CHAPTER IV
RESULTS AND DISCUSSION

This chapter illustrates the simulation results of the natural gas reservoir with different shapes; rectangular, cylindrical, and irregular shapes.

The validation of the ADI model was done by comparing the result from ADI method with the one from FEMLAB, the commercial finite element modeling software as shown in Appendix B.

The operating conditions and properties of natural gas reservoir are shown in Table 4.1.

Table 4.1 List of operating condition and input parameters of regular and irregular shape reservoirs.

Item (unit)	Symbol	Value
Operating conditions:		
Reservoir temperature (R)	T_{re}	609.67
Reservoir pressure (psia)	P_{re}	4000 - 4050
Well pressure (psia)		
- Single well	P_w	3000.0
- Double well	P_{w1}	3000.0
	P_{w2}	2800.0
Properties of gas reservoir:		
Gas Viscosity (cP)	μ	0.05
Permeability (md)	k	0.001
Porosity	ε	0.148
Initial conditions:		
Well radius (ft)	r_w	0.5
Δt (days)	Δt	1.0
Amount of grid	N	51.0

The simulation results discussed in this section are the pressure profiles obtained from finite different methods, ADI method. The reservoir geometries considered here are in rectangular, cylindrical, and irregular shapes as mentioned earlier in Section 3.1. For rectangular, cylindrical, and irregular shapes, the effect of single- and double-well on the pressure profile inside the reservoir was also investigated. The basic case input data of rectangular, cylindrical, irregular shaped reservoirs is summarized in Table 4.1.

4.1 Rectangular Shaped Reservoir with One Well

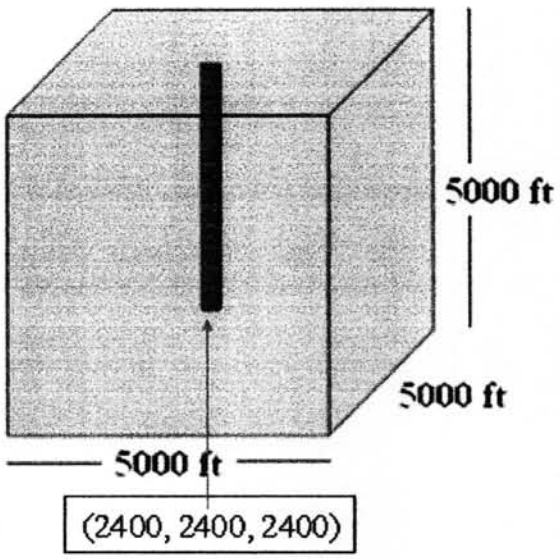
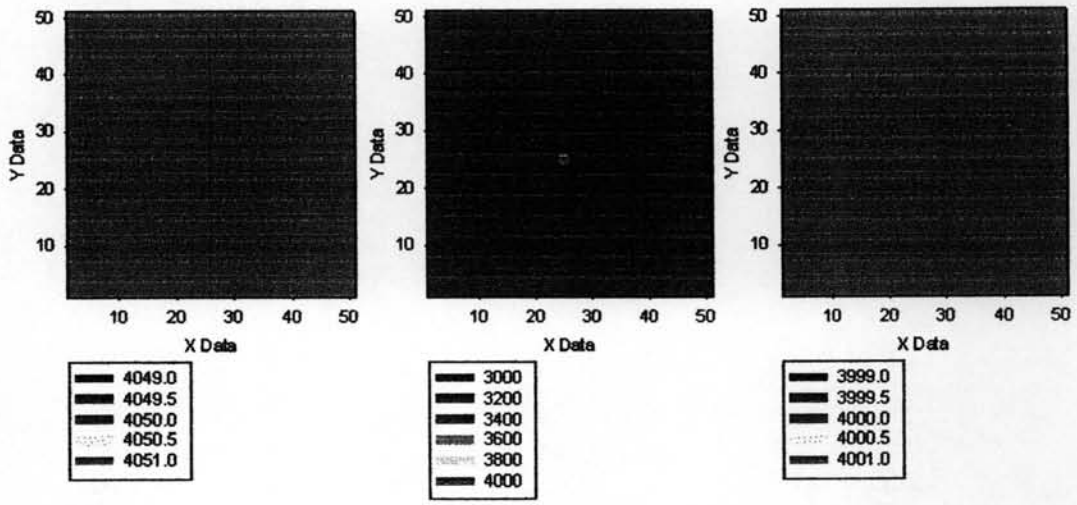


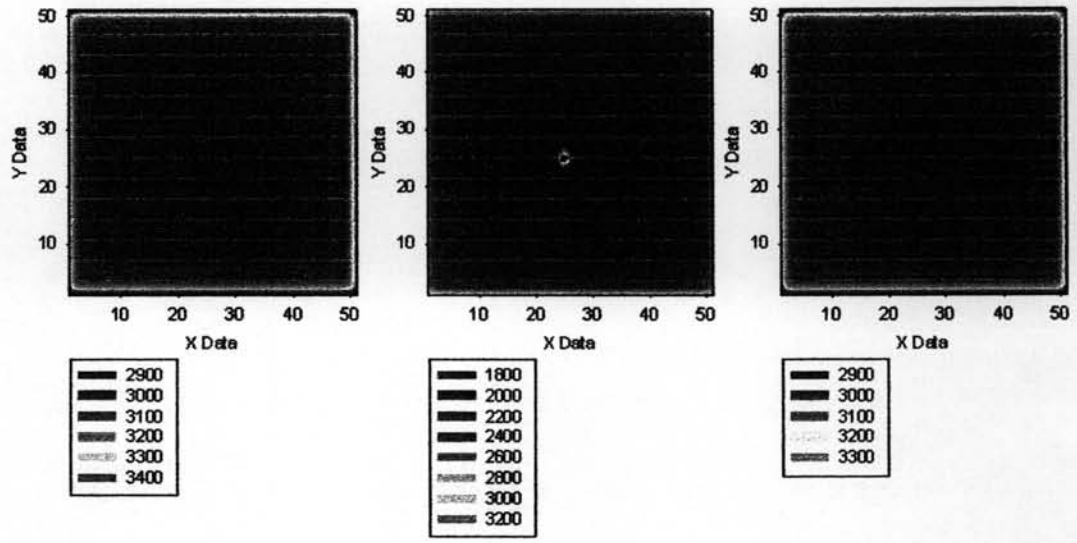
Figure 4.1 The rectangular shaped reservoir modeling of single-well.

The rectangular shaped reservoir with one well as show in Figure 4.1 and the well location is (2400, 2400, 2400 ft). The pressure profiles after gas withdrawal using finite difference are shown in Figure 4.2.

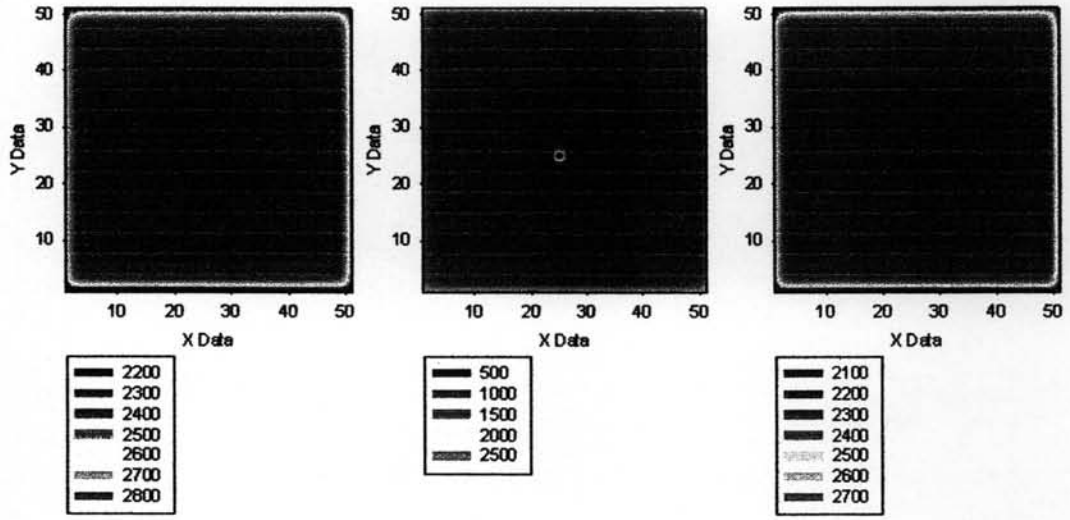
(a) Initial Pressure



(b) Pressure at time 10 days



(c) Pressure at time 20 days



(d) Pressure at time 95 days

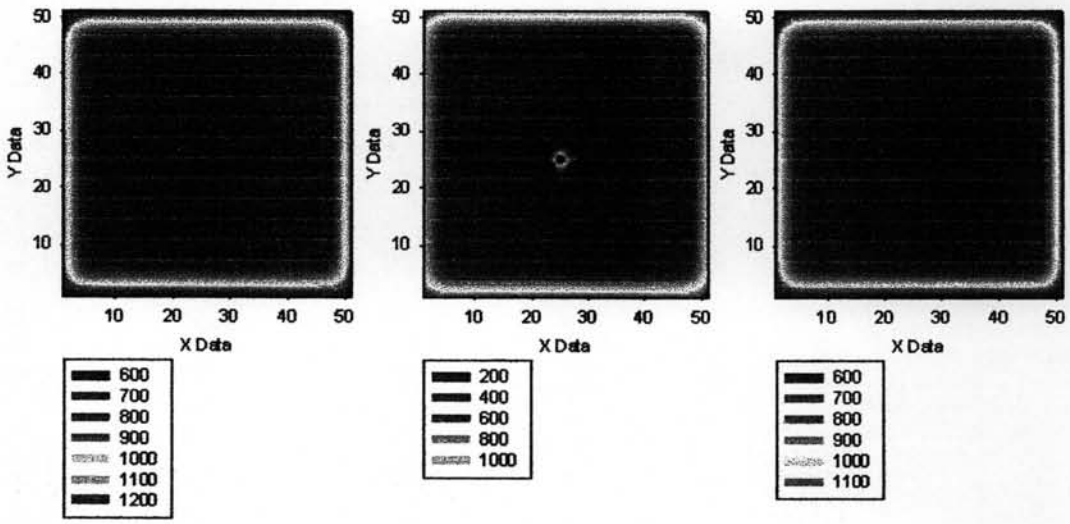


Figure 4.2 Pressure profile in X-Y dimension of rectangular shaped with one well at bottom, well, and top levels, respectively, (a) initial pressure, (b) pressure at time 10 days, (c) Pressure at time 20 days, (d) Pressure at time 95 days.

When the production occurs, the pressure in reservoir decrease until reaching steady-state, as shown in Figures 4.3.

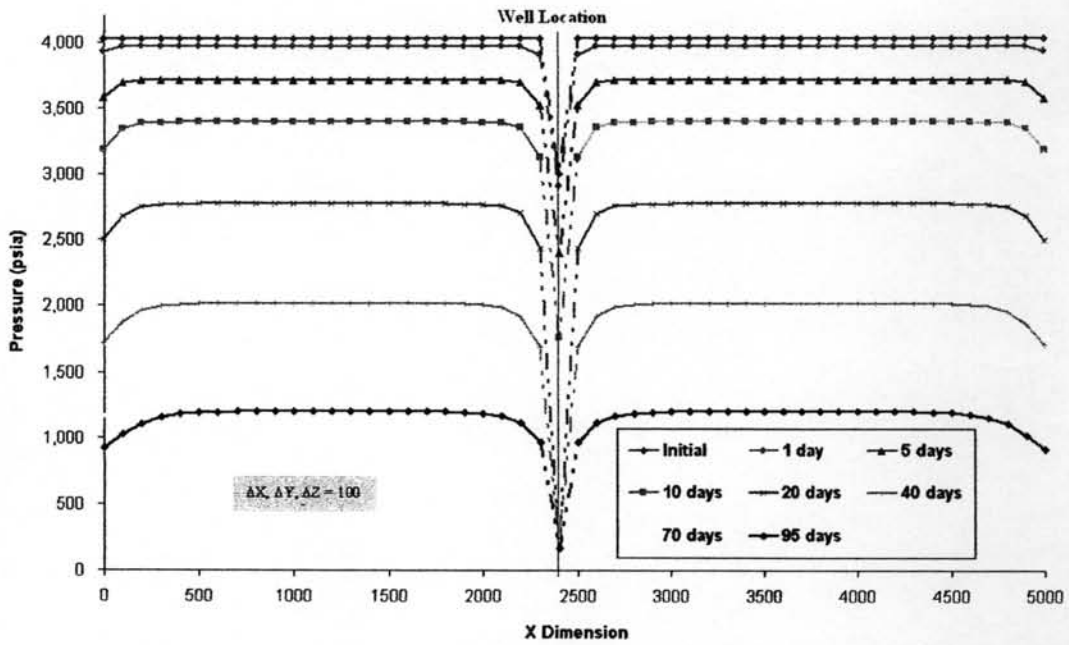


Figure 4.3 Pressure profile of rectangular shaped with one well at well level.

The production rate is developed, as shown in Figure 4.4.

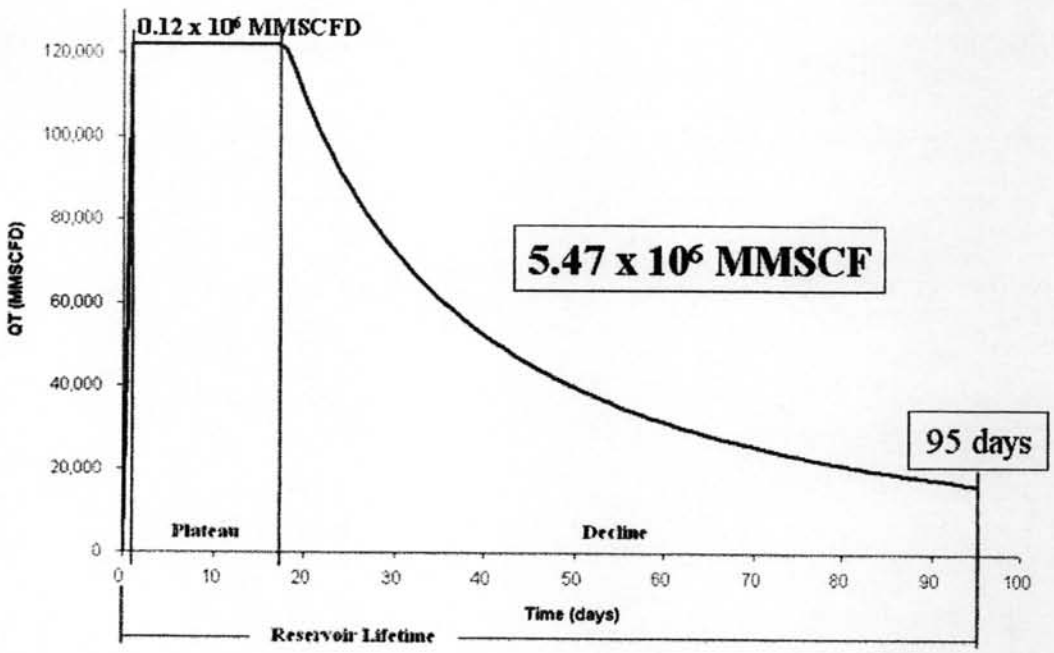


Figure 4.4 Production pattern of rectangular shaped gas reservoir with one well.

There are two regions, plateau and decline. The plateau period is 17 days and the maximum volumetric flow rate is 0.12×10^6 MMSCFD. The final step is the decline step, during which the wellhead pressure becomes insufficient to maintain a constant flow rate. The production rate of natural gas will decrease and constant when time is 95 days and the total volumetric flow is 5.47×10^6 MMSCF.

4.2 Rectangular Shaped Reservoir with Two Wells

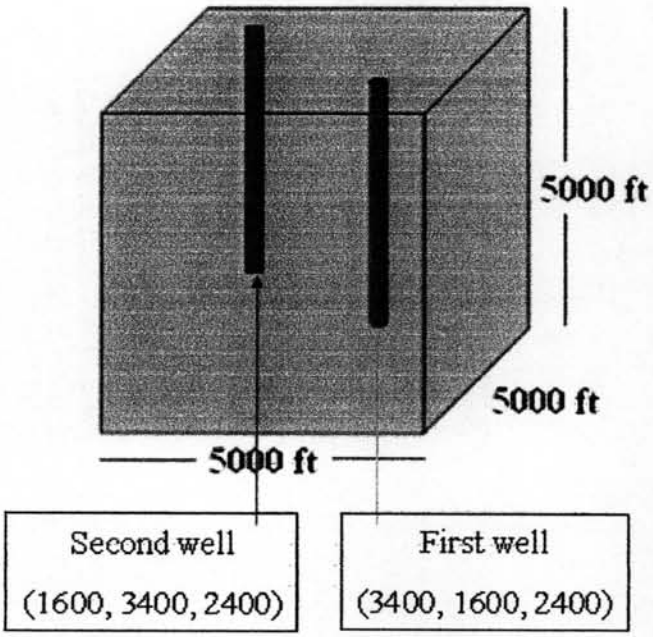
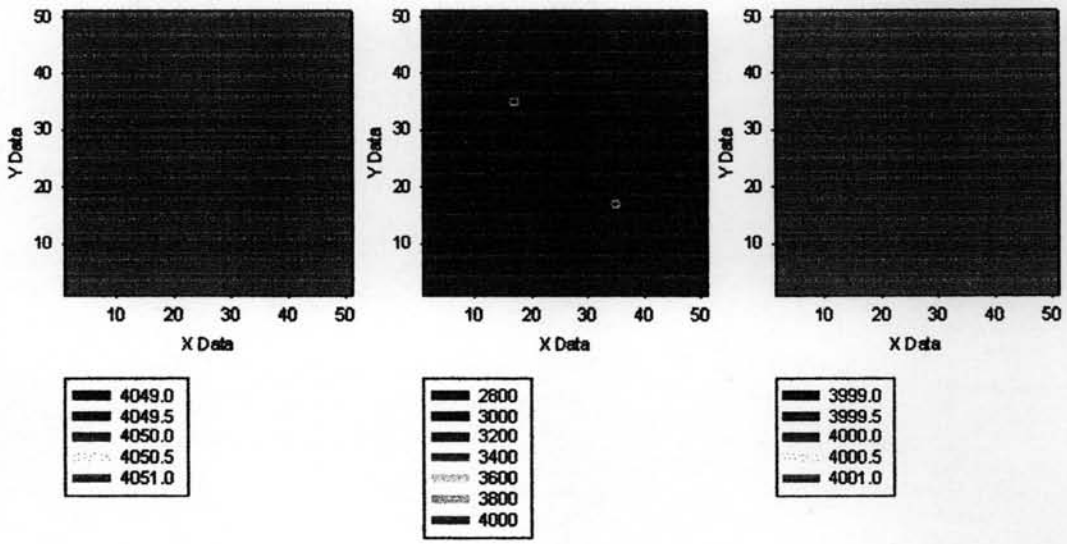


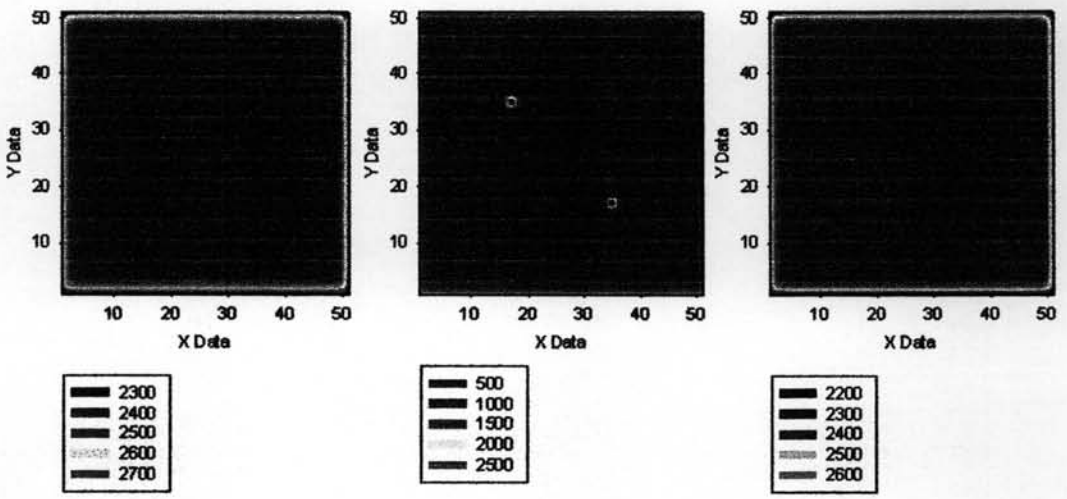
Figure 4.5 The rectangular shaped reservoir modeling of double-well.

The rectangular shaped reservoir with two wells as show in Figure 4.5 and the well locations are (3400, 1600, 2400 ft) for first well and (1600, 3400, 2400 ft) for second well. The pressure profiles after gas withdrawal using finite difference are shown in Figure 4.6.

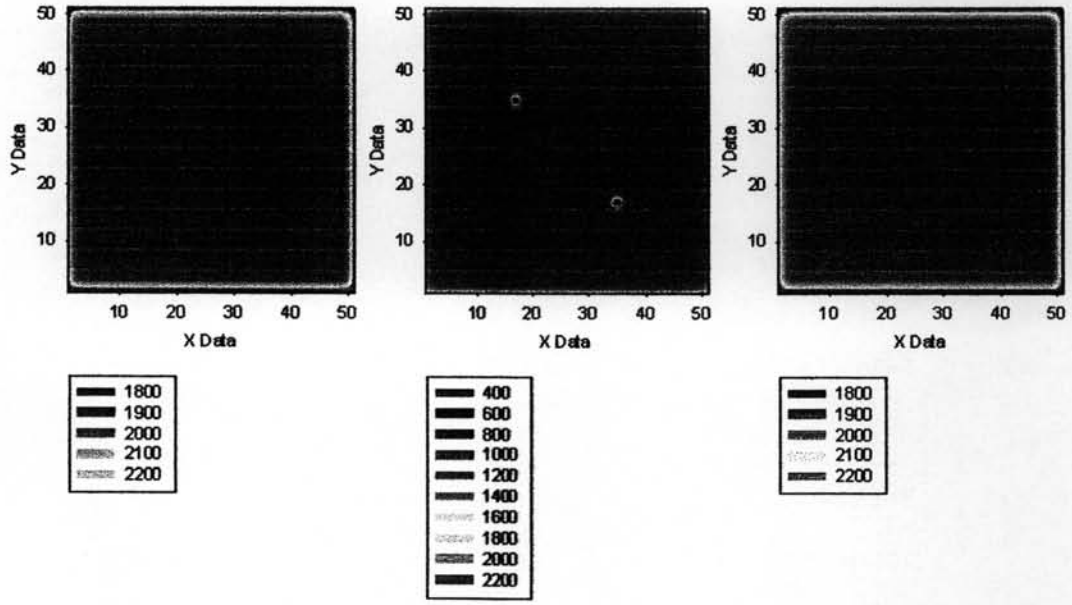
(a) Initial Pressure



(b) Pressure at time 10 days



(c) Pressure at time 15 days



(d) Pressure at time 51 days

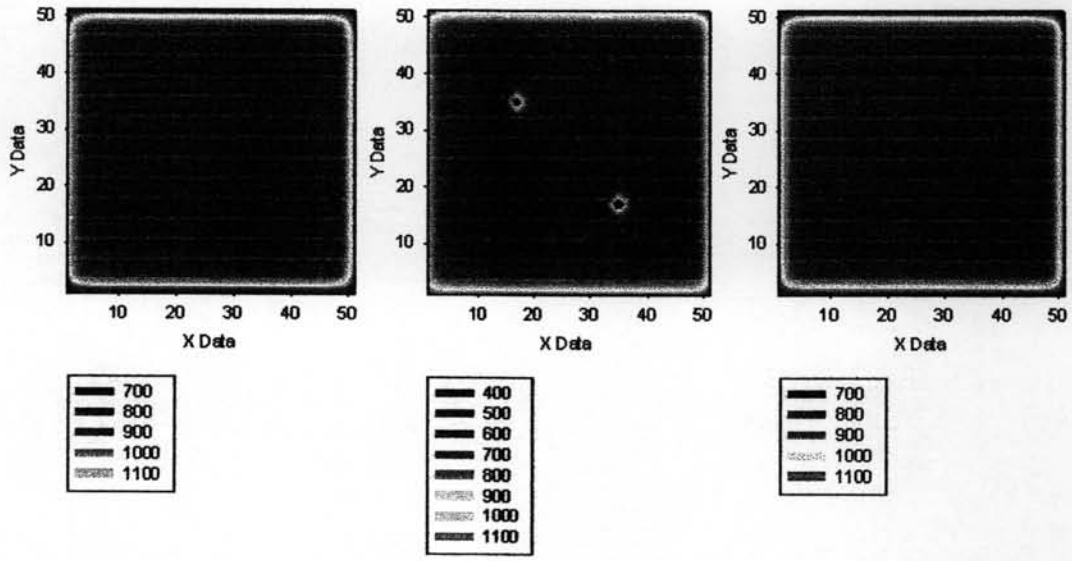


Figure 4.6 Pressure profile in X-Y dimension of rectangular shaped with two wells at bottom, well, and top levels, respectively, (a) initial pressure, (b) pressure at time 10 days, (c) Pressure at time 15 days, (d) Pressure at time 51 days.

When the production occurs, the pressure in reservoir decrease until reaching steady-state, as shown in Figures 4.7-4.8.

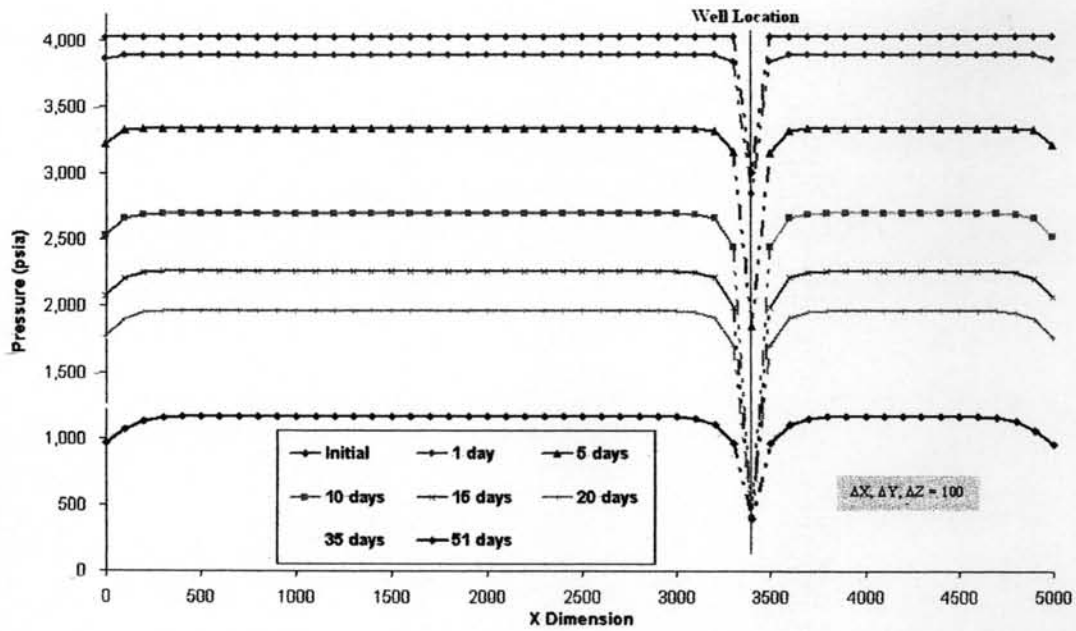


Figure 4.7 Pressure profile of rectangular shaped with two wells at first well level.

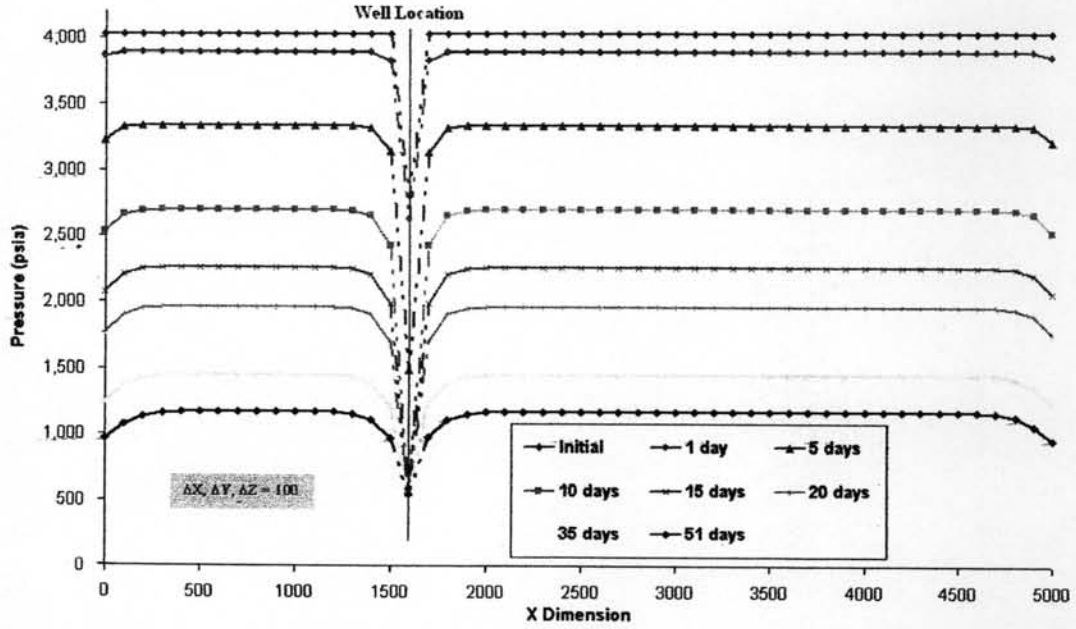


Figure 4.8 Pressure profile of rectangular shaped with two wells at second well level.

The production rate is developed, as shown in Figure 4.9.

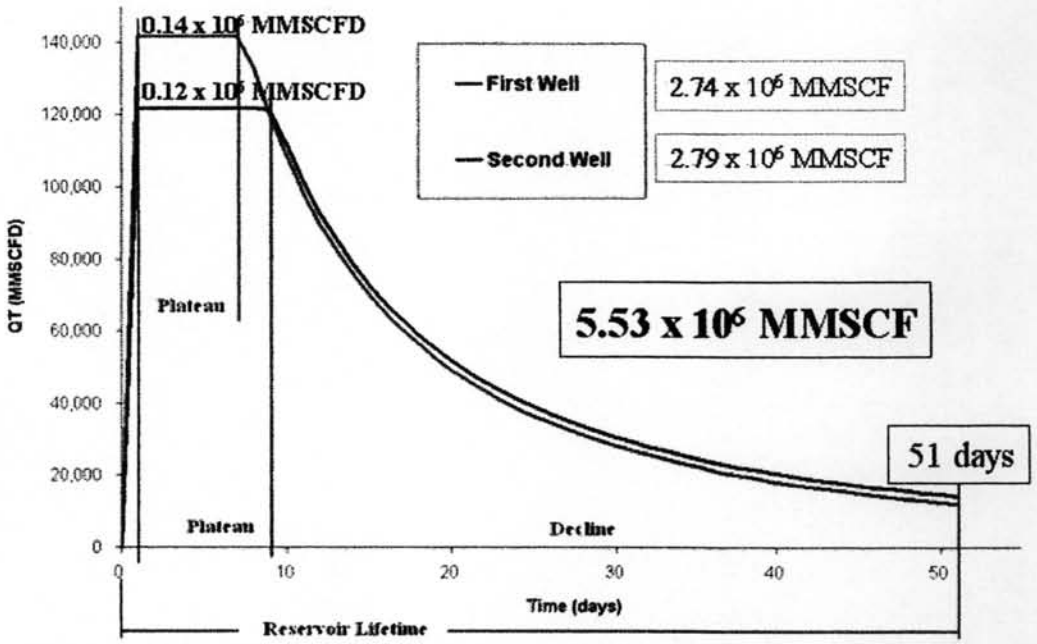


Figure 4.9 Production pattern of rectangular shaped gas reservoir with two wells.

There are two regions, plateau and decline. The plateau periods are 9 days for first well and 7 days for second well and the maximum volumetric flow rates are 0.1 x 10^6 MMSCFD for first well and 0.14 x 10^6 MMSCFD for second well. The final step is the decline step, during which the wellhead pressure becomes insufficient to maintain a constant flow rate. The production rate of natural gas will decrease and constant when time is 51 days and the low well pressure can withdraw the natural gas more than high well pressure and the total volumetric flow is 5.53 x 10^6 MMSCF.

4.3 Cylindrical Shaped Reservoir with One Well

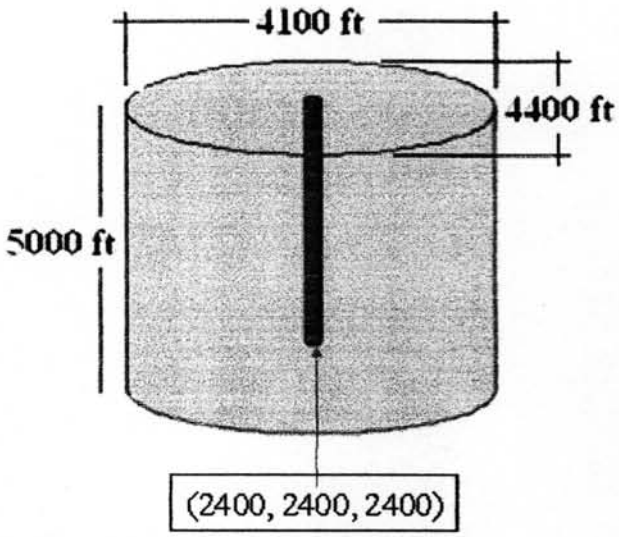
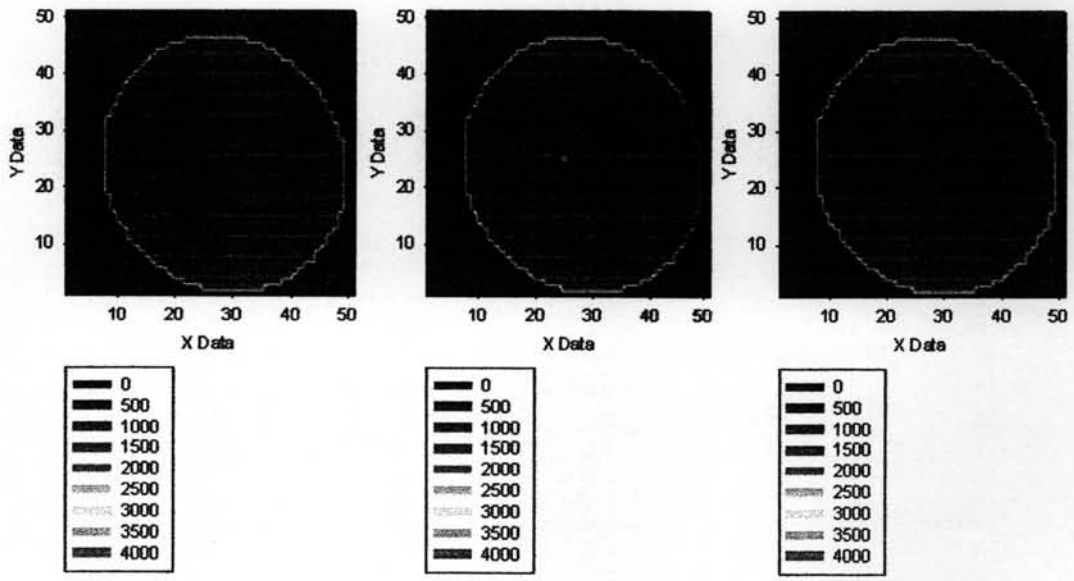


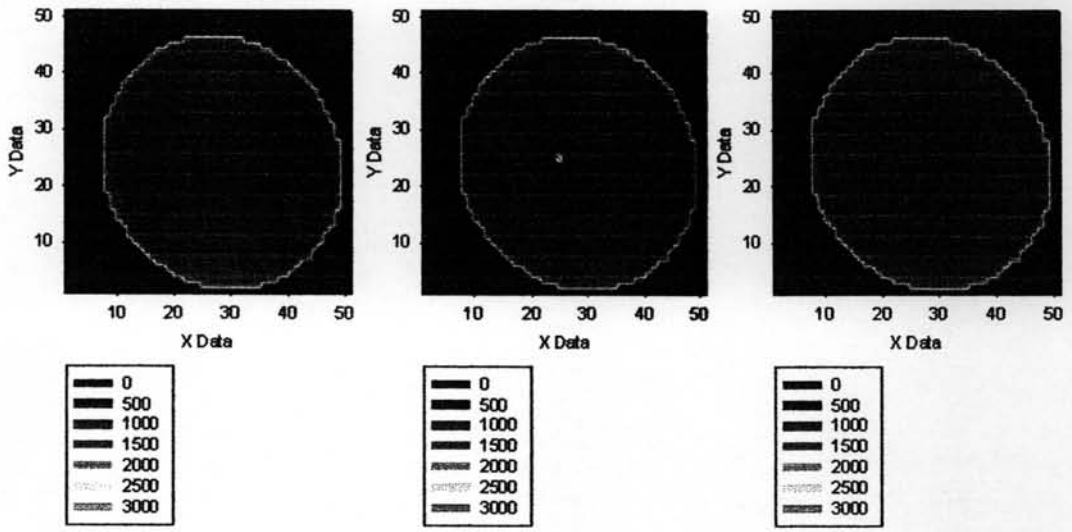
Figure 4.10 The cylindrical shaped reservoir modeling of single-well.

The cylindrical shaped reservoir with one well as show in Figure 4.10 and the well location is (2400, 2400, 2400 ft). The pressure profiles after gas withdrawal using finite difference are shown in Figure 4.11.

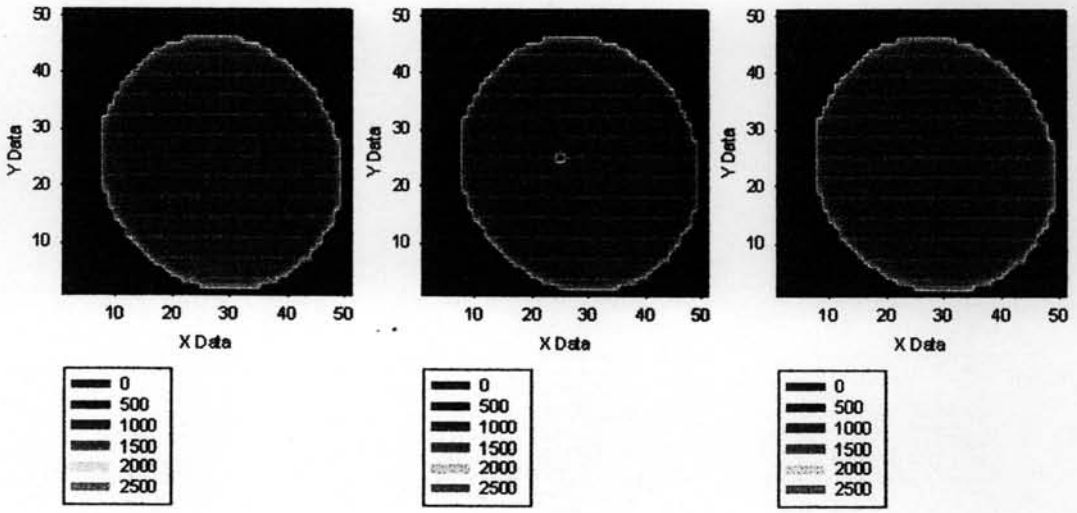
(a) Initial Pressure



(b) Pressure at time 10 days



(c) Pressure at time 20 days



(d) Pressure at time 95 days

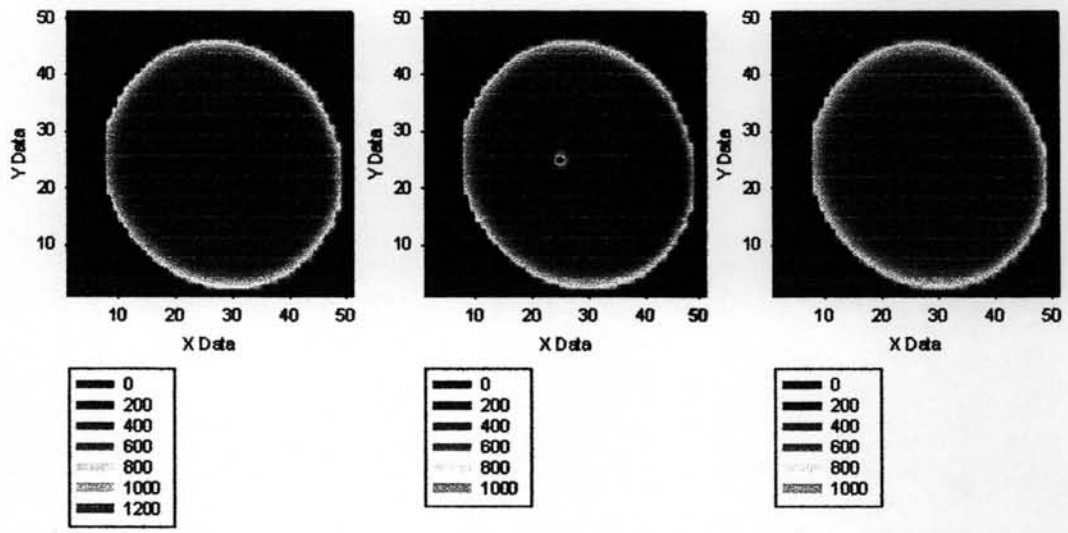


Figure 4.11 Pressure profile in X-Y dimension of cylindrical shaped with one well at bottom, well, and top levels, respectively, (a) initial pressure, (b) pressure at time 10 days, (c) Pressure at time 20 days, (d) Pressure at time 95 days.

When the production occurs, the pressure in reservoir decrease until reaching steady-state, as shown in Figures 4.12.

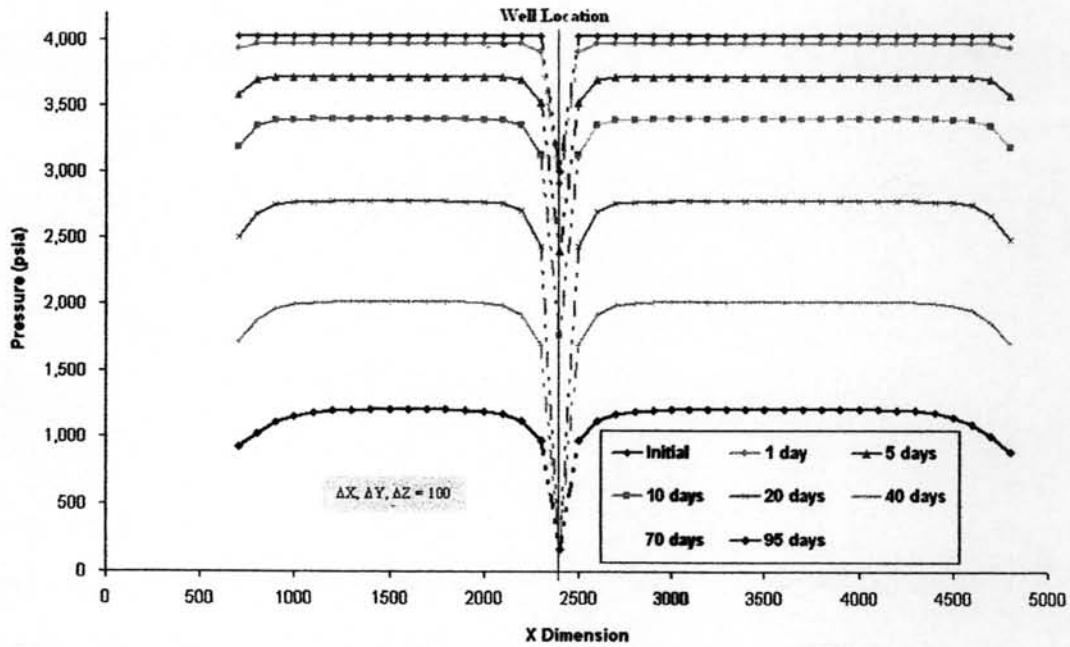


Figure 4.12 Pressure profile of cylindrical shaped with one well at well level.

The production rate is developed, as shown in Figure 4.13.

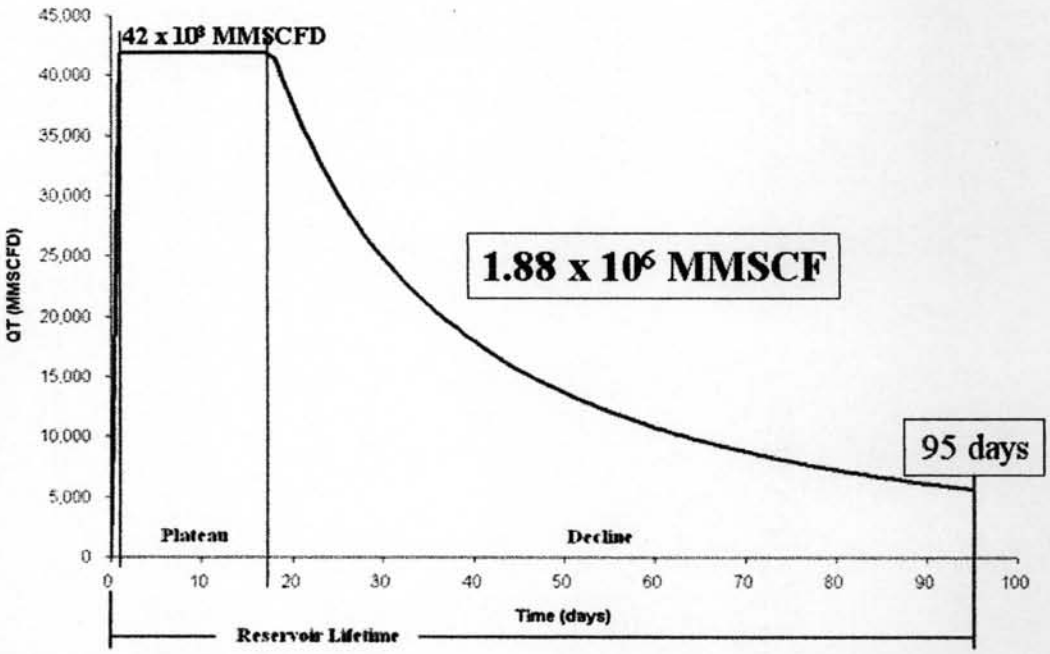


Figure 4.13 Production pattern of cylindrical shaped gas reservoir with one well.

There are two regions, plateau and decline. The plateau period is 17 days and the maximum volumetric flow rate is 42 x 10^3 MMSCFD. The final step is the decline step, during which the wellhead pressure becomes insufficient to maintain a constant flow rate. The production rate of natural gas will decrease and constant when time is 95 days and the total volumetric flow is 1.88 x 10^6 MMSCF.

4.4 Cylindrical Shaped Reservoir with Two Wells

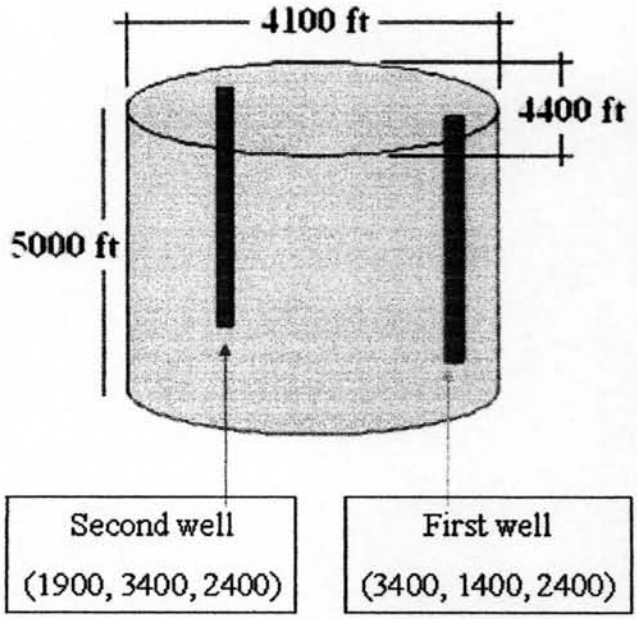
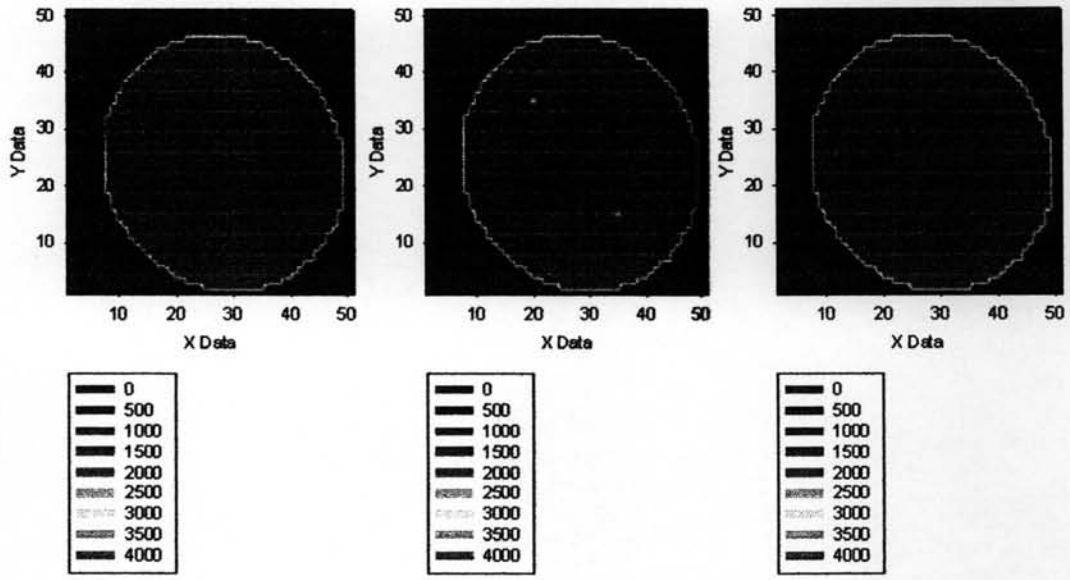


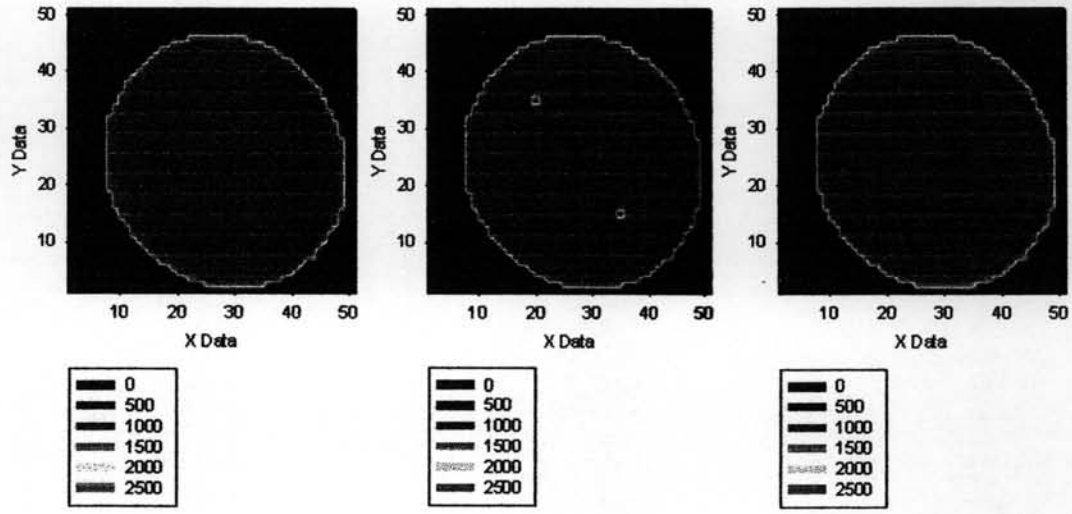
Figure 4.14 The cylindrical shaped reservoir modeling of double-well.

The cylindrical shaped reservoir with two wells as show in Figure 4.14 and the well locations are (3400, 1400, 2400 ft) for first well and (1900, 3400, 2400 ft) for second well. The pressure profiles after gas withdrawal using finite difference are shown in Figure 4.15.

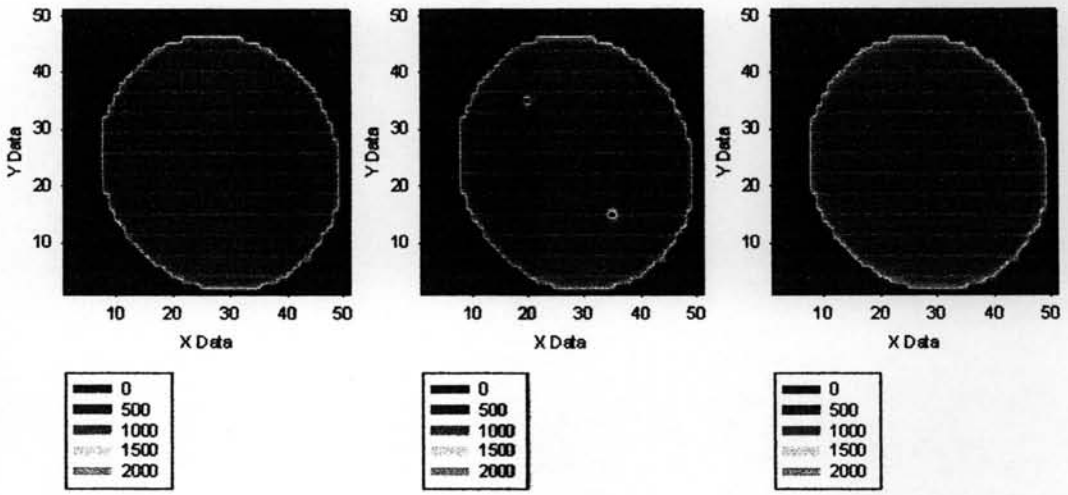
(a) Initial Pressure



(b) Pressure at time 10 days



(c) Pressure at time 15 days



(d) Pressure at time 51 days

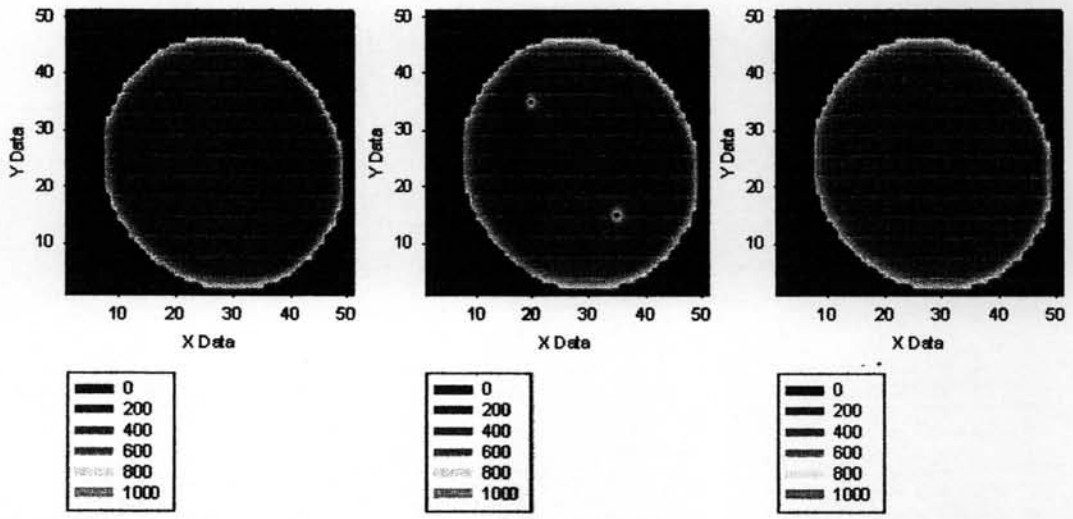


Figure 4.15 Pressure profile in X-Y dimension of cylindrical shaped with two wells at bottom, well, and top levels, respectively, **(a)** initial pressure, (b) pressure at time 10 days, (c) Pressure at time 15 days, (d) Pressure at time 51 days.

When the production occurs, the pressure in reservoir decrease until reaching steady-state, as shown in Figures 4.16-4.17.

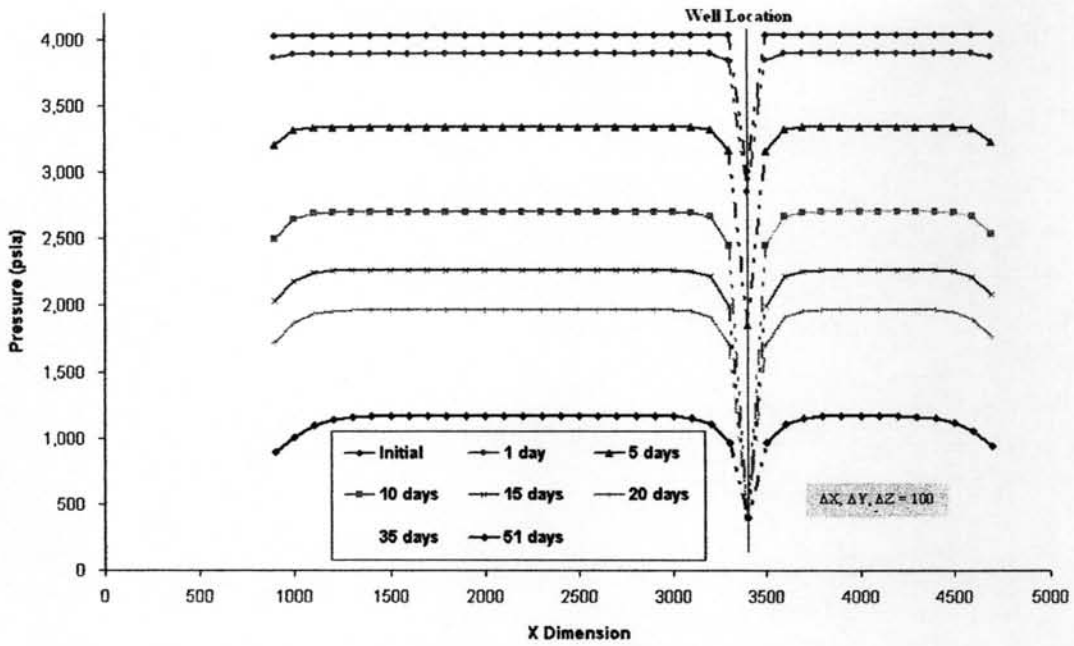


Figure 4.16 Pressure profile of cylindrical shaped with two wells at first well level.

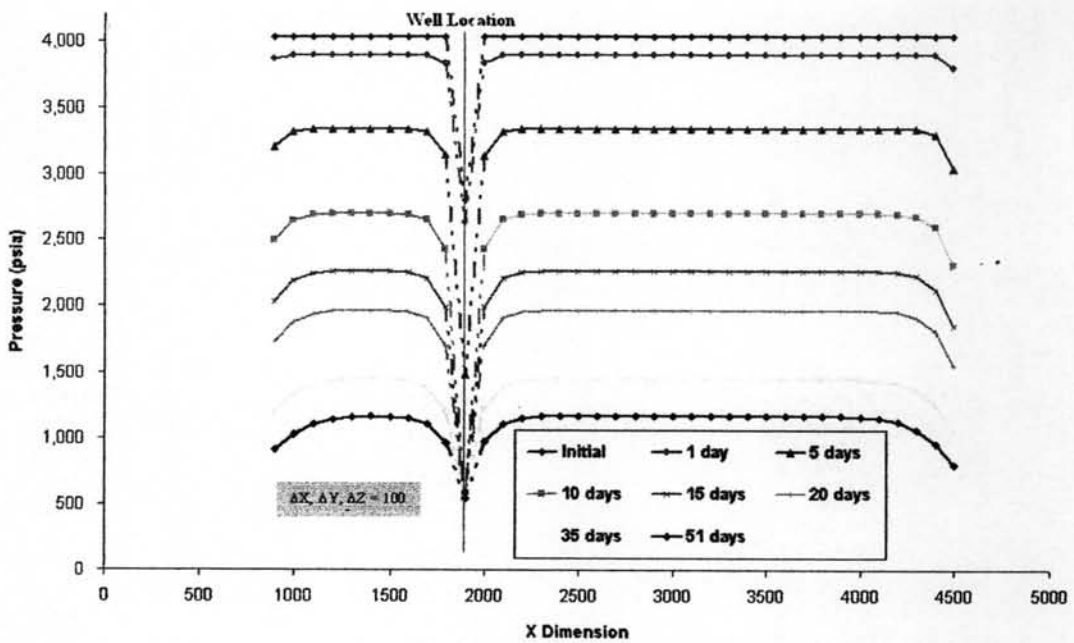


Figure 4.17 Pressure profile of cylindrical shaped with two wells at second well level.

The production rate is developed, as shown in Figure 4.18.

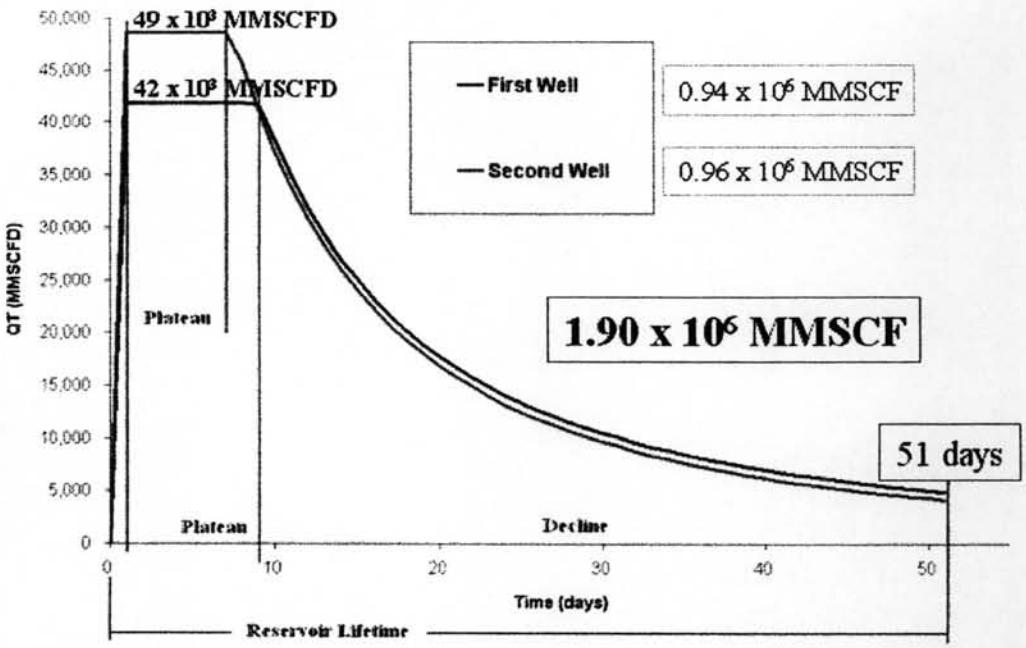


Figure 4.18 Production pattern of cylindrical shaped gas reservoir with two wells.

There are two regions, plateau and decline. The plateau periods are 9 days for first well and 7 days for second well and the maximum volumetric flow rates are 42 x 10^3 MMSCFD for first well and 49 x 10^3 MMSCFD for second well. The final step is the decline step, during which the wellhead pressure becomes insufficient to maintain a constant flow rate. The production rate of natural gas will decrease and constant when time is 51 days and the low well pressure can withdraw the natural gas more than high well pressure and the total volumetric flow is 1.90 x 10^6 MMSCF.

4.5 Irregular Shaped Reservoir with One Well

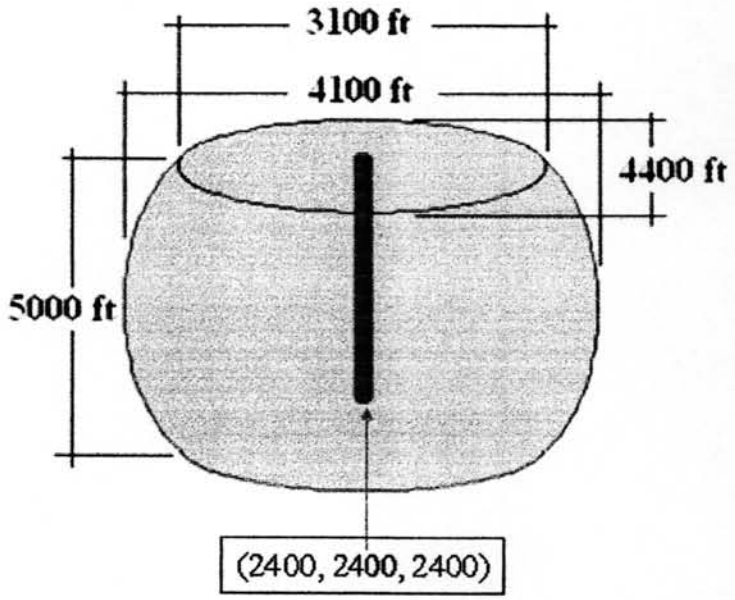
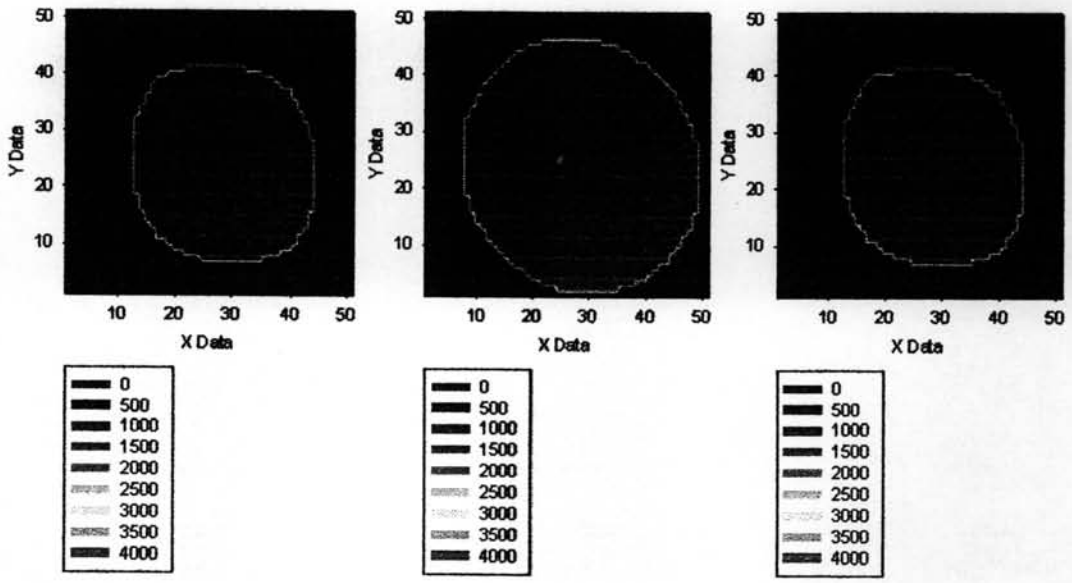


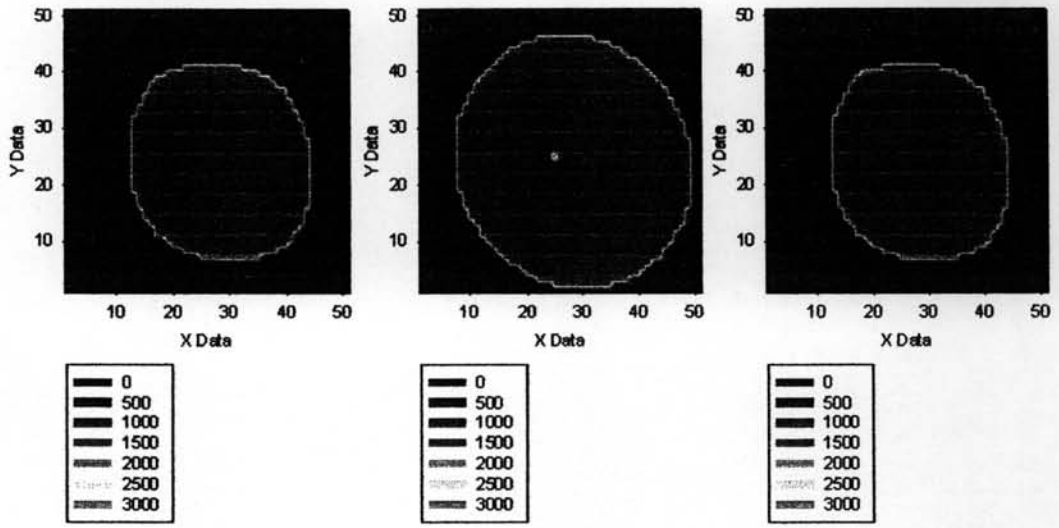
Figure 4.19 The irregular shaped reservoir modeling of single-well.

The irregular shaped reservoir with one well as show in Figure 4.19 and the well location is (2400, 2400, 2400 ft). The pressure profiles after gas withdrawal using finite difference are shown in Figure 4.20.

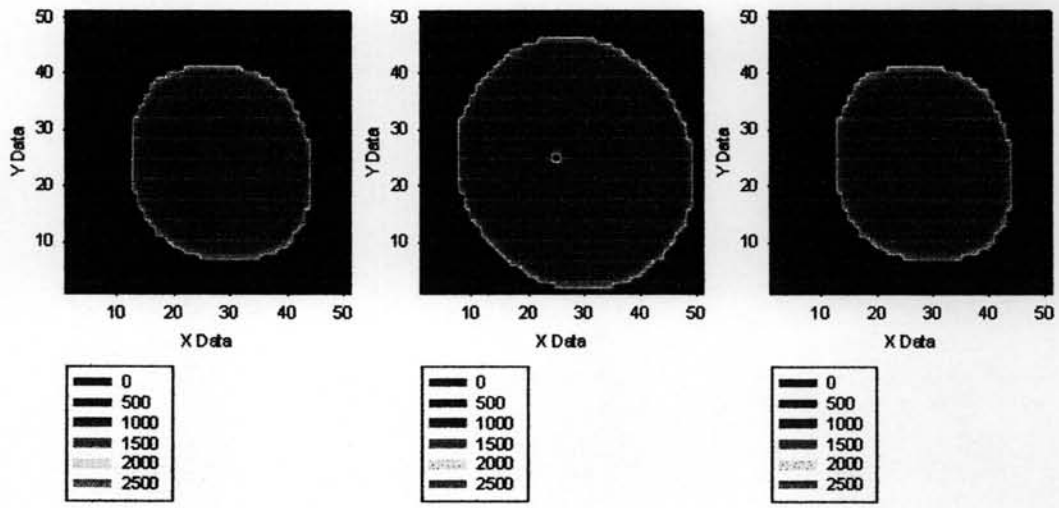
(a) Initial Pressure



(b) Pressure at time 10 days



(c) Pressure at time 20 days



(d) Pressure at time 95 days

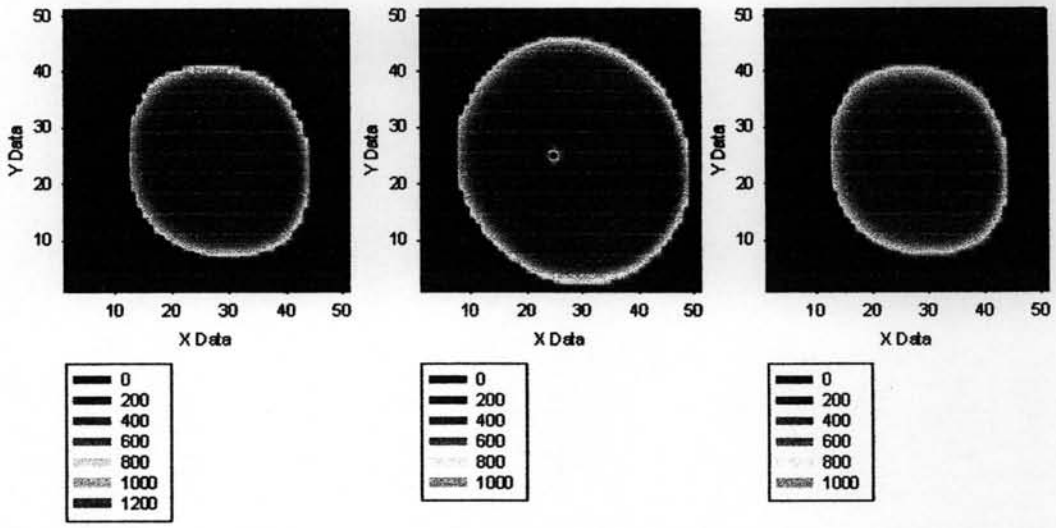


Figure 4.20 Pressure profile in X-Y dimension of irregular shaped with one well at bottom, well, and top levels, respectively, (a) initial pressure, (b) pressure at time 10 days, (c) Pressure at time 20 days, (d) Pressure at time 95 days.

When the production occurs, the pressure in reservoir decrease until reaching steady-state, as shown in Figure 4.21.

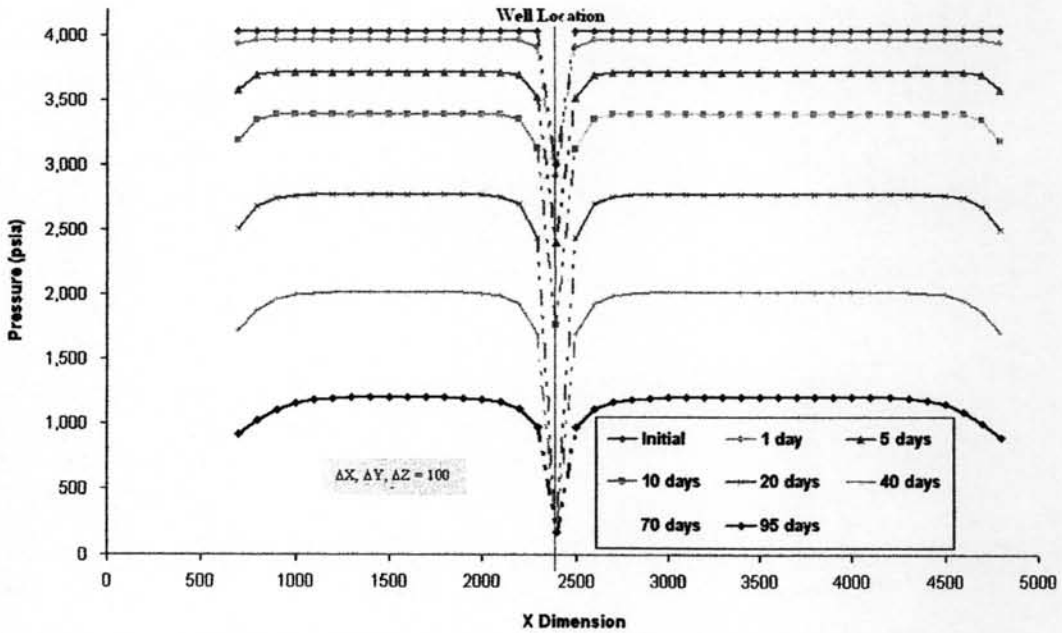


Figure 4.21 Pressure profile of irregular shaped with one well at well level.

The production rate is developed, as shown in Figure 4.22.

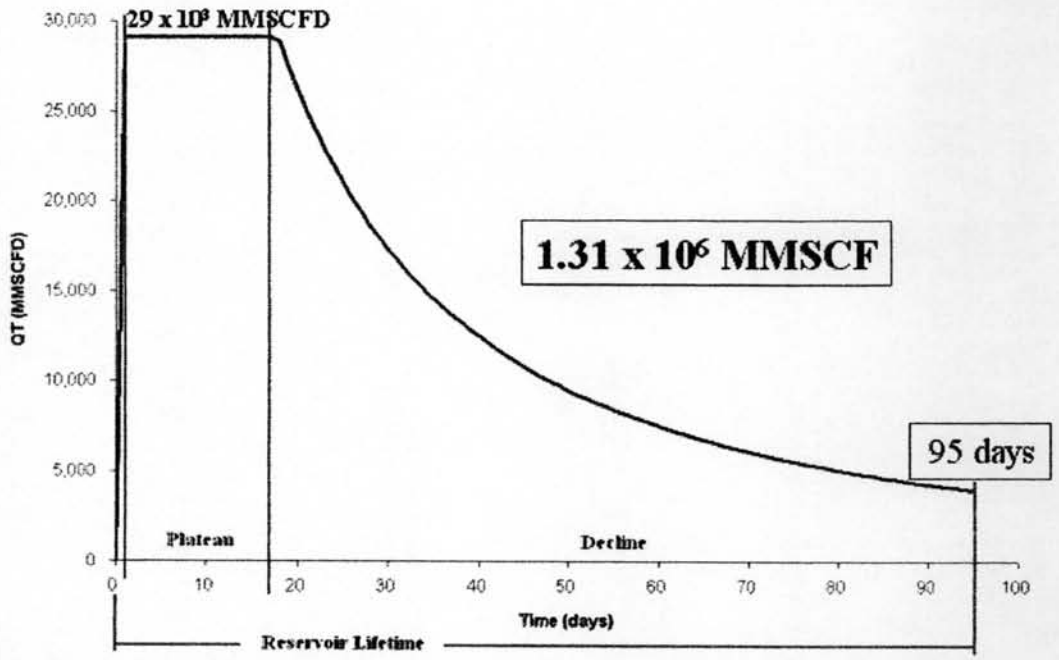


Figure 4.22 Production pattern of irregular shaped gas reservoir with one well.

There are two regions, plateau and decline. The plateau period is 17 days and the maximum volumetric flow rate is 29 x 10^3 MMSCFD. The final step is the decline step, during which the wellhead pressure becomes insufficient to maintain a constant flow rate. The production rate of natural gas will decrease and constant when time is 95 days and the total volumetric flow is 1.31 x 10^6 MMSCF.

4.6 Irregular Shaped Reservoir with Two Wells

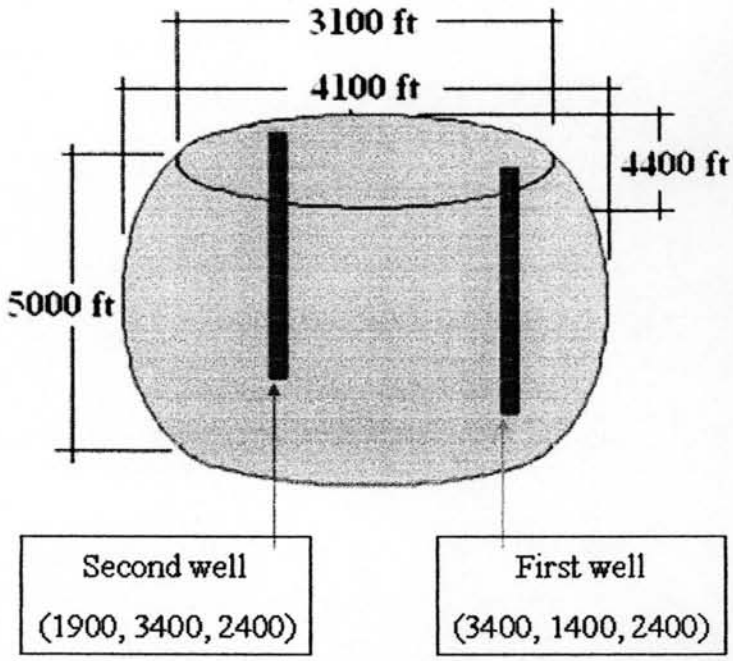
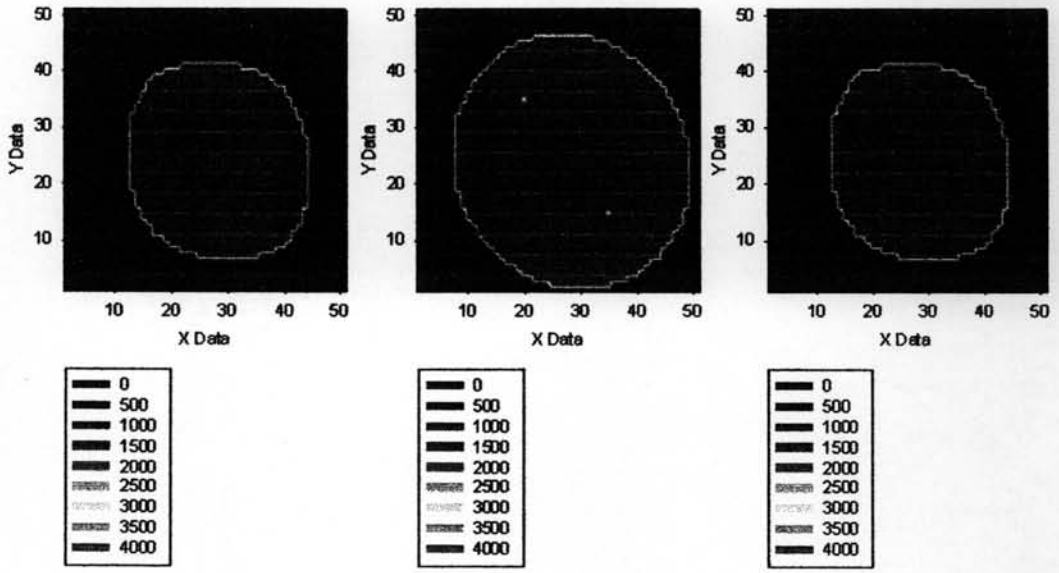


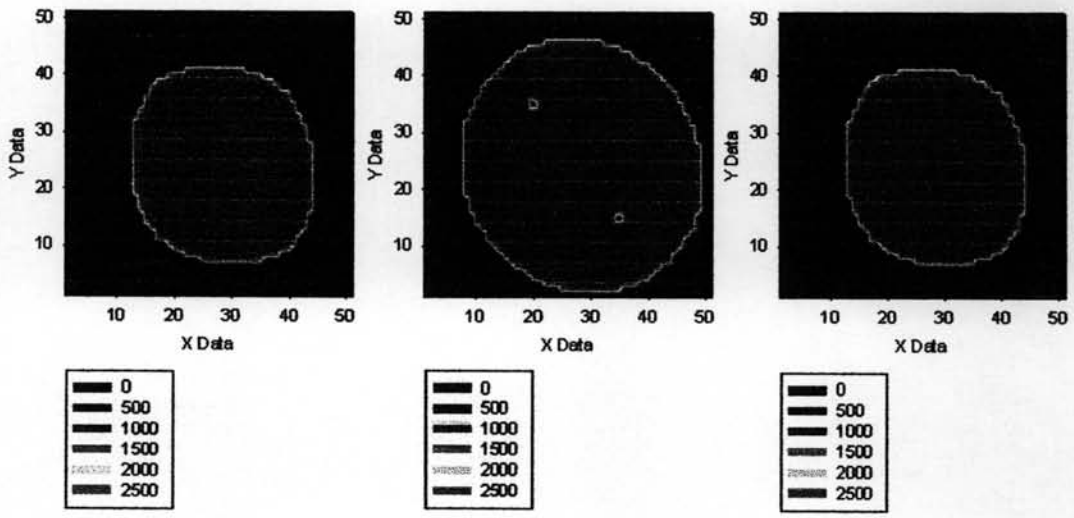
Figure 4.23 The irregular shaped reservoir modeling of double-well.

The irregular shaped reservoir with two wells as show in Figure 4.23 and the well locations are (3400, 1400, 2400 ft) for first well and (1900, 3400, 2400 ft) for second well. The pressure profiles after gas withdrawal using finite difference are shown in Figure 4.24.

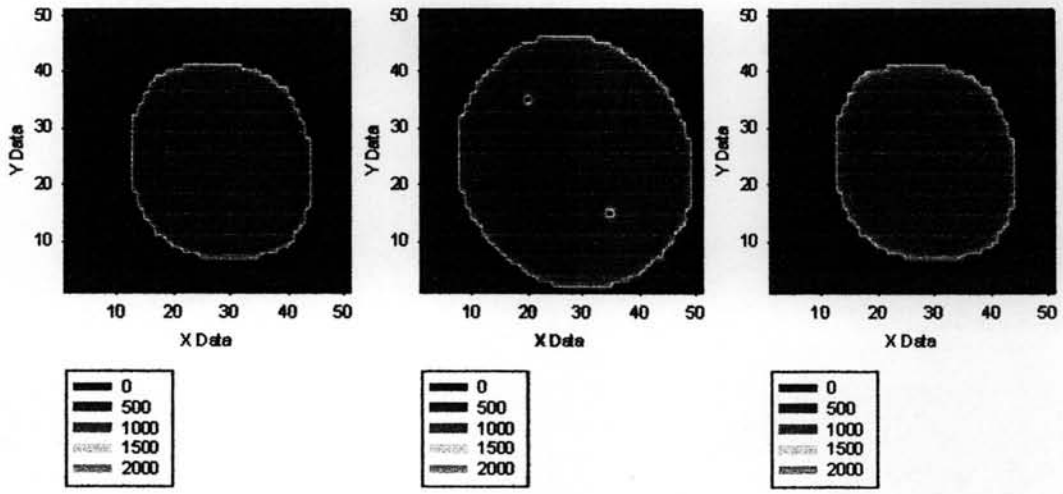
(a) Initial Pressure



(b) Pressure at time 10 days



(c) Pressure at time 15 days



(d) Pressure at time 51 days

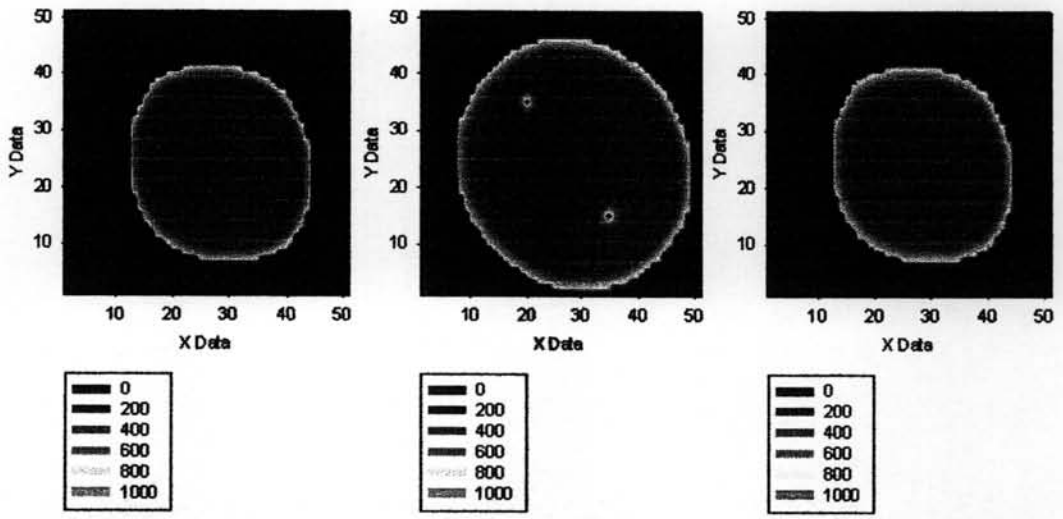


Figure 4.24 Pressure profile in X-Y dimension of irregular shaped with two wells at bottom, well, and top levels, respectively, (a) initial pressure, (b) pressure at time 10 days, (c) Pressure at time 15 days, (d) Pressure at time 51 days.

When the production occurs, the pressure in reservoir decrease until reaching steady-state, as shown in Figures 4.25-4.26.

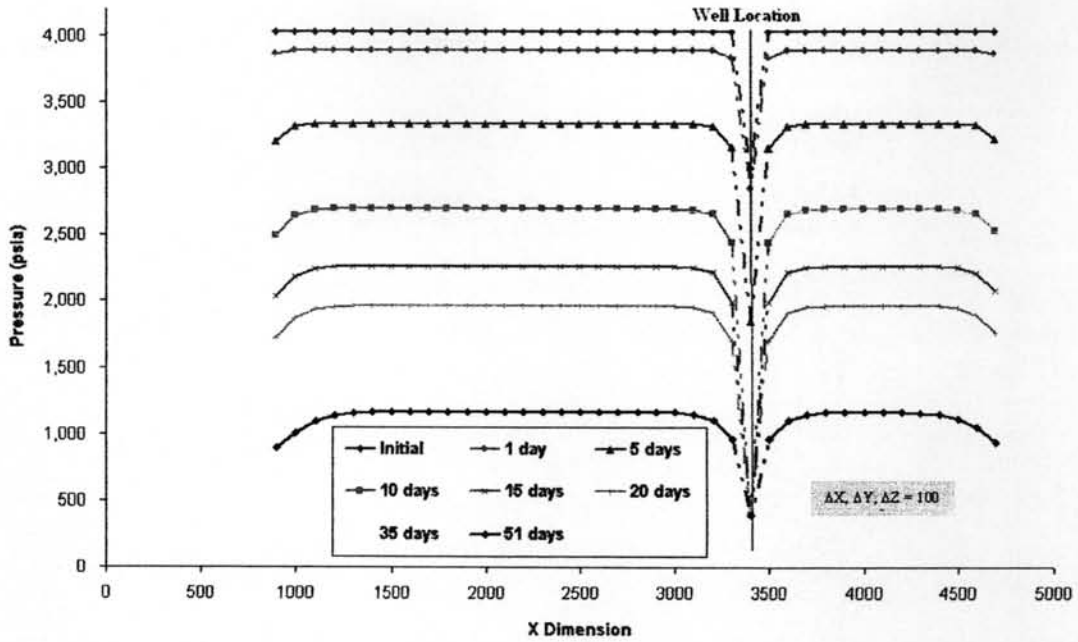


Figure 4.25 Pressure profile of irregular shaped with two wells at first well level.

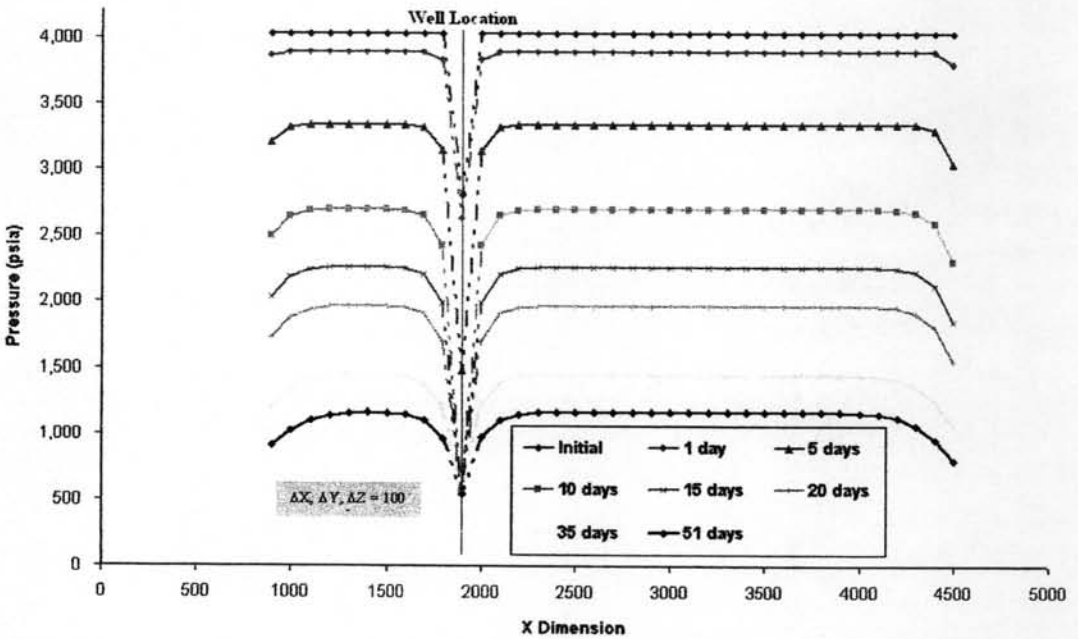


Figure 4.26 Pressure profile of irregular shaped with two wells at second well level.

The production rate is developed, as shown in Figure 4.27.

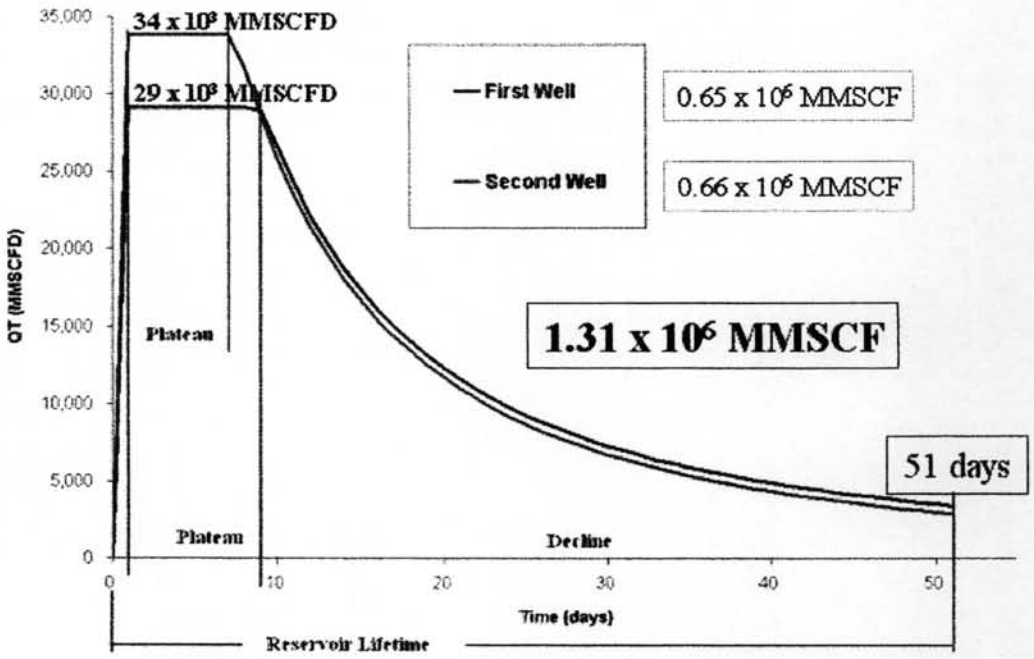


Figure 4.27 Production pattern of irregular shaped gas reservoir with two wells.

There are two regions, plateau and decline. The plateau periods are 9 days for first well and 7 and the maximum volumetric flow rates are 29 x 10^{36} MMSCFD for first well and 34 x 10^{3} MMSCFD for second well. The final step is the decline step, during which the wellhead pressure becomes insufficient to maintain a constant flow rate. The production rate of natural gas will decrease and constant when time is 51 days and the low well pressure can withdraw the natural gas more than high well pressure and the total volumetric flow is 1.31 x 10^{6} MMSCF.