THE IMPACT OF THE PRODUCTION OF NEIGHBOUR WELLS ON WELL PRODUCTIVITY IN A SHALE GAS RESERVOIR

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ABSTRACT: A shale gas reservoir is a self-contained source-reservoir system, characterized by extremely low matrix-permeability and low porosity, which typically requires an extensive fracturing to produce gas at commercial rates. This paper presents a simulation experiment, intended to study the impact of well interference on gas recovery in a shale gas reservoir. The simulation model was constructed to study well interference through variation of horizontal well length, fracture half length, the number of fractures, and well spacing. The results show that the increment of recovery factor of a well in the presence of neighbour wells is up to 7%. In this study, fracture half length is the most influential parameter affecting recovery factor, initial rate and reservoir pressure decline.

ABSTRAK: Takungan gas syal merupakan sistem sumber-takungan kandung sendiri, khasnya kerana ia mempunyai kebolehtelapan-matriks yang begitu rendah dan keliangan yang rendah. Sifat sebegini memerlukan ia melalui peretakan yang ekstensif untuk menghasilkan gas pada nilai komersial. Kertas kerja ini membentangkan eksperimen simulasi yang bertujuan untuk mengkaji impak perigi interferens terhadap perolehan gas dalam takungan gas syal. Model simulasi di konstruksi untuk mengkaji interferens perigi; iaitu menerusi pelbagai variasi panjang mendatar perigi, retakan separuh panjang dan jarak perigi. Keputusan menunjukkan peningkatan faktor perolehan perigi sebanyak 7% dengan kehadiran perigi bersebelahan. Dalam kajian ini, retakan separuh panjang merupakan ciri utama dalam faktor perolehan, kadar awalan dan penurunan tekanan takungan.

KEYWORDS: *heterogeneity; porosity; surfactant-polymer flooding; recovery factor; shake flask*

1. INTRODUCTION

Shale gas is one of a number of unconventional sources of natural gas. Shale gas areas are often known as resource plays as opposed to exploration plays. The geological risk of not finding gas is low in resource plays, but the potential profits per successful well are usually also lower. Shale has low matrix permeability, so gas production in commercial quantities requires fractures to provide adequate permeability [1, 2]. Shale gas has been produced for years from shale with natural fractures. The shale gas reservoirs become a significant source of gas supply due to the advancement of hydraulic fracturing to create extensive artificial fractures around the well bores [3].

Shale gas wells often use horizontal drilling with lateral lengths of up to 10,000 feet within the shale to maximize borehole surface area in contact with the shale. This field-based study uses reservoir data from a field located on Central Sumatra, Indonesia as depicted in Fig. 1. The objective of this paper is to analyze the impact of well interference on well gas productivity.

2. GEOLOGICAL REVIEW

Shale gas reservoir in Central Sumatra has not been developed. However, according to geological studies, the gas potential in the area is predicted to yield about 558 TCF. Shale gas layers are precipitated in Central Sumatra basin as shown in Figs. 1 and 2. The basin is bounded to the north by submerged basement high Asahan Arch and to the west is bounded by pre-Tertiary basement in the uplifted Barisan Mountain. While to the northeast it wedges out onto the Sunda Craton in Malacca Strait and to the southeast it is separated by Kampar uplift and Tigapuluh High from South Sumatra Basin. Central Sumatra Basin is filled with up to 3500 meters tertiary sediment with average thickness of 1500 meters [4].

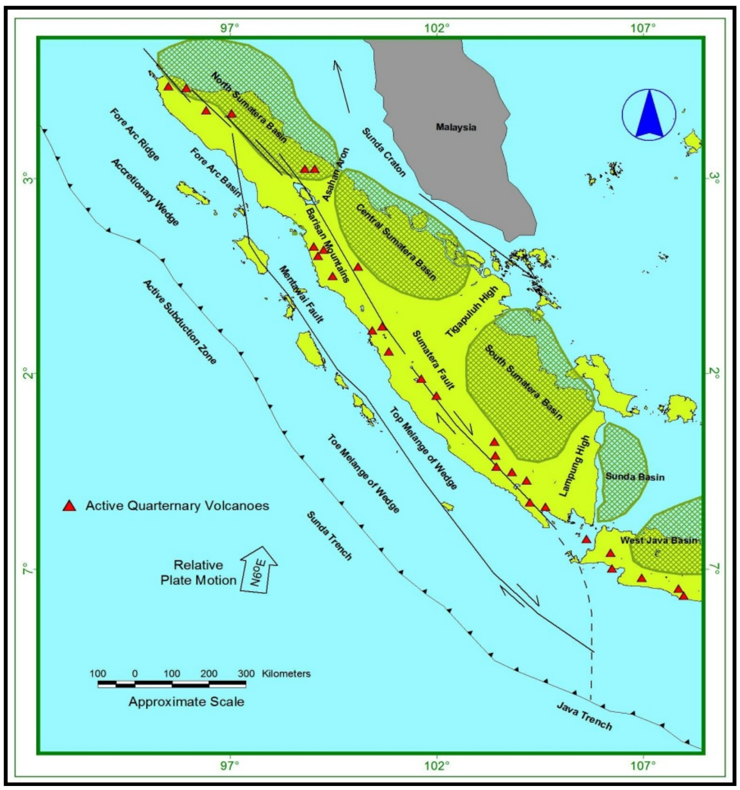


Fig.1: Shale gas potential in Central Sumatra Basin.

3. METHOD

Fekete's F.A.S.T Evolution software was used to generate analytical gas forecasts for the shale gas reservoir. The horizontal well model is shown in Fig. 3.The model has the wells located in a rectangular shaped reservoir with homogeneous characteristics and the horizontal section located in the middle of the formation. Green's function solution as developed by Thompson et al. [5] with slight modifications has been implemented in this model. To simulate an infinite-conductivity vertical fracture, the vertical permeability of the formation was assumed to be very large, as suggested by Gringarten et al. [6].

A reservoir model equipped with well(s) was constructed with properties from the field. The wells were located in 1, 3, 5, 7, and 9 spot patterns as illustrated in Fig. 4. The analytical simulation method used to study the impact of neighbour wells interference on the well located on the centre. The software handles interference between wells even when they come on production at different times.

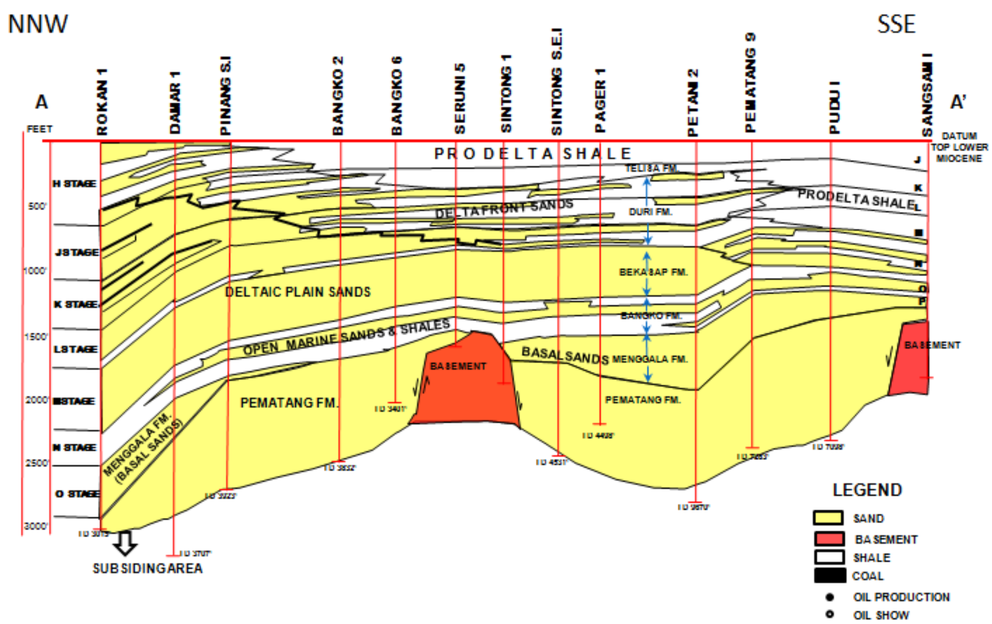


Fig. 2: Stratigraphy cross section of Central Sumatra Basin.

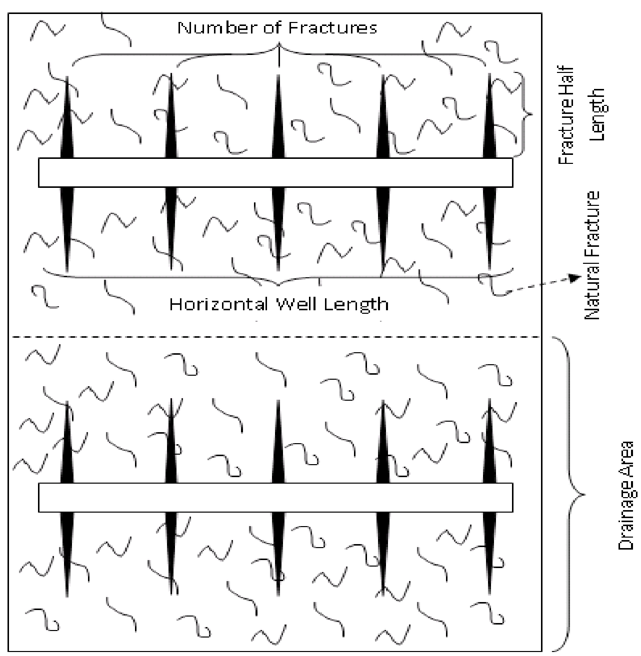


Fig. 3: Horizontal well model.

The variables studied were:

a) Horizontal Well Length.
b) Fracture Half Length.
c) Number of Fractures.
d) Well Spacing.

Base Case data from the Field were obtained from laboratory and field data and are given in Table 1. Twelve sensitivity cases were made as listed in Table 2. In every case, only one of the values of the four variables fixed for Base Case was changed while the others were kept constant. The horizontal length section, fracture half length, number of fracture and well spacing were varied from 1500 ft to 3000 ft, 150 to 900 ft, 3 to 15, and 180 acres to 390 acres, respectively.

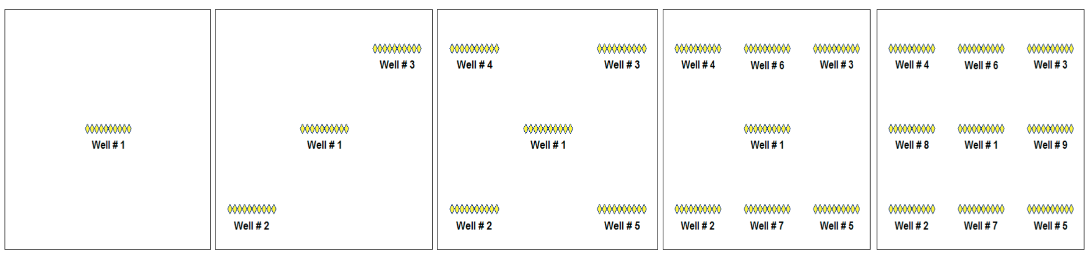
Table 1: Reservoir properties of base case.

Parameters	**Value**
Reservoir Pressure, P_i, psi	3084
Reservoir Temperature, T_r, ^oF	271
Permeability in x direction, k_x, md	0.0001
Permeability in y direction, k_y, md	0.0001
Permeability in z direction, k_z, md	0.00001
Net Pay, h, ft	222.2
Porosity, ϕ, %	3.57
Gas Saturation, S_g, %	42.69
Formation Compressibility, c_f, 1/psi	7.46E-06
Drainage Area, A_D, acres	250
Well Radius, r_w, ft	0.3
Well type	Horiz with fracs
Skin Damage, Sd	0
Horiz. Section Length, L_e, ft	2000
Number of Fractures	10
Fracture Half Length, X_f, ft	400
Dimensionless Frac. Conductivity, FCD	10000
Gas Gravity	0.65
Gas Content, scf/ton	16.94
Bulk density, ρ, g/cm^3	2.24
Sandface Pressure, P_{wf}, psi	500
Flow Duration, t_{flow}, month	360

Simulations were conducted for all cases and run for a 30 year period. Each case was run five times with different spot pattern as depicted in Fig. 4. The results of the cases were grouped and compared to analyze the effects of the parameters studied as well as that of number of neighbour wells.

Table 2: Parameter sensitivity for various scenarios.

Scenario	Horizontal Length, ft	Fracture Half Length, ft	Number of Fractures	Well Spacing, Acres
Base Case	2000	400	10	250
Case - 1	1500	400	10	250
Case - 2	2500	400	10	250
Case - 3	3000	400	10	250
Case - 4	2000	150	10	250
Case - 5	2000	650	10	250
Case - 6	2000	900	10	250
Case - 7	2000	400	3	250
Case - 8	2000	400	5	250
Case - 9	2000	400	15	250
Case - 10	2000	400	10	180
Case - 11	2000	400	10	320
Case - 12	2000	400	10	390



(a) (b) (c) (d) (e)

Fig. 4: A centered horizontal well surrounded by various numbers of neighbour wells.

4. RESULTS AND DISCUSSION

The results of the simulations described in the preceding section are analysed. The effects of the four variables are discussed as follows.

4.1 The Effect of Horizontal Length

Figure 5 and 6 show the effect of number of neighbour wells and horizontal well length on the central well productivity such as well recovery factor and initial rate, and final reservoir pressure, respectively. Figure 5 shows that the number of neighbour wells slightly increases the recovery factor. The increment of recovery factor if eight neighbour wells produced is about 4 % for the various horizontal lengths. As expected, the recovery factor is proportional to the horizontal length. This is due to the increase of drainage area of the well. The increment of recovery if the horizontal length of the well is extended from 2000 ft (base case) to 3000 ft is about 39% for various number of neighbour wells.

Figure 6 shows that the effect of horizontal length on the initial rate can be ignored. At the same time, the initial rate of the central well considerably reduces as the number of neighbour wells increases. The initial rate of the central well decreases from 2.65 MMscfd in the absence of any neighbour well to 1.11 MMscfd if eight identical wells produce simultaneously around the central well.

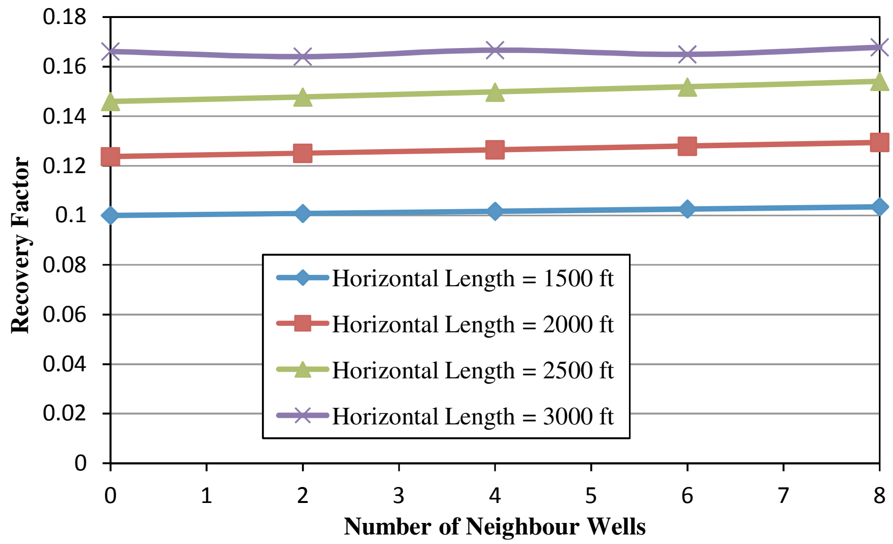


Fig. 5: The effect of horizontal length section and number of neighbour wells on recovery factor.

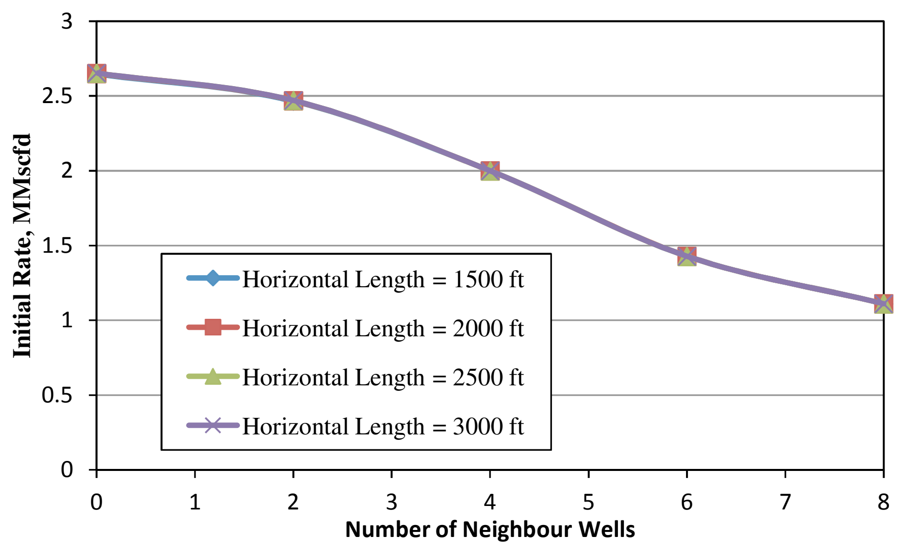


Fig. 6: The effect of horizontal length section and number of neighbour wells on initial rate.

4.2 The Effect of Fracture Half Length

The size of fracture is represented by fracture half length. The fracture half length denotes a wing of fracture. Figure 7 and 8 show the effect of number of neighbour wells and fracture half length on the central well productivity and reservoir pressure. Figure 7 shows that recovery factor increases as the size of fracture half length is longer. This is caused a greater fracture half length connects the well to a greater reservoir volume. The increment of recovery if the fracture half length is extended from 400 ft (base case) to 900 ft is about 156 % for various numbers of neighbour wells. Further result presented in Fig.

7 indicates that the number of neighbour wells slightly increases the recovery factor. The increment of recovery factor if eight neighbour wells produced is about 7% for the various fracture lengths.

Figure 8 shows that the fracture half length significantly affects the initial rate of the central well especially if no well is in the vicinity. However, the effect reduces as the number of neighbour wells increases. The increment of initial rate if the fracture half length is extended from 400 ft (base case) to 900 ft is about 41 % in average for various numbers of neighbour wells.

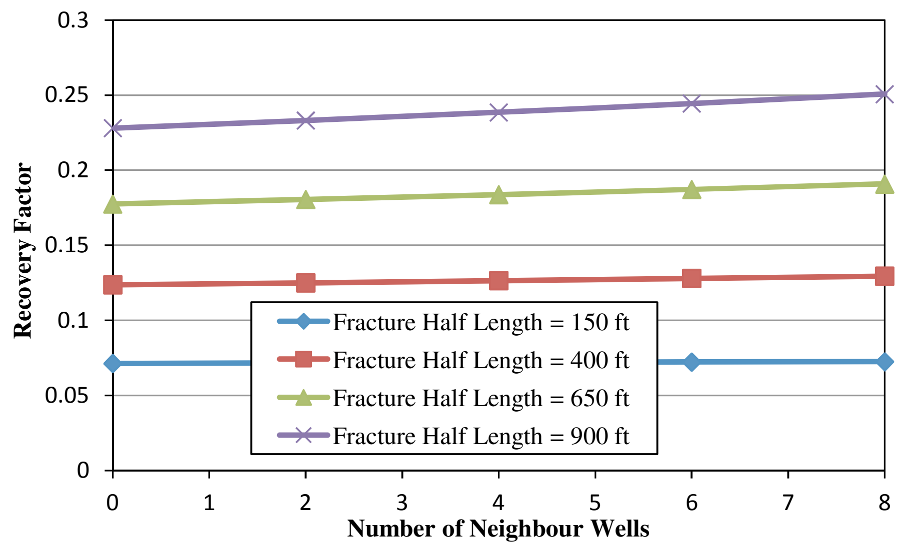


Fig. **7**: The effect of fracture half length and number of neighbour wells on recovery factor.

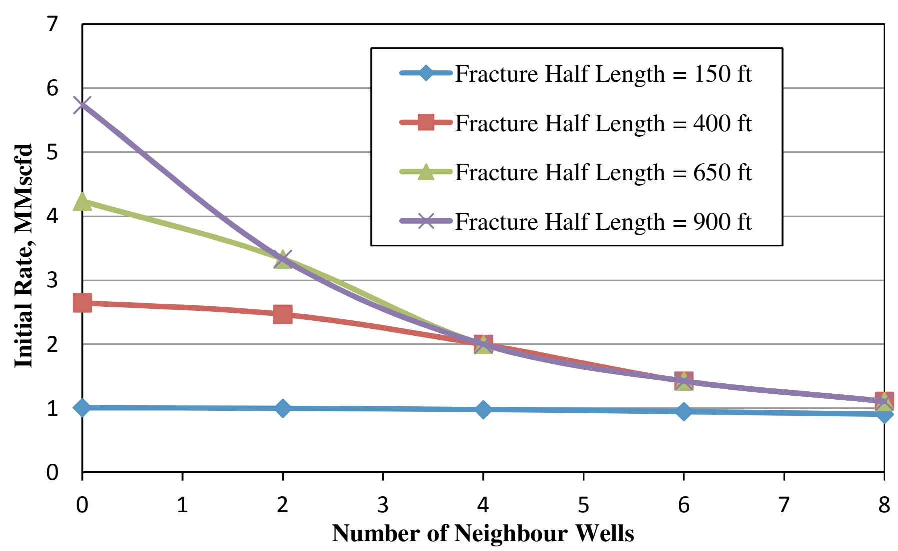


Fig. 8: The effect of fracture half length and number of neighbour wells on initial rate.

4.3 The Effect of Number of Fractures

Figures 9 and 10 show the effect of number of heighbour wells and number of fractures on the central well productivity and reservoir pressure. Figure 9 shows that recovery factor increases but tends to heap up as the number of fractures increases. As the number of fractures increases, the depleted area of every fracture is more limited. This decelerates the rise of recovery factor. The increment of recovery if the number of fractures is added from 10 (base case) to 15 is about 2 % for various number of neighbour wells. Another result presented in Fig. 9 indicates that the number of neighbour wells slightly increases the recovery factor. The increment of recovery factor if eight neighbour wells produced is about 4% for the various number of fractures.

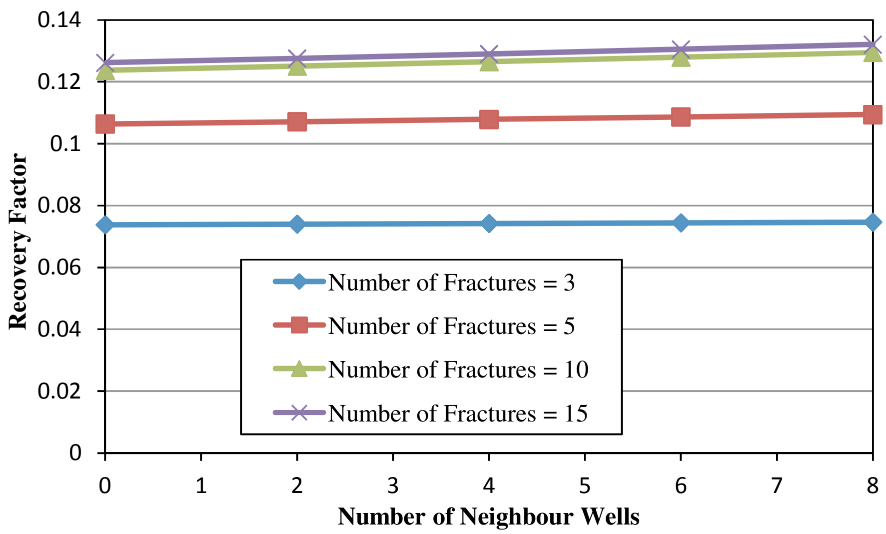


Fig. 9: The effect of number of fractures and number of neighbour wells on recovery factor.

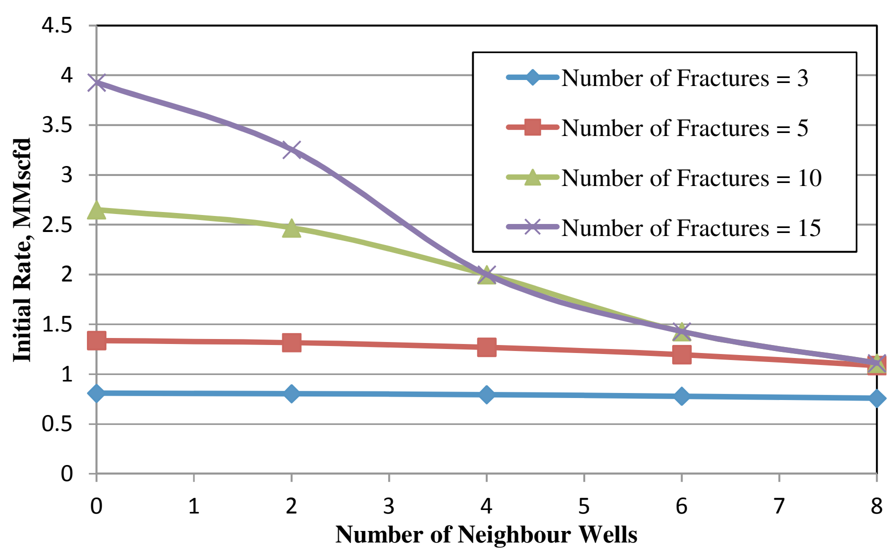


Fig. 10: The effect of number of fractures and number of neighbour wells on initial rate.

Figure 10 shows that the number of fractures has a similar effect with fracture half length on the initial rate as illustrated in Fig. 8. It can be noted here that initial rate has strong relation with fracture. The increment of initial rate if the number of fractures is added from 10 (base case) to 15 is about 21 % in average for various number of neighbour wells.

4.4 The Effect of Well Spacing Area

Figure 11 and 12 show the effect of number of neigbour wells and well spacing on the central well productivity and reservoir pressure. Figure 11 shows that recovery factor decreases as the well spacing increases. The ability of a well to depleted fluid is limited by some properties such as permeability and porosity of reservoir rock and viscosity and compressibility of reservoir fluid [7]. Therefore when the well spacing established larger, the ratio of drainage area to well spacing area becomes smaller.

The decrement of the recovery factor if the well spacing is increased from 250 acres (base case) to 390 acres is about 37% for various numbers of neighbour wells. Another result presented in Fig. 11 indicates that the number of neighbour wells slightly increases the recovery factor. The increment of recovery factor if eight neighbour wells produced is about 5 % for the various well spacing areas.

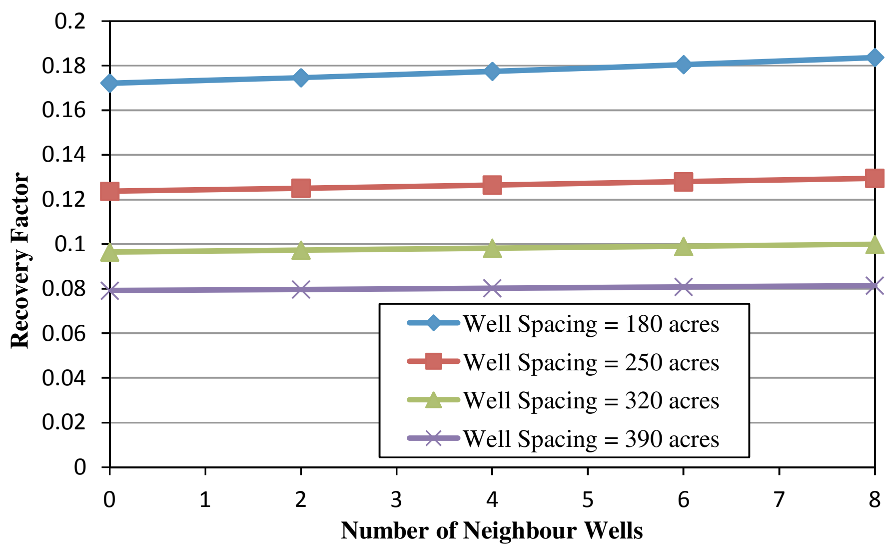


Fig. 11: The effect of well spacing and number of neighbour wells on recovery factor.

Figure 12 shows that the number of fractures has a similar effect with horizontal length on the initial rate as illustrated in Fig. 8, where the effect can be ignored. It can be noted here that initial rate has weak relation with horizontal length and well spacing parameters. On the other hand, Fig. 12 shows similar profile with that of Fig. 8 where the initial rate of the central well decreases from about 2.65 MMscfd in the absence of any neighbour well to 1.11 MMscfd if eight identical wells produced simultaneously around the central well.

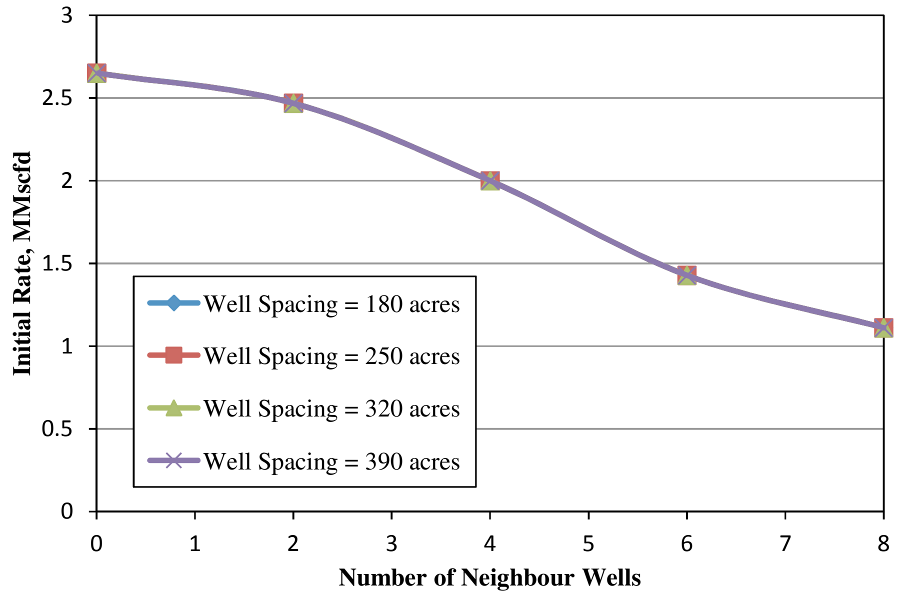


Fig. 12: The effect of well spacing and number of neighbour wells on initial rate.

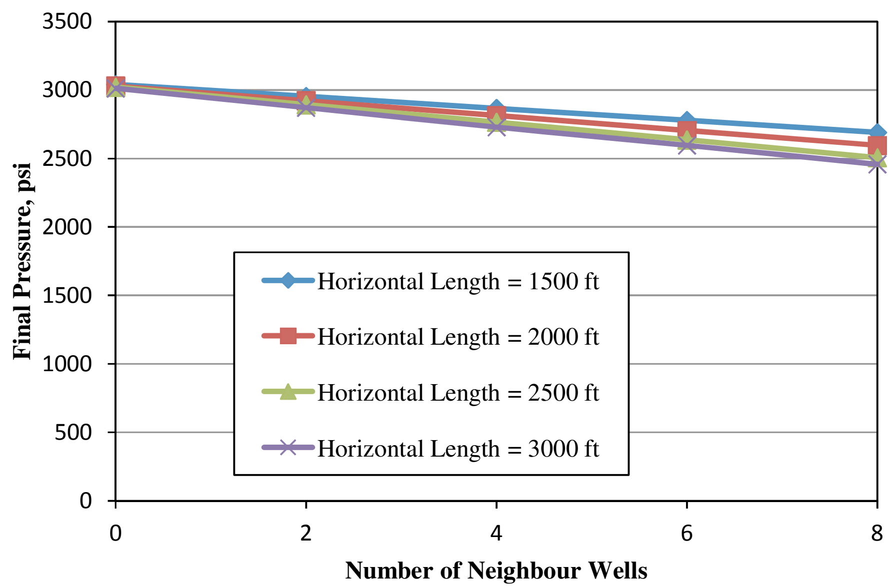


Fig. 13: The effect of horizontal length section and number of neighbour wells on final reservoir pressure.

The effect of the horizontal length, fracture half length, number of fractures, and well spacing area on final reservoir pressure is shown in Figs. 13, 14, 15, and 16, respectively. The change of the recovery factor in every case mentioned above may have a relation with that of reservoir pressure, where the lower the level of reservoir pressure, the more the gas desorbed from the surface of the matrix. On the other hand, the pressure decline is initiated by the production of free gas. This means that that decline of the reservoir pressure controls the production gas both free gas which initially occupies natural fracture and pores, and sorbed gas which is initially adsorbed in matrix. The maximum decreasing of final pressure compared with the initial pressure for the four parameters mentioned above is 18 %, 28 %, 14 %, and

8%. This indicates that the pressure decline is primarily affected by fracture half length parameter. A large pressure decline is required to obtain a large recovery factor.

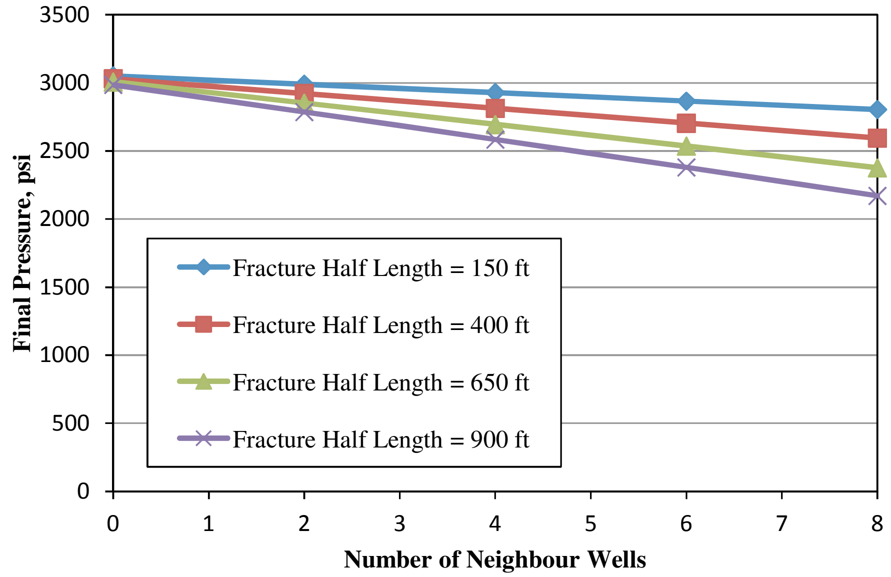


Fig. 14: The effect of fracture half length and number of neighbour wells on final reservoir pressure.

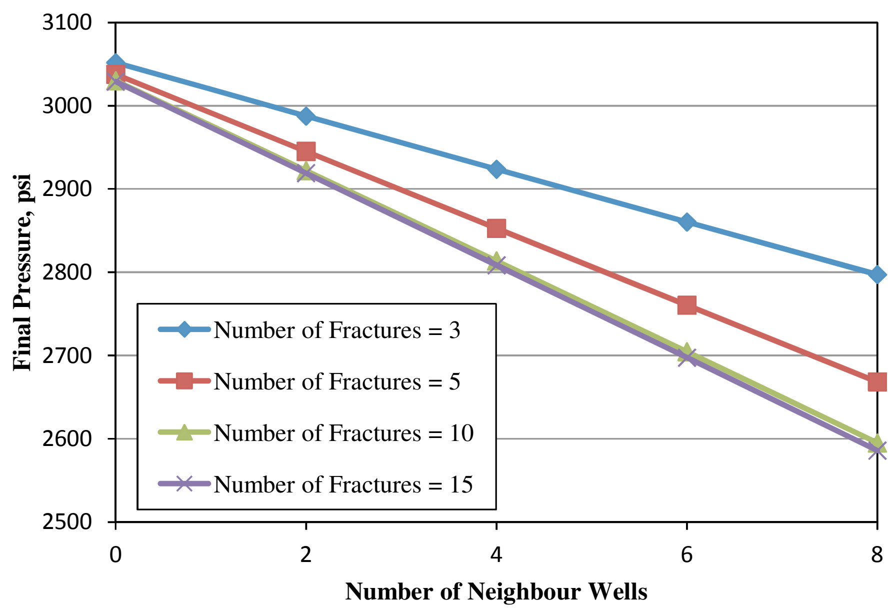


Fig. 15: The effect of number of fractures and number of neighbour wells on final reservoir pressure.

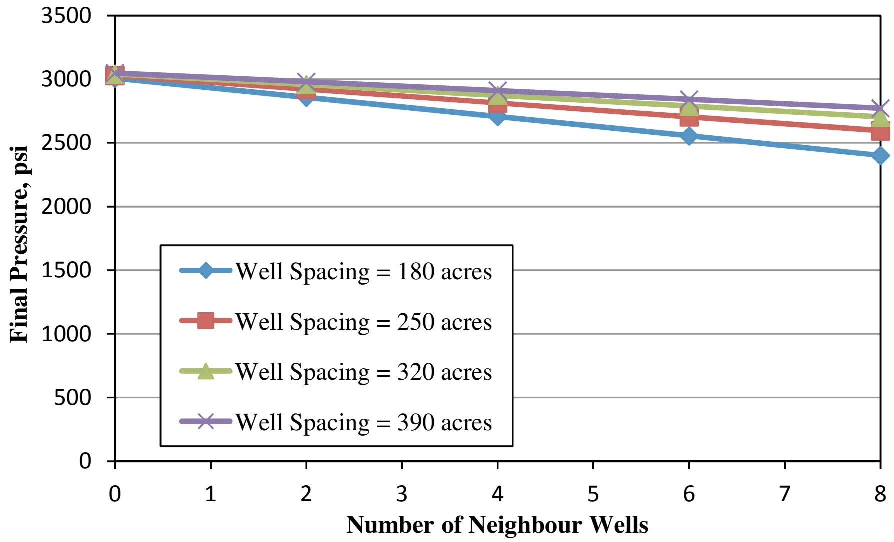


Fig. 16: The effect of well spacing and number of neighbour wells on final reservoir pressure.

5. CONCLUSIONS

Based on the simulation results and analyses shown above, several conclusions are made as follows:

a) Well interference affects the drainage radius, production profile and gas recovery factor. The recovery factor of the central well increases as the number of neighbour well increase. The maximum increment of recovery factor due the presence of neighbour wells within the range studied is 7%.
b) Horizontal well, fracture half length, and number of fractures is proportional to recovery factor, whereas well spacing has a reverse influence.
c) Initial rate is affected by fracture half length and the number of fractures. While the effect of horizontal length of well and well spacing on the initial rate can be ignored.
d) The most influential parameter on recovery factor, initial rate and reservoir pressure decline in this study is fracture half length.

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