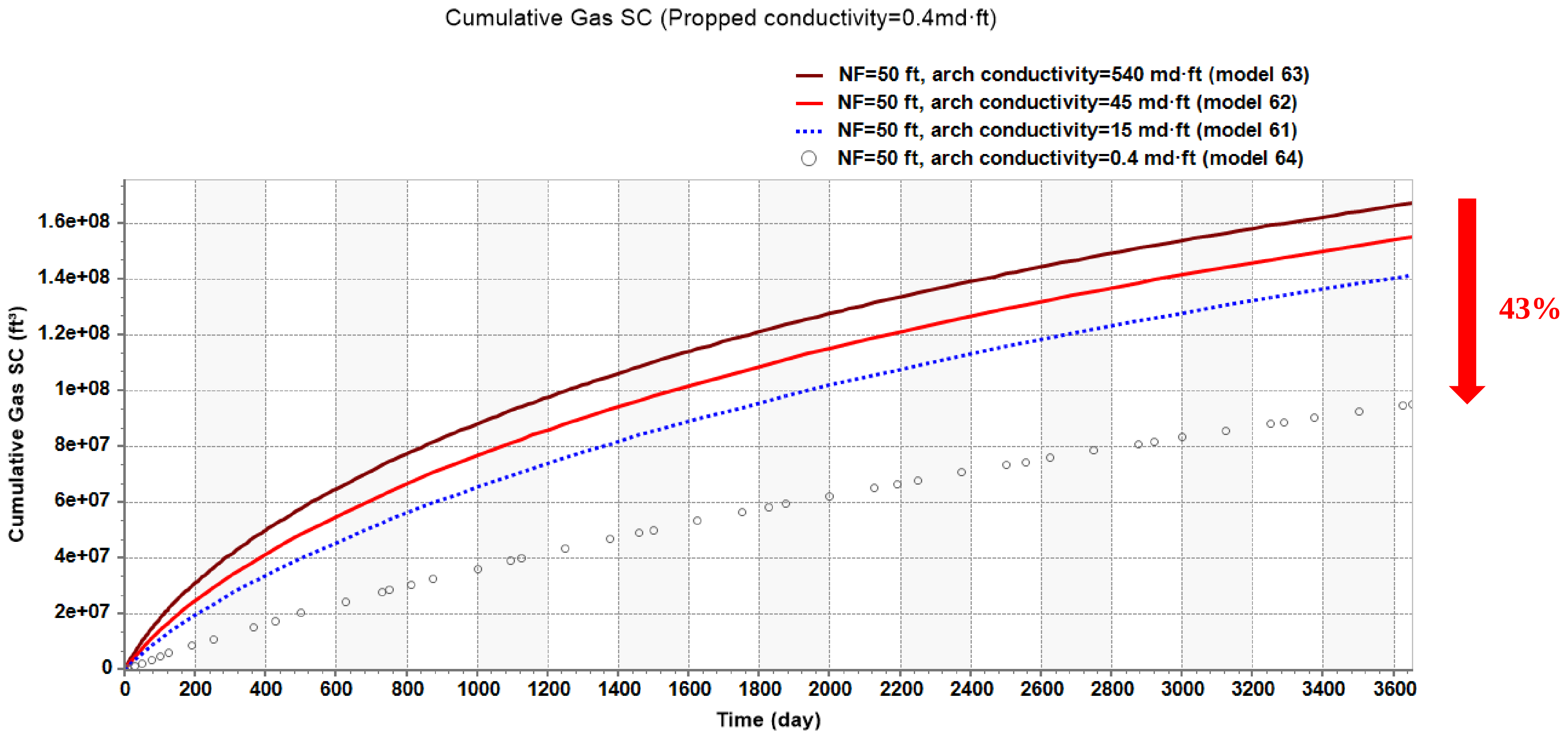
➢ Effect of pore pressure for $C_{f,SRV} = 15$ md·ft



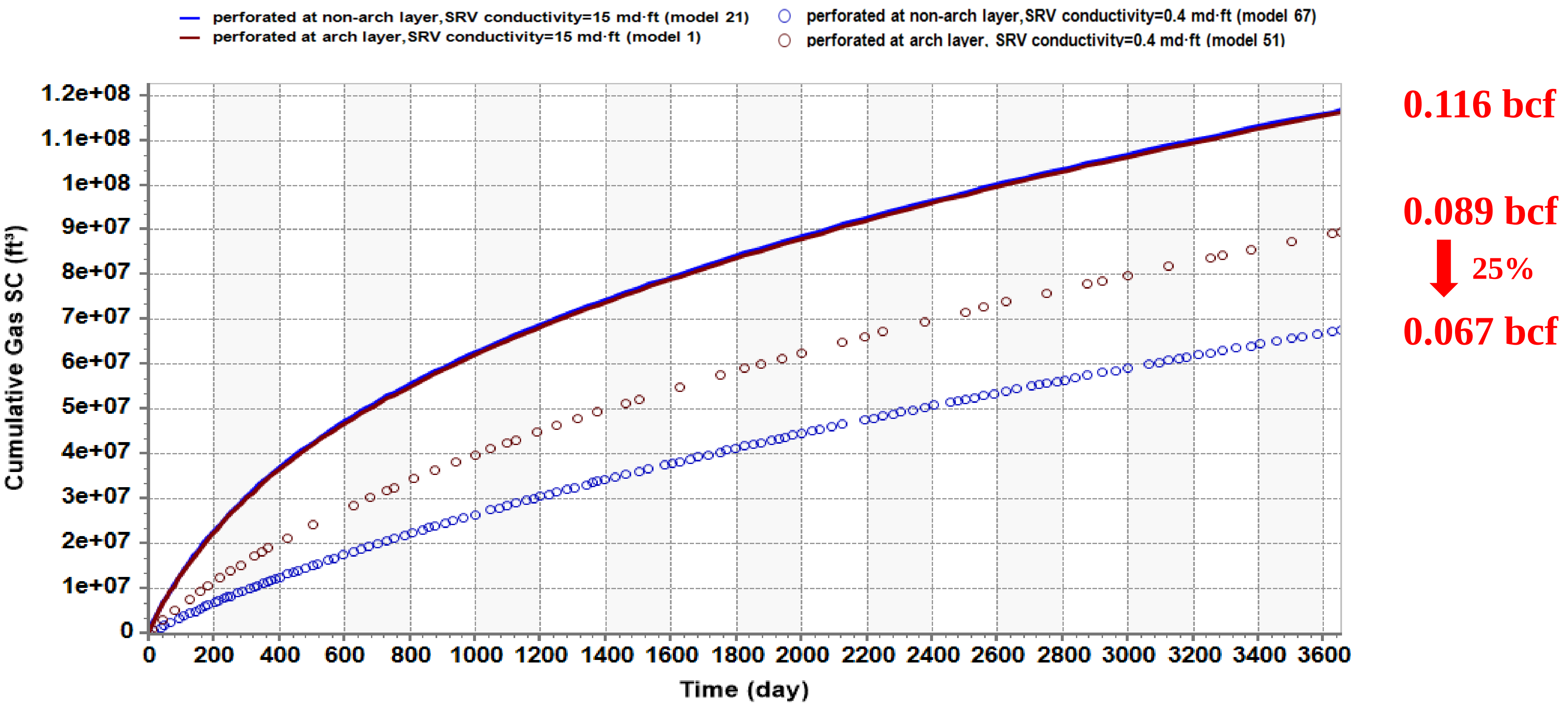
➢ Effect of pore pressure for $C_{f,SRV}$ = 0.4 md·ft



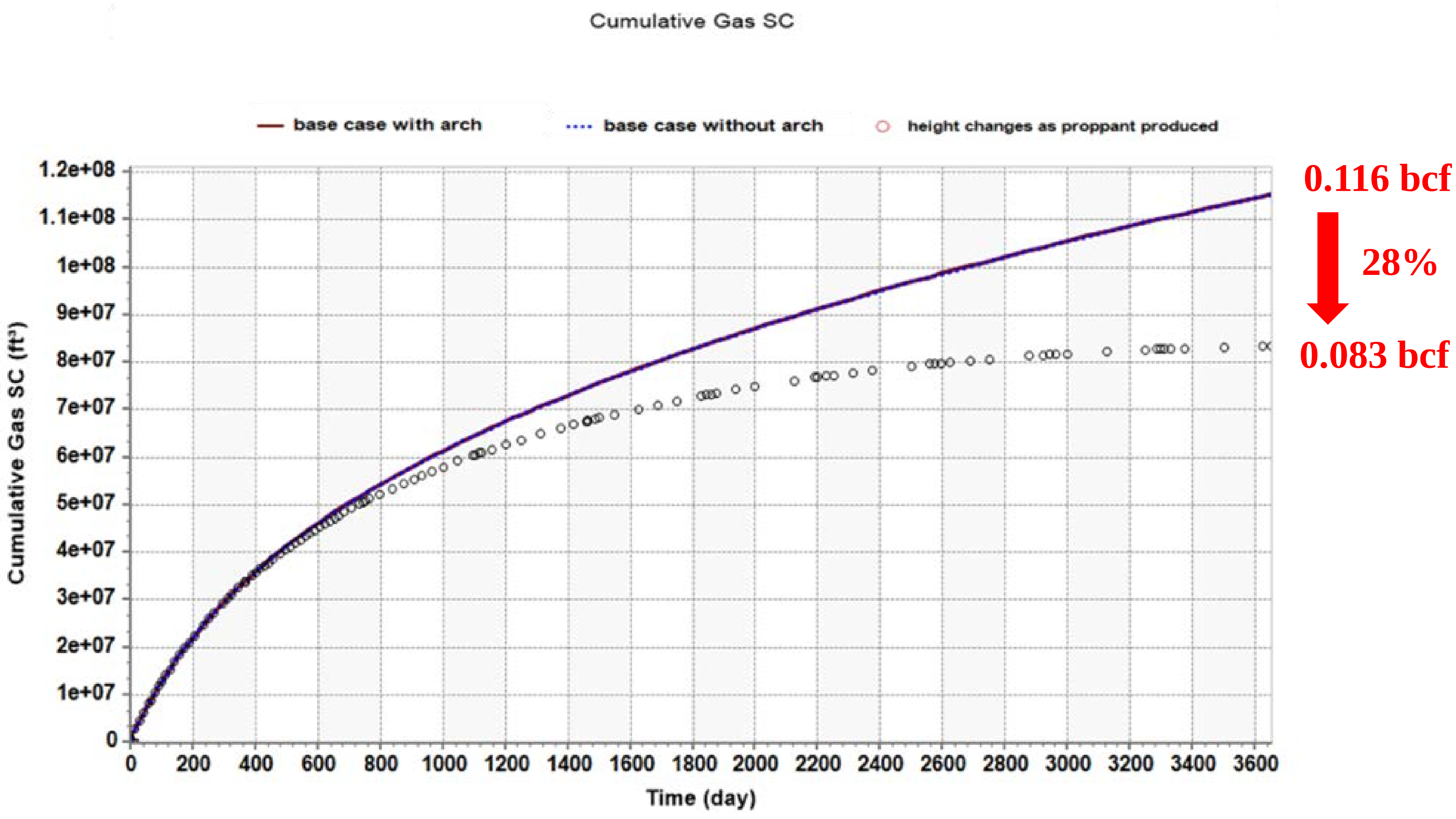
➢ Effect of natural fracture spacing for $C_{f,SRV}$ = 0.4 md·ft



➢ Effect of landing point



➢ Effect of propped height changes



5. Conclusions

- When the conductivity of the SRV is 15 md·ft, effect of arch and its conductivity is negligible; While, when SRV conductivity is 0.4 md·ft, 10-year gas production increased by 41% for arch conductivity of 54,000 md·ft compared to that without arch.
- When SRV conductivity is high as 15 md·ft, effect of arch and its conductivity (15-540 md·ft) on gas production is negligible for pore pressures of 0.4 psi/ft and 0.8 psi/ft. While, when SRV conductivity is 0.4 md·ft, an arch increases 10-year gas production by 41% to 52% for both 0.4 psi/ft and 0.8 psi/ft.
- When SRV conductivity is 0.4 md·ft, pore pressure of 0.8 psi/ft without arch yields same production as 0.4 psi/ft with arch conductivity of 540 md·ft during the first three years despite a difference of 23% in 10 years.

5. Conclusions

- **For fracture spacing of 50 ft and 100 ft, when SRV conductivity is high as 15 md·ft, effect of arch and its conductivity on gas production is negligible, but when SRV conductivity is 0.4 md·ft, an arch increases 10-year gas production by 41% to 43%. Fracture spacing of 50 ft increases 10-year gas production by 40% to 42% compared to fracture spacing of 100 ft.**
- **For landing point, when SRV conductivity is high (15 md·ft), there are no differences between landing at the upper or lower section of the pay, but when SRV conductivity is low (0.4 md·ft), landing at the upper section (at the arch layer) increases 10-year gas production by 25% compared to landing at the lower section.**
- **Dynamic propped height changes, as evidence of proppant production that observed in the field, decreased gas production by 28% in 10 years.**

Thank you!