CHAPTER-7

INFLUENCING FACTORS SENSITIVITY ANALYSIS

In present thesis, Sensitivity analysis has been performed based on the developed model and variable range of shale gas properties. In total five parameters have been considered for performing sensitivity analysis. The ranges of the shale gas properties was summarized in the below table 7.1.These shale gas parameters were classified into two categories: a) Reservoir Parameters and b) Induced or hydraulic fracture parameters. The Reservoir parameters include matrix permeability, matrix porosity, Langmuir volume and Langmuir pressure. Induced or Hydraulic fracture parameters include fracture spacing, no of hydraulic fractures, fracture half-length and fracture height.

Table 7.1 Classification of Shale Reservoir Parameters in the Simulation Model and their Ranges for Sensitivity Analysis.

Reservoir Parameters	Range	Hydraulic Fracture Parameters.	Range
Matrix porosity (%)	2-17	Number of Hydraulic Fractures	2-19
Matrix Permeability (mD)	10^{-7} – 0.01	Hydraulic Fracture Spacing (ft)	100-300
Initial Reservoir Pressure (psi)	3000-7000	Hydraulic Fracture width (ft)	0.01-0.0417
Langmuir Pressure (psi)	300-1500	Hydraulic Fracture Permeability (mD)	$10\text{-}10^{7}$.
Langmuir Volume (scf/ton)	50-200	Fracture half length (ft)	100-850

7.1 Sensitivity analysis on Different Reservoir and Hydraulic Fracture Parameters:

The effect of each parameter will be studied separately from this section. Parameters that are studied in this section includes: Matrix porosity, Langmuir volume and Langmuir pressure.

7.1.1 Effect of Matrix Porosity:

In general, the porosity of conventional gas reservoirs will be around 47% (Micheal D. Max 2007), but the porosity of the shale gas reservoir is in the range of 2% to 17%. Figure 7.1 and Figure 7.2 will give the idea of distribution of matrix porosity as mentioned in the published papers.

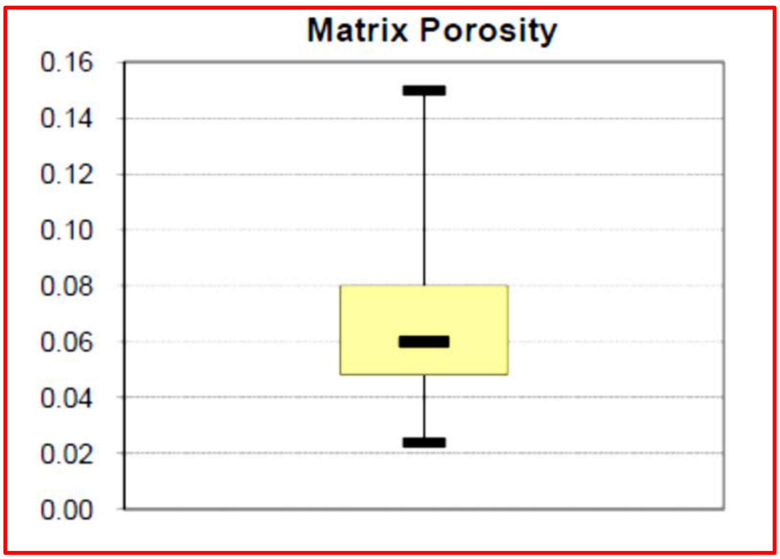

Figure 7.1: Box plot of Collected Matrix Porosity.

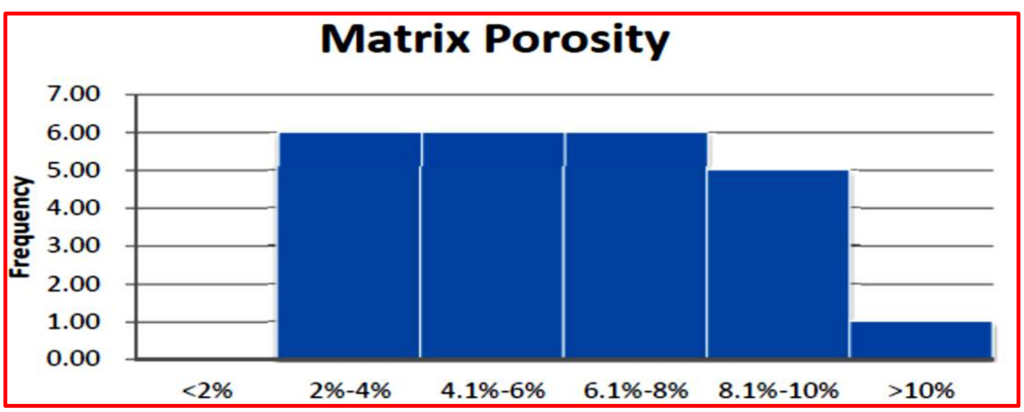

Figure 7.2: Histogram of Matrix Porosity Data.

Based on the data collected from the literature, sensitivity analysis of matrix porosity to gas production from shale gas reservoirs was finished by using commercial CMG-GEM simulator.

The effect of matrix porosity on gas production from shale reservoirs are demonstrated in Figure 7.3 and Figure 7.4.

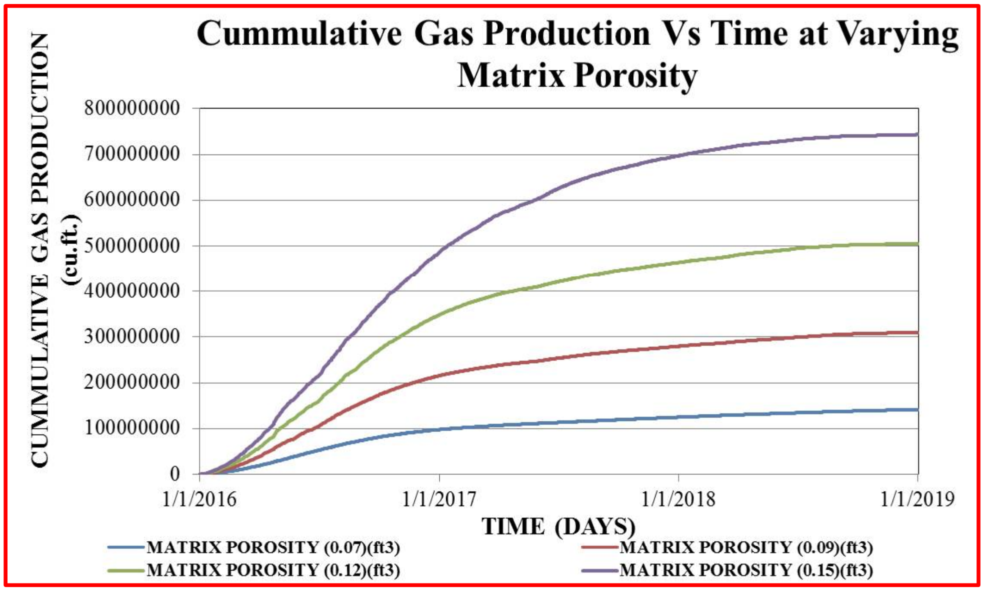

Figure 7.3: Effect of Matrix Porosity on Cumulative Gas Production.

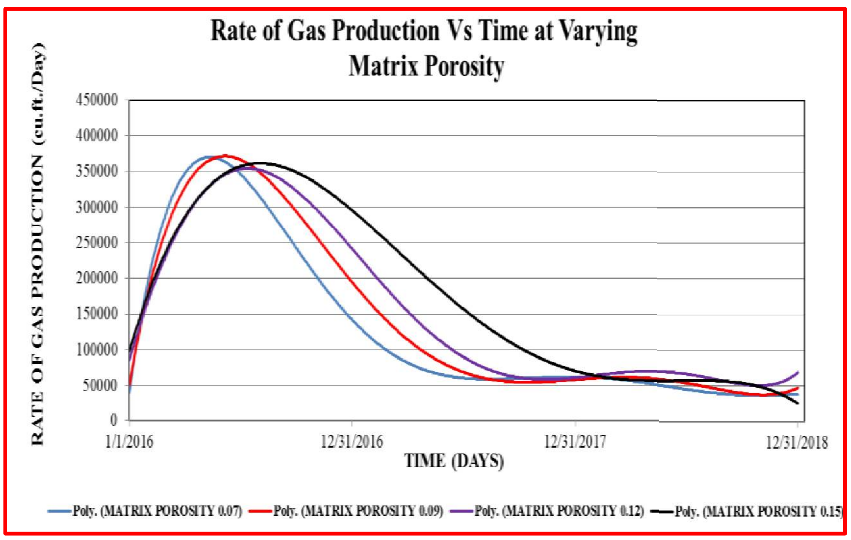

Figure 7.4: Effect of Matrix Porosity on Rate of Gas Production.

The effect of matrix porosity on shale gas reservoir pressure is demonstrated in Figure 7.5.

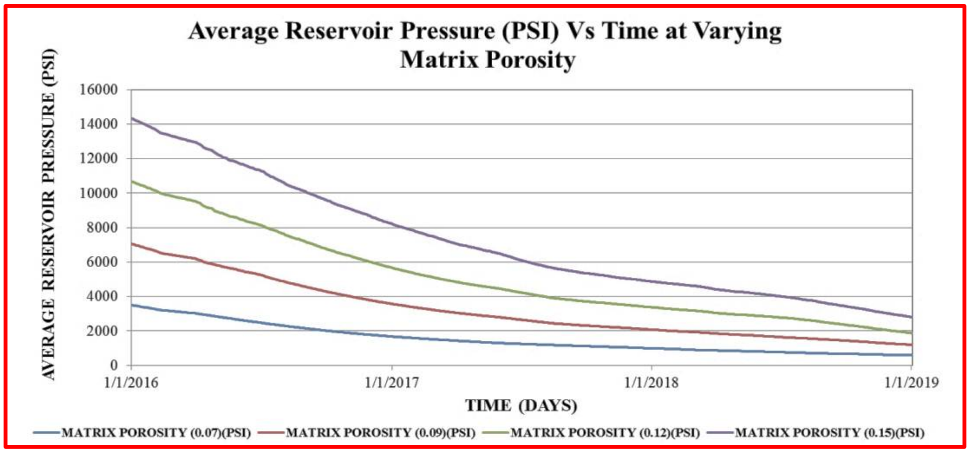

Figure 7.5: Effect of Matrix Porosity on Reservoir Pressure.

7.1.2 <u>Effect of Gas Desorption:</u>

According to Langmuir Isotherm equation, the desorption of gas is controlled by two parameters: Langmuir Volume and Langmuir Pressure. In this section, the effect of Langmuir volume and Langmuir pressure on shale gas production is analyzed.

7.1.2.1 <u>Effect of Langmuir Pressure:</u>

Langmuir pressure is defined as the pressure at which the amount of adsorbed gas is half of the Langmuir Volume. The ranges of Langmuir pressure is represented in Figure 7.6 and Figure 7.7.

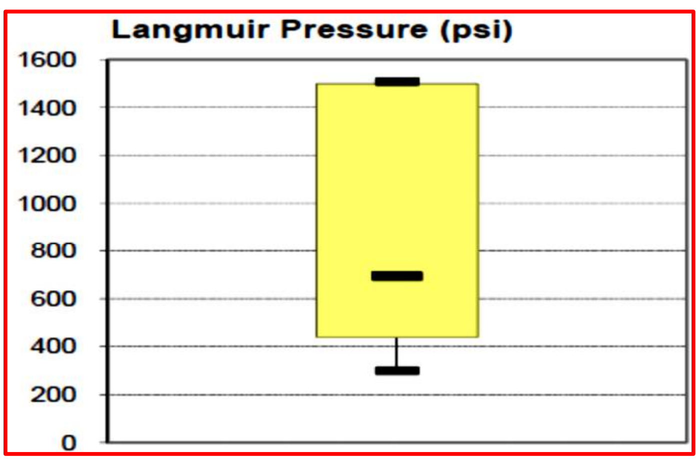

Figure 7.6: Box plot of Langmuir Pressure Data.

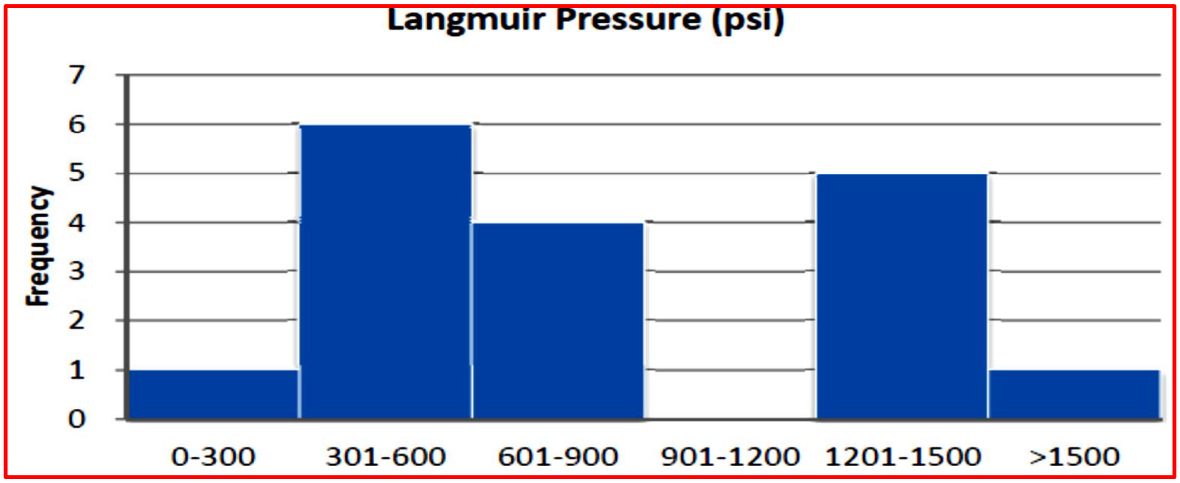

Figure 7.7: Histogram Representation of Langmuir Pressure Data.

Based on the above two Figures, it can be stated that the range of the Langmuir pressure considered is 400-1500 psi. During this analysis, the Langmuir volume is fixed at 197 Scf/ton. Figure 7.8 and Figure 7.9 will give the effect of Langmuir pressure on gas production from shale reservoirs.

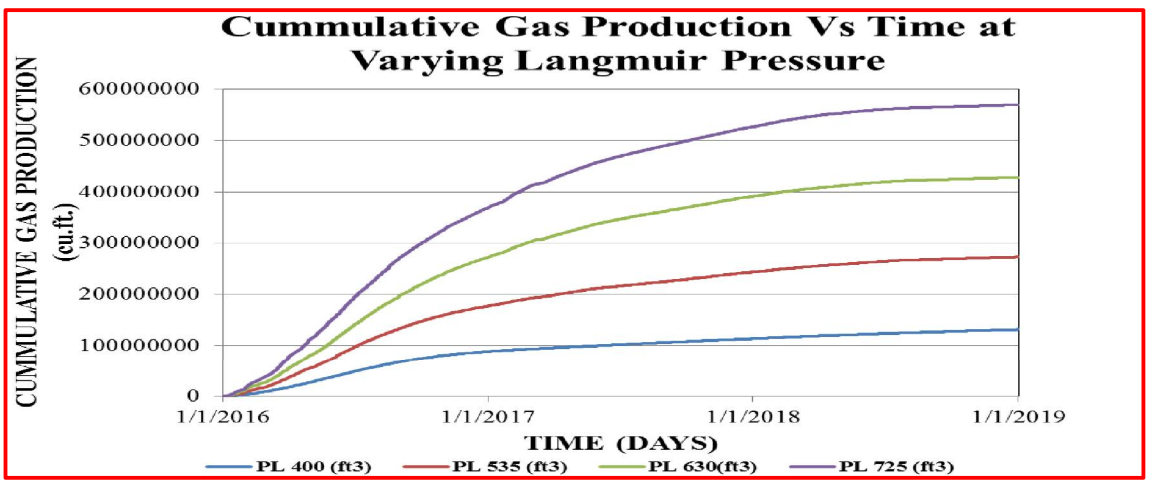

Figure 7.8: Effect of Langmuir Pressure on Cumulative Gas Production.

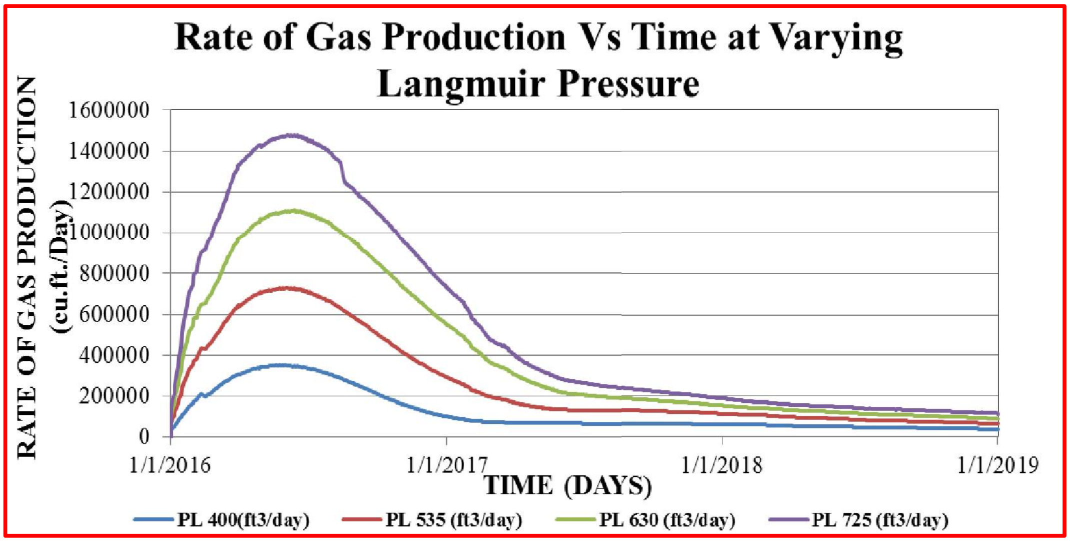

Figure 7.9: Effect of Langmuir Pressure on Rate of Gas Production.

The effect of Langmuir Pressure on shale gas reservoir pressure is demonstrated in Figure 7.10.

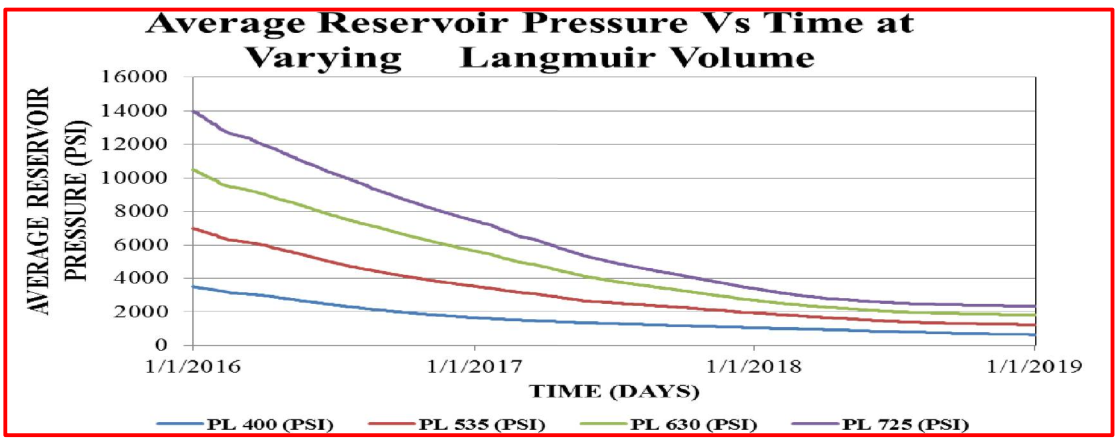

Figure 7.10: Effect of Langmuir Pressure on Reservoir Pressure.

7.1.2.2 <u>Effect of Langmuir Volume:</u>

Langmuir volume is defined as the maximum amount of gas that can be adsorbed on the rock surface under infinite pressure.

The distribution of Langmuir volume data have been shown in Figure 7.11 and Figure 7.12 respectively.

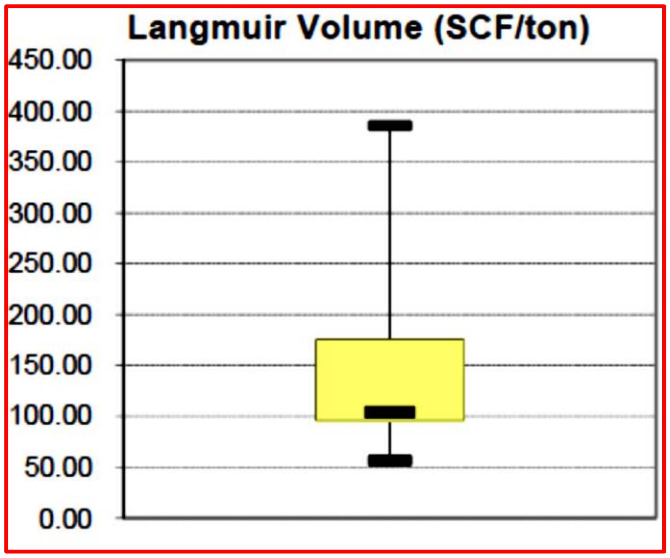

Figure 7.11: Box plot of Langmuir Volume Data.

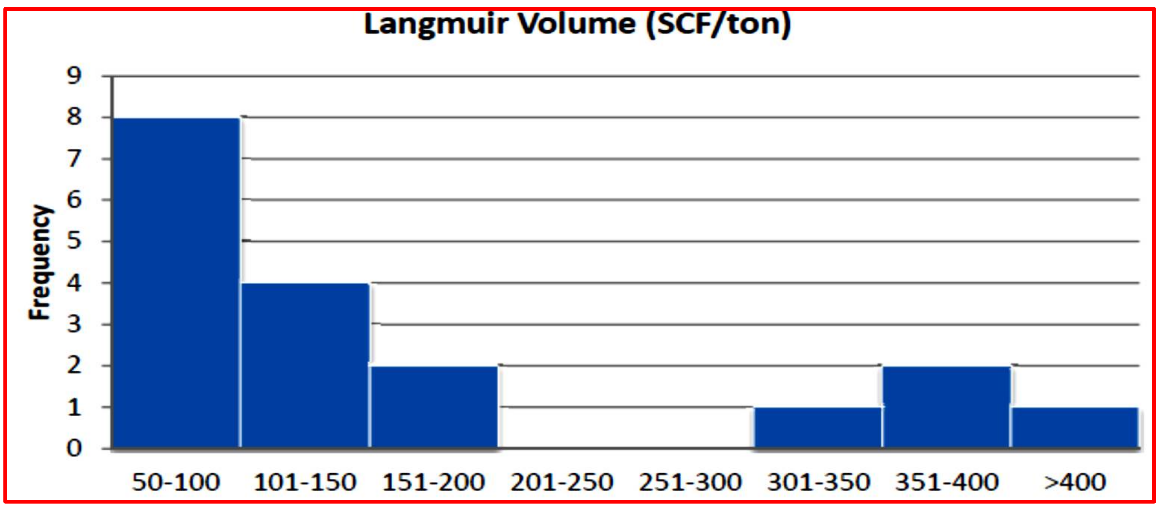

Figure 7.12: Histogram of Langmuir Volume Data.

Based on the above two Figures, the range of Langmuir volume 70 $\frac{scf}{ton}$ to 220 $\frac{scf}{ton}$ is considered for sensitivity analysis. During this analysis, the Langmuir pressure has been fixed at 535 psi. The effect of Langmuir volume on gas production from shale reservoirs is analyzed in Figure 7.13 and Figure 7.14.

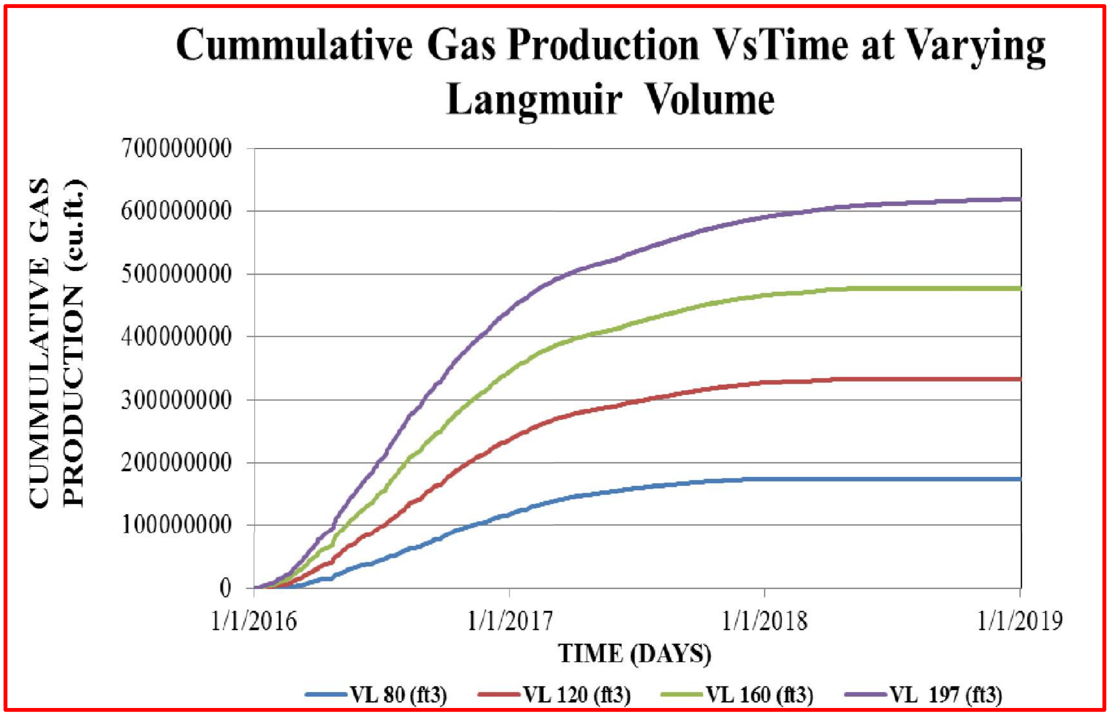

Figure 7.13: Effect of Langmuir Volume on Cumulative Gas Production.

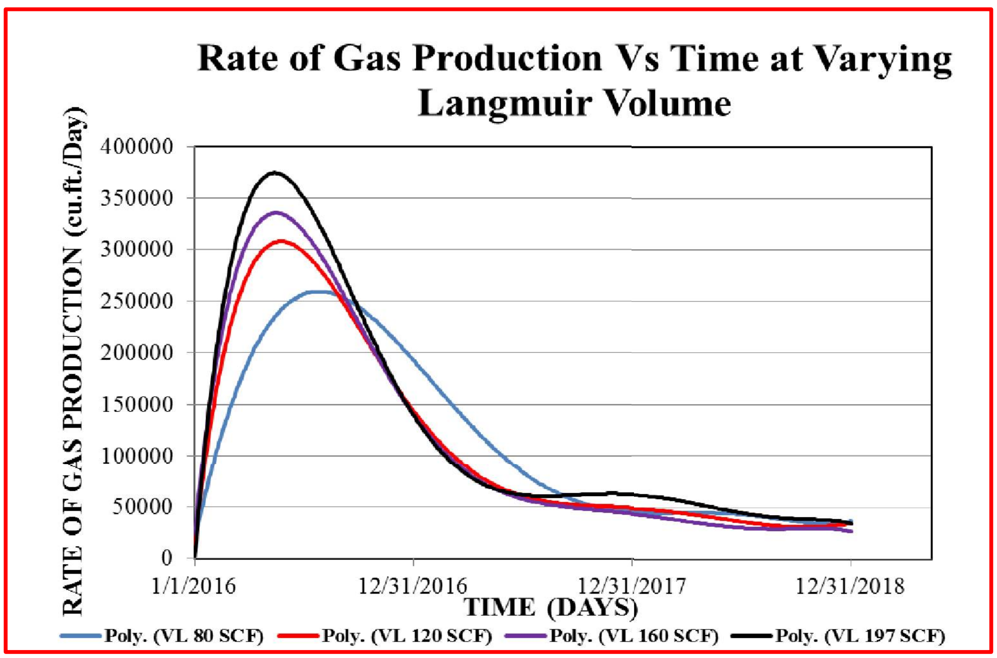

Figure 7.14: Effect of Langmuir volume on Rate of Gas Production.

The effect of Langmuir Volume on shale gas reservoir pressure is demonstrated in Figure 7.15.

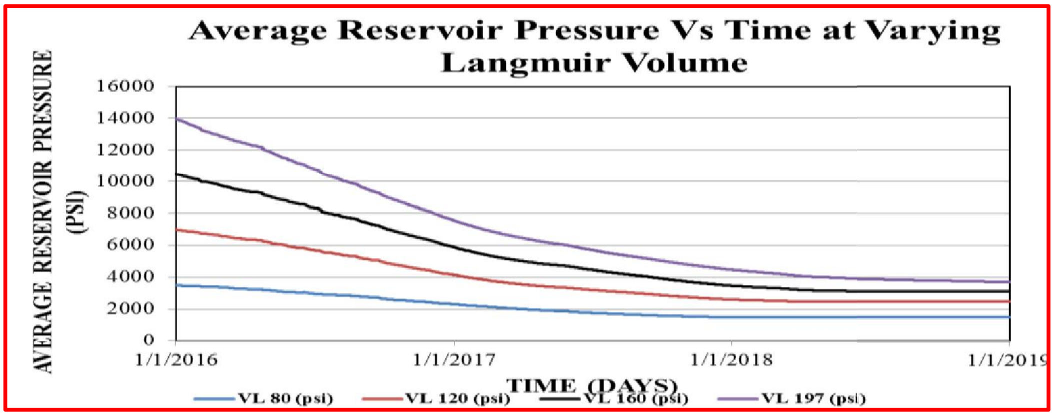

Figure 7.15: Effect of Langmuir Volume on Reservoir Pressure.

7.1.3 Effect of Number of Hydraulic Fractures:

In shale gas reservoirs, permeability will be in the range of Nano-Darcy. For producing gas at economic rates from these reservoirs, hydraulic fracturing of the shale formations is a must. Gas production from these reservoirs will depend upon the number of hydraulic fractures. As the hydraulic fractures number is more the pressure difference across the fracture and the matrix will be more and so the gas production also will be more. The number of hydraulic fractures may vary from 2 to 19. The effect of number of hydraulic fractures on gas production is illustrated in Figure 7.16 and Figure 7.17.

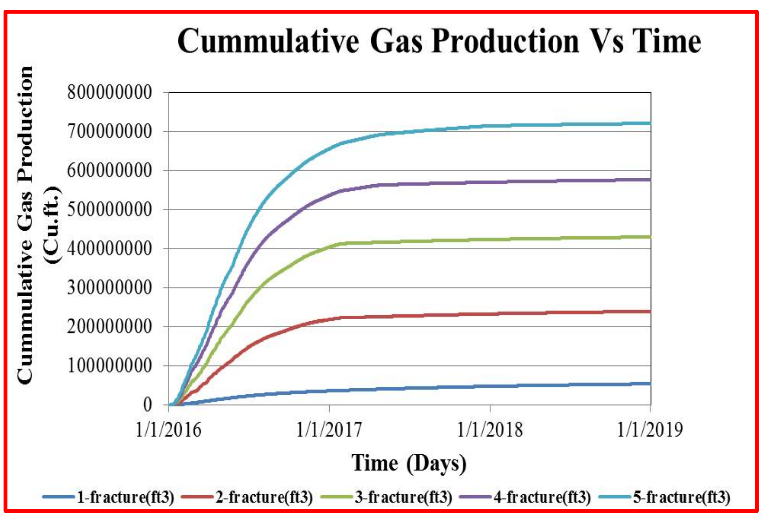

Figure 7.16: Effect of number of hydraulic fractures on cumulative gas production.

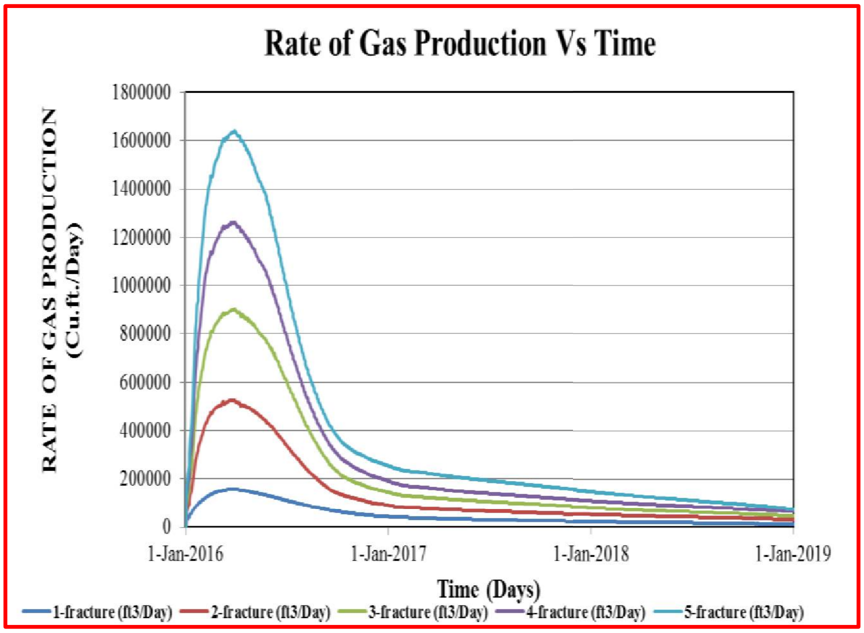

Figure 7.17: Effect of number of hydraulic fractures on rate of gas production.

The effect of number of hydraulic fractures on shale gas reservoir pressure is demonstrated in Figure 7.18.

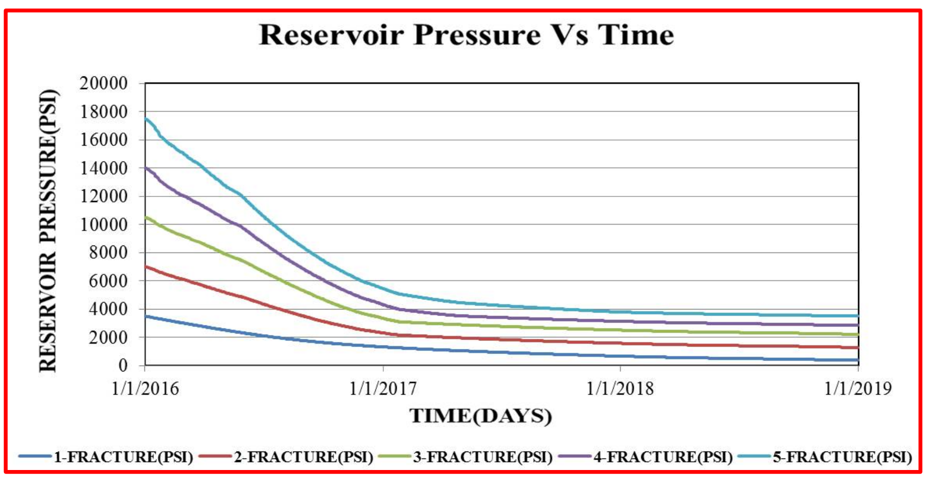

Figure 7.18: Effect of number of hydraulic fractures on reservoir pressure.

7.1.4 **<u>Effect of the Hydraulic Fracture Permeability:</u>**

Hydraulic fracture permeability is the path created during hydraulic fracturing for the flow of gas from the shale reservoir to the horizontal wellbore. The economic aspects of any shale gas reservoir mainly depend upon the permeability of the induced or hydraulic fracture. In this work, relationship of gas production from shale reservoirs with hydraulic fracture permeability is performed by changing the hydraulic fracture permeability's from 1000 mD to 1000000 mD. Figure 7.19 and 7.20 shows the influence of hydraulic fracture permeability on cumulative and rate of gas production from shale reservoirs.

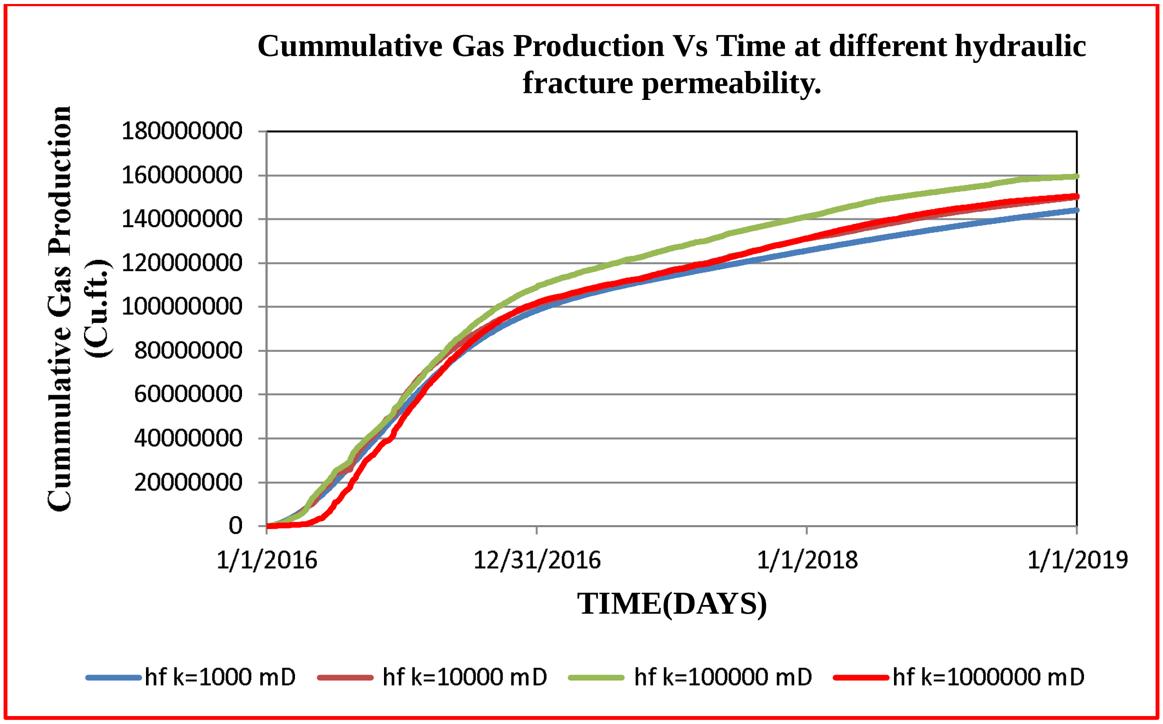

Figure 7.19: Impact of Hydraulic Fracture Permeability on Cumulative Gas Production.

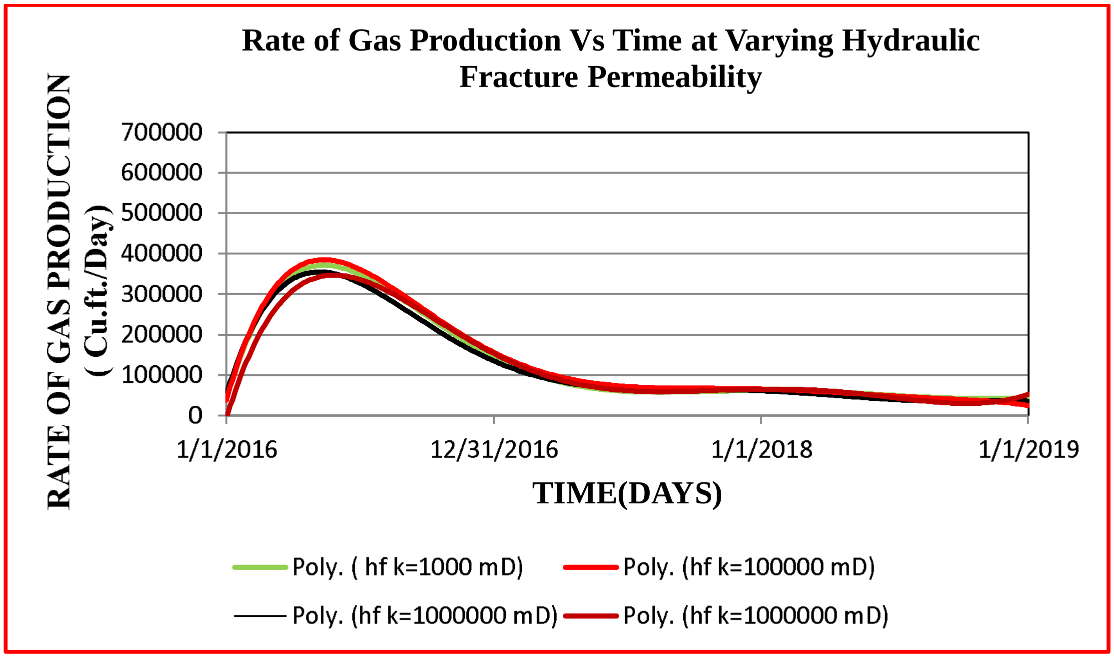

Figure 7.20: Impact of Hydraulic Fracture Permeability on Rate of Gas Production.

From Figure 7.19 and 7.20, it is shown that t the cumulative and rate of gas production increases with increase in hydraulic fracture permeability. But this increase in production is only when the hydraulic fracture permeability is in the range of 1000 mD to 100000 mD there after there is a decrease in the production of gas once the hydraulic fracture permeability reaches 1000000 mD. That means, increasing the hydraulic fracture permeability will enhance the gas production from shale reservoirs, but the rate of increase of production will gradually decreases with the increase of hydraulic fracture permeability.

Figure 7.21, shows the variation of average reservoir pressure with change in hydraulic fracture permeability (hf k) from 1000 mD to 1000000 mD.

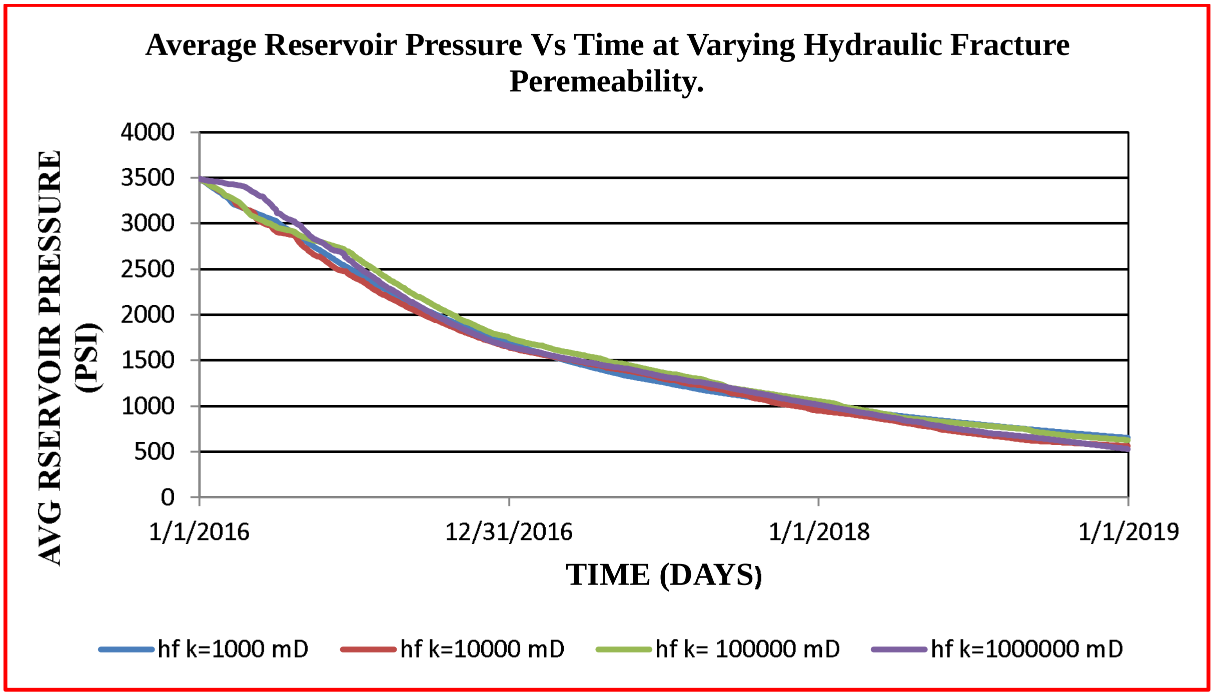

Figure 7.21: Impact of Hydraulic Fracture Permeability on Average Reservoir Pressure.

Figure 7.21 clearly shows that the pressure variation in the shale reservoir is increasing by varying the hydraulic fracture permeability from 1000 mD to 1000000 mD. This pressure variation for some time period is almost increasing for all the hydraulic fracture permeability's ranges. But after a period of time, the reservoir pressure variation for high hydraulic fracture permeability cases is declining at a slower rate which will decrease the production.

7.1.5 <u>Effect of Hydraulic Fracture Width:</u>

The Hydraulic fracture width is the distance between the vertical boundaries of the hydraulic or induced fracture. In this work, relationship of gas production from shale reservoirs with hydraulic fracture width is performed by changing the hydraulic or induced fracture width from 0.01 ft to 0.0416 ft. Figure 7.22 and Figure 7.23 shows the influence of hydraulic fracture width on cumulative and rate of gas production.

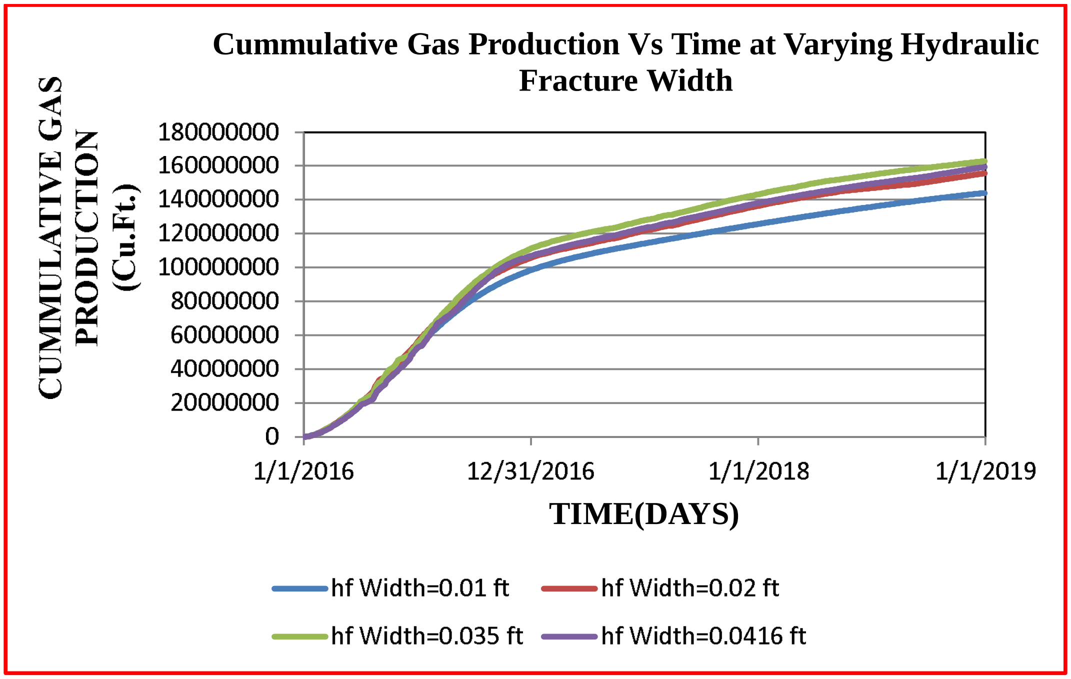

Figure 7.22: Impact of Hydraulic Fracture Width on Cumulative Gas Production.

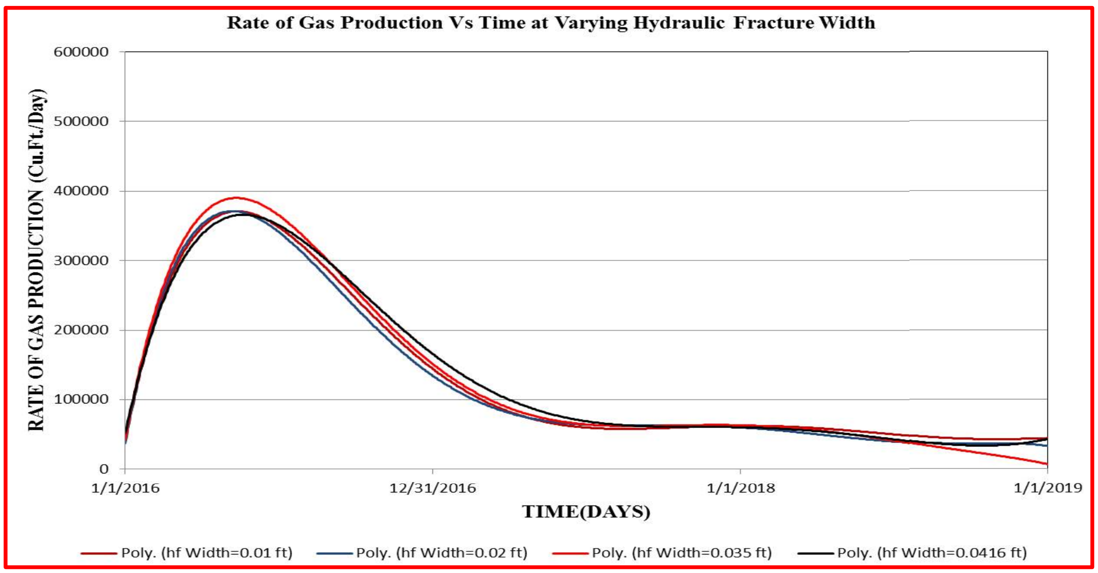

Figure 7.23: Impact of Hydraulic Fracture Width on Rate of Gas Production.

From Figure 7.22 and 7.23, it is shown that though the cumulative and rate of gas production increases with increase in hydraulic fracture width. But this increase in production is only when the hydraulic fracture width is in the range of 0.01 ft to 0.035 ft there after their is a decrease in the production of gas once the hydraulic fracture width reaches the maximum value 0.0416 ft. That means, increasing the hydraulic fracture width will enhance the gas production from shale reservoirs, but the rate of increase of production will gradually decreases with the increase of hydraulic fracture width.

Figure 7.24, shows the variation of average reservoir pressure with change in hydraulic fracture width from 0.01 ft to 0.0416 ft.

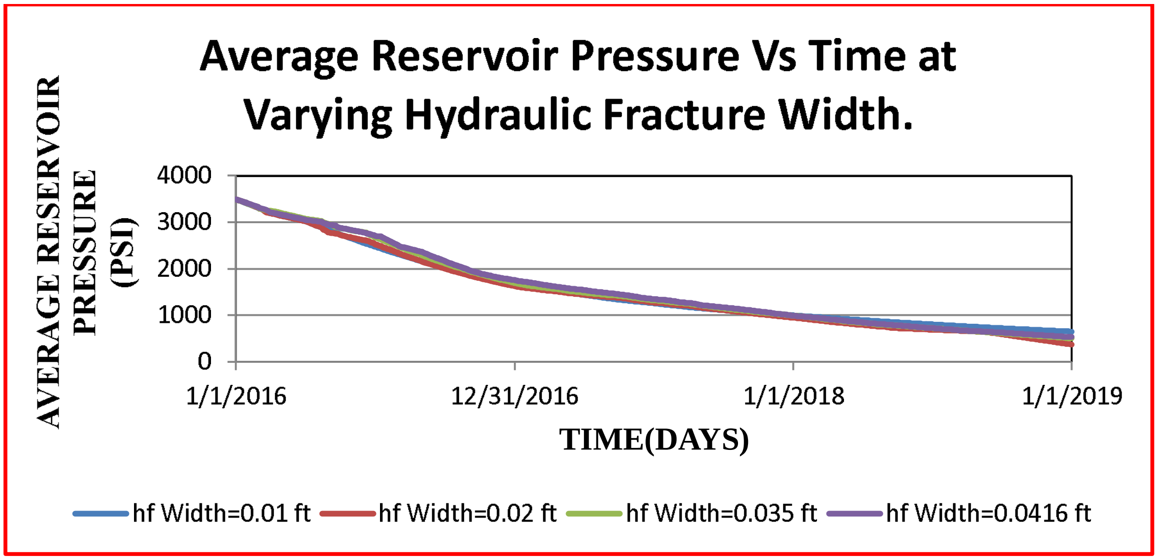

Figure 7.24: Impact of Hydraulic Fracture Width on Average Reservoir Pressure.

The pressure variation in the shale reservoir is increasing by varying the hydraulic fracture width from 0.01 ft. to 0.0416 ft clearly shows in Figure 7.24. This pressure variation for some time period is almost increasing for all the hydraulic fracture width ranges. But after a period of time, the reservoir pressure variation for high hydraulic fracture width cases is declining at a slower rate which will decrease the production.