SAN JUAN BASIN COALBED METHANE SPACING STUDY

Addendum to

RESULTS FOR SENSITIVITY ANALYSIS OF THE SAN JUAN BASIN AREA 1 TYPE RESERVOIR

(Presented in Interim Report of June 18, 1990)

Submitted To

GAS RESEARCH INSTITUTE
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SUMMARY AND CONCLUSIONS

On the basis of the history match results from the Cedar Hill field, the sensitivity analysis for Area 1 of the San Juan Basin has been re-done at 0.25 percent porosity. The purpose of this document is to present these supplementary results as an addendum to the Sensitivity Analysis of the San Juan Basin Area 1 Type Reservoir Interim Report dated June 18, 1990.

The COMETPC 3-D simulations for the 0.25% porosity cases utilized the same reservoir parameters as those presented in the Interim Report of June 18, 1990 (Table 1). The simulated production performance is summarized in Table 2, where both the 3% porosity cases completed for the Interim Report of June 18, 1990 and the 0.25% porosity cases are presented. For both the single well and full section cases, the presentation format includes the gas production rate (Mscf/D), cumulative gas production (Bcf), gas recovery as a percentage of the initial gas-in-place, water production rate (Bbls/D), and cumulative water production (MBbls/D) as a function of production time (years), with well spacing being the parametric variable (Figures 1-24). In addition, single well abandonment rate (Mscf/D/Well) is presented as a function of both full section cumulative gas production and gas recovery, with well spacing being the parametric variable (Figures 25-32). It should be noted that although fracture half-lengths of 100, 300 and 500 feet were evaluated, only the results from the 300 feet cases have been included in Figures 1-32.

Gas recovery is shown as a function of permeability, at a constant coal thickness of 35 feet, with parametric well spacing for all fracture half-lengths evaluated (Figures 33-53). The simulation results presented in Figures 33-50 are for 10, 20, 30, 40, 50 and 75 years. Similar plots, but at a 50 Mscf/D cutoff rather than for fixed times, are given in Figures 51-53.

The sensitivity analysis presented in the Interim Report of June 18, 1990 included some limited variations on the Base Case conditions which included cleat porosity. The simulation results for the 0.25%, 2% and 3% porosity cases are illustrated in Figures 54-56, where both gas and water production results are shown. These results are also summarized in Table 3.

Comparison of the Area 1 sensitivity analysis simulated at both 0.25% and 3% porosity does not alter the conclusions presented in the Interim Report of June 18, 1990. These conclusions are repeated here for the sake of completeness.

1. Gas recovery, expressed as a percentage of gas-in-place, increases with decreasing well spacing. Magnitudes of variability for different values of permeability and fracture half-length are indicated in Table 2.

2. Both cumulative gas production and gas recovery increase with decreasing abandonment rates, with a corresponding increase in the production time.

3. Gas recovery increases with both increasing permeability and increasing fracture half-length.

4. Cumulative gas production and recovery are greater for a 0.25% porosity coal than for either a 2% or a 3% porosity coal due to lower water production rates and the shorter time required to dewater the reservoir.

TABLE 1

RESERVOIR PARAMETERS FOR AREA 1 SENSITIVITY ANALYSIS

FIXED PARAMETERS

Depth	=	3000 ft.	) Assume slightly overpressured
$P_{initial}$	=	1320 psi	) 3000 ft * 0.44 psia/ft) = 1320 psia.
$P_{desorption}$	=	$P_{initial}$	
C_{pore}	=	200 x 10^{-6} psi^{-1}	(uncoupled from stress sensitive k)
Gas Content	=	345 SCF/Ton	
Porosity	=	0.0025	
h, ft		35	
Sorption time, days		10	
V_L	=	610 SCF/Ton (427 @ 30% Ash)	
P_L	=	315 psi	
FBHP	=	100 psi	
Temperature	=	$T_{3000\ ft.}$ (= 120°F)	
k_{rw}, k_{rg}		(Figure 2 of Interim Reported dated June 18, 1990)	

VARIABLE PARAMETERS

k, md	1, 5, 10*, 50
X_f, ft	100, 300*, 500
Spacing, acres	160, 320*, 640

Total Simulations Required: 36

* Base Case

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TABLE 2

SUMMARY OF SIMULATION RESULTS FOR AREA 1 TYPE RESERVOIR								
			POROSITY = 3 PERCENT			POROSITY = 0.25 PERCENT		
			Assuming 50 mscf/d Cutoff in Gas Production Rate		25 Year Cutoff	Assuming 50 mscf/d Cutoff in Gas Production Rate		25 Year Cutoff
Permeability (md)	Fracture Half-Length (feet)	Well Spacing (acres)	Time (years)	Gas Recovery (% IGIP)	Gas Recovery (% IGIP)	Time (years)	Gas Recovery (% IGIP)	Gas Recovery (% IGIP)
1	100	160	0.3	0.2	8.7	34.0	35.9	30.4
1	100	320	0.3	0.1	3.3	68.0	34.4	17.7
1	100	640	0.3	0.0	1.3	133.0	32.0	7.9
1	300	160	28.8	18.1	16.0	33.0	45.2	40.3
1	300	320	41.8	11.1	6.4	67.0	42.4	25.2
1	300	640	2.1	0.5	2.5	134.0	39.3	12.4
1	500	160	40.1	31.4	22.1	31.0	50.0	46.5
1	500	320	68.2	23.4	9.5	64.0	47.0	30.6
1	500	640	6.2	1.4	3.7	131.0	43.7	16.1
5	100	160	40.1	46.3	35.7	26.7	57.7	56.8
5	100	320	80.9	44.7	19.5	53.5	56.8	44.7
5	100	640	165.0	42.7	3.7	109.0	55.5	30.6
5	300	160	34.3	54.2	47.9	22.0	61.9	63.3
5	300	320	72.4	52.0	28.7	46.0	60.7	52.2
5	300	640	151.0	49.4	13.6	96.0	59.2	37.7
5	500	160	30.4	58.0	54.7	19.0	63.9	66.2
5	500	320	65.3	55.8	35.8	40.5	62.6	56.7
5	500	640	140.0	53.2	17.7	87.0	61.2	42.5

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TABLE 2 (Continued)

SUMMARY OF SIMULATION RESULTS FOR AREA 1 TYPE RESERVOIR								
			POROSITY = 3 PERCENT			POROSITY = 0.25 PERCENT		
			Assuming 50 mscf/d Cutoff in Gas Production Rate		25 Year Cutoff	Assuming 50 mscf/d Cutoff in Gas Production Rate		25 Year Cutoff
Permeability (md)	Fracture Half- Length (feet)	Well Spacing (acres)	Time (years)	Gas Recovery (% IGIP)	Gas Recovery (% IGIP)	Time (years)	Gas Recovery (% IGIP)	Gas Recovery (% IGIP)
10	100	160	33.5	56.2	50.6	21.0	62.9	64.6
10	100	320	67.7	55.0	33.6	42.5	62.3	55.5
10	100	640	140.1	53.6	17.5	87.0	61.5	42.7
10	300	160	26.9	61.2	60.2	16.7	65.6	68.2
10	300	320	56.8	59.7	44.0	34.7	64.7	61.4
10	300	640	121.4	58.1	24.9	74.0	63.9	49.4
10	500	160	22.6	63.3	64.5	14.1	66.8	69.4
10	500	320	49.7	62.1	50.5	30.0	66.0	64.4
10	500	640	108.4	60.5	30.7	65.0	65.1	53.6
50	100	160	15.7	66.5	69.1	9.9	68.5	70.1
50	100	320	32.5	66.4	63.7	19.6	68.3	69.3
50	100	640	67.8	66.0	50.9	40.0	68.1	64.7
50	300	160	11.8	68.0	69.9	7.4	69.2	70.2
50	300	320	24.6	67.6	67.7	15.0	69.0	70.0
50	300	640	53.7	67.2	58.1	31.8	68.7	67.5
50	500	160	9.6	68.5	70.0	6.2	69.5	70.1
50	500	320	20.7	68.2	69.0	12.6	69.3	70.1
50	500	640	45.6	67.8	62.0	27.0	69.0	68.8

TABLE 3

PRODUCTION SUMMARY OF POROSITY VARIATIONS ON BASE CASE FOR AREA 1				
	GAS		WATER	
CASE DESCRIPTION*	Cumulative BCF	% Recovery	Cumulative MSTB	% Recovery
3% Porosity	4.3	63.5	947	36.4
2% Porosity	4.5	65.6	655	37.8
0.25% Porosity	4.8	69.2	90	41.6
* Assumes 10 md, 300 ft x_f, V_L = 17.64 scf/cf, P_D = 1320 psia, and 75 year life on a 320 acre well spacing.				

Figure 1

San Juan Basin Sensitivity Analysis
Area 1 - Single Well Case

Gas Production vs. Time

Ø=0.25%, k=1md, and Xf=300 Ft.

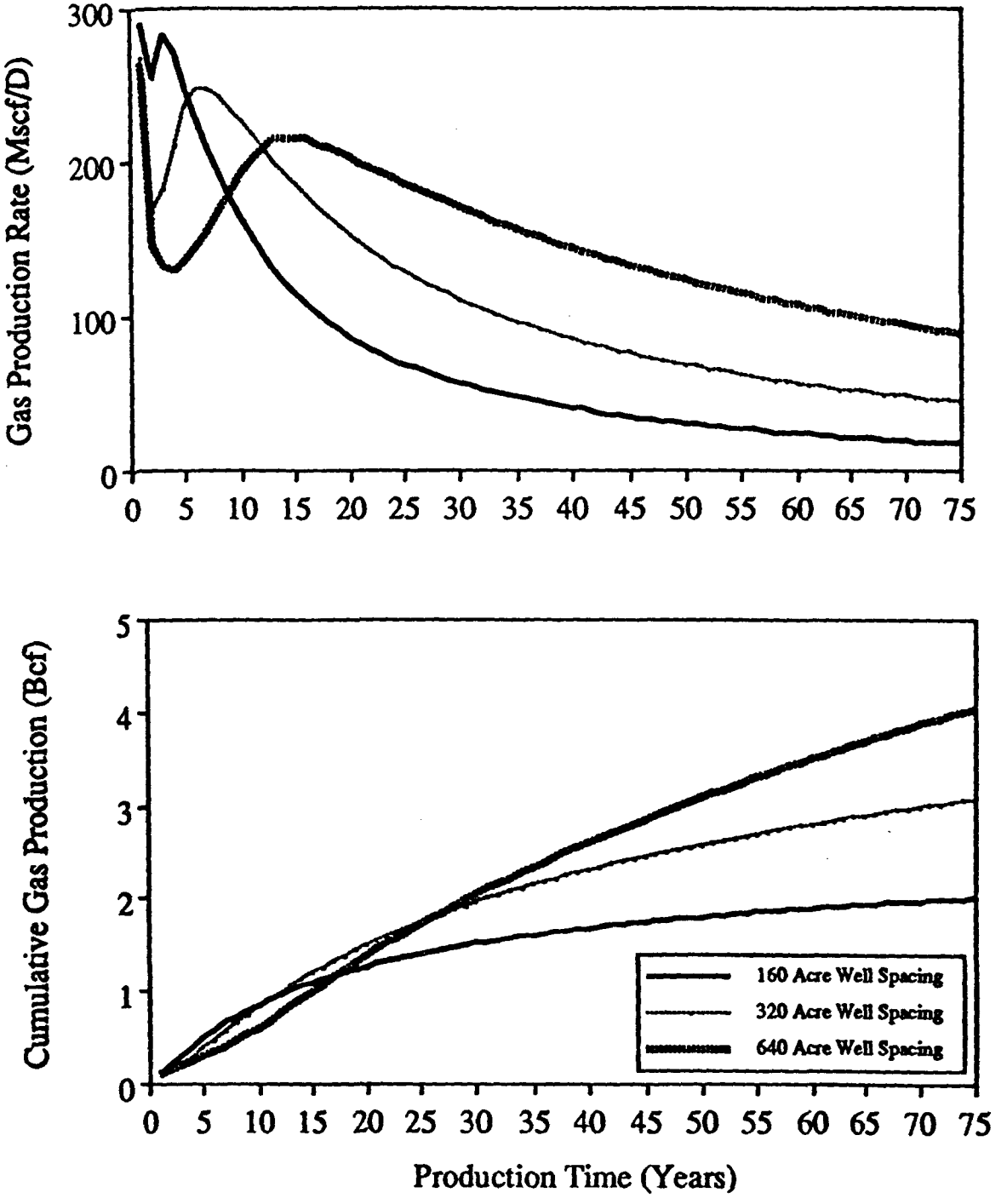

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Figure 2

San Juan Basin Sensitivity Analysis
Area 1 - Single Well Case

Gas Recovery vs. Time

Ø=0.25%, k=1md, and Xf=300 Ft.

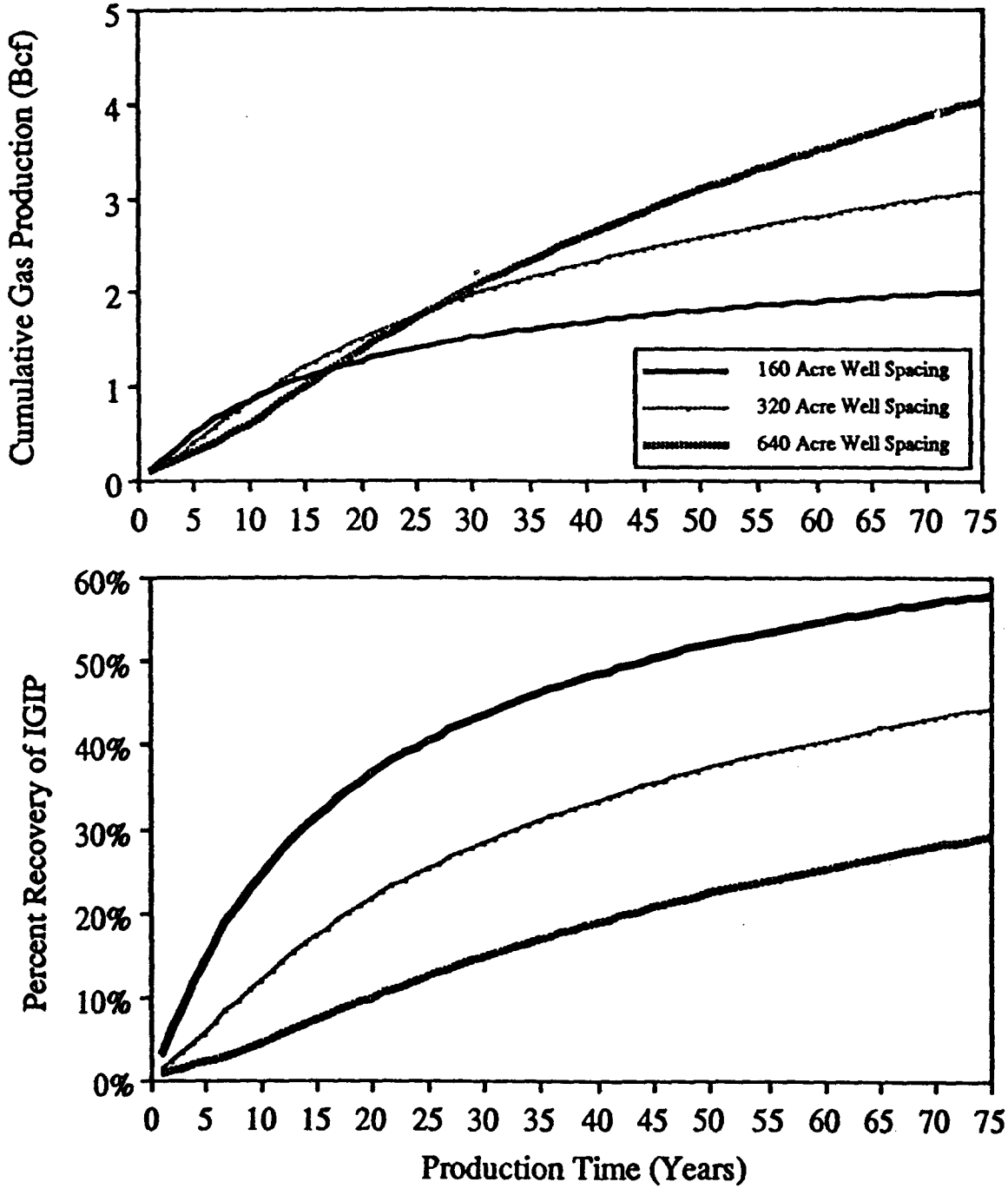

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Figure 3

San Juan Basin Sensitivity Analysis
Area 1 - Single Well Case

Water Production vs. Time

Ø=0.25%, k=1md, and Xf=300 Ft.

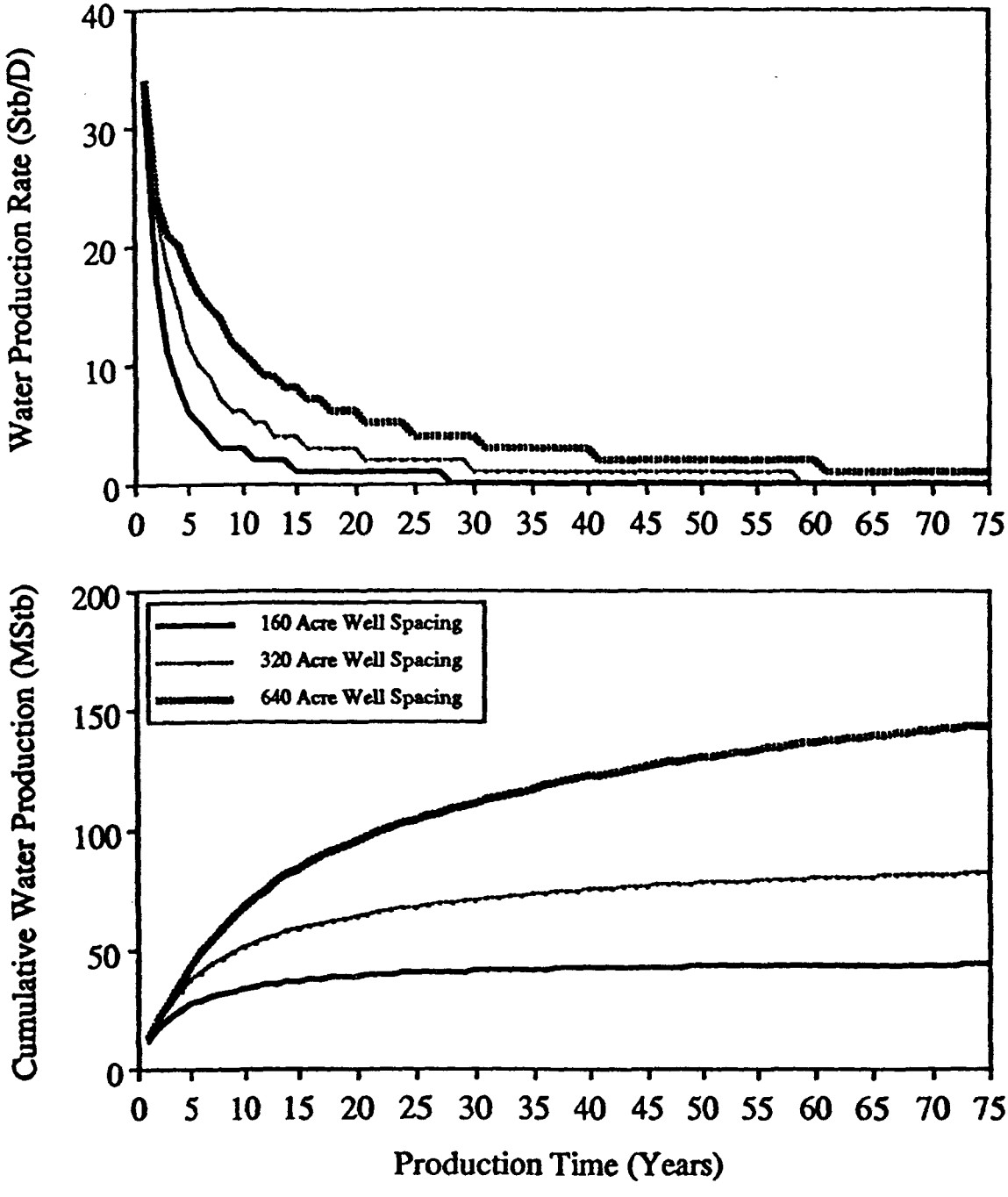

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Figure 4

San Juan Basin Sensitivity Analysis
Area 1 - Single Well Case

Gas Production vs. Time

Ø=0.25%, k=5md, and Xf=300 Ft.

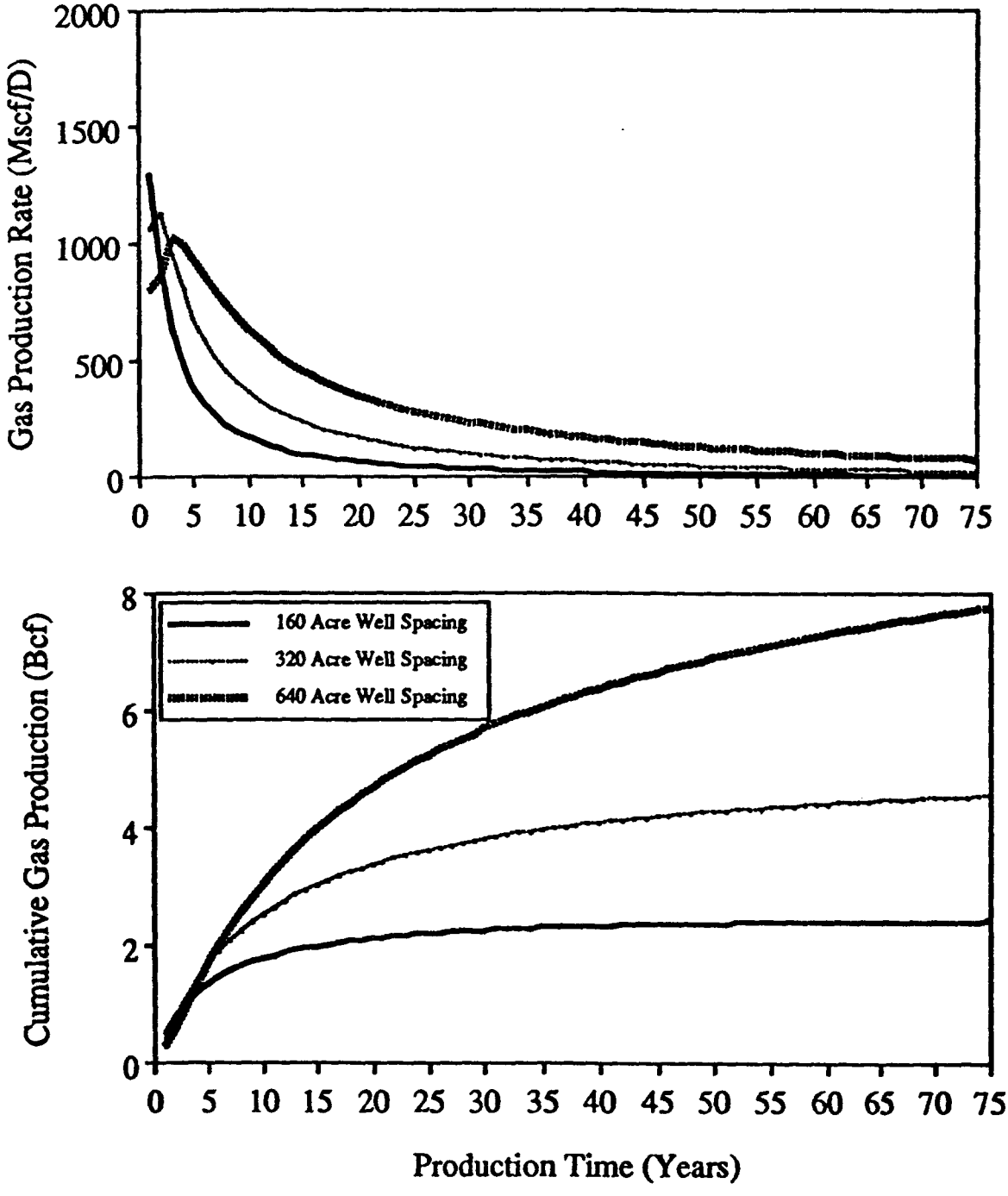

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Figure 5

San Juan Basin Sensitivity Analysis
Area 1 - Single Well Case

Gas Recovery vs. Time

Ø=0.25%, k=5md, and Xf=300 Ft.

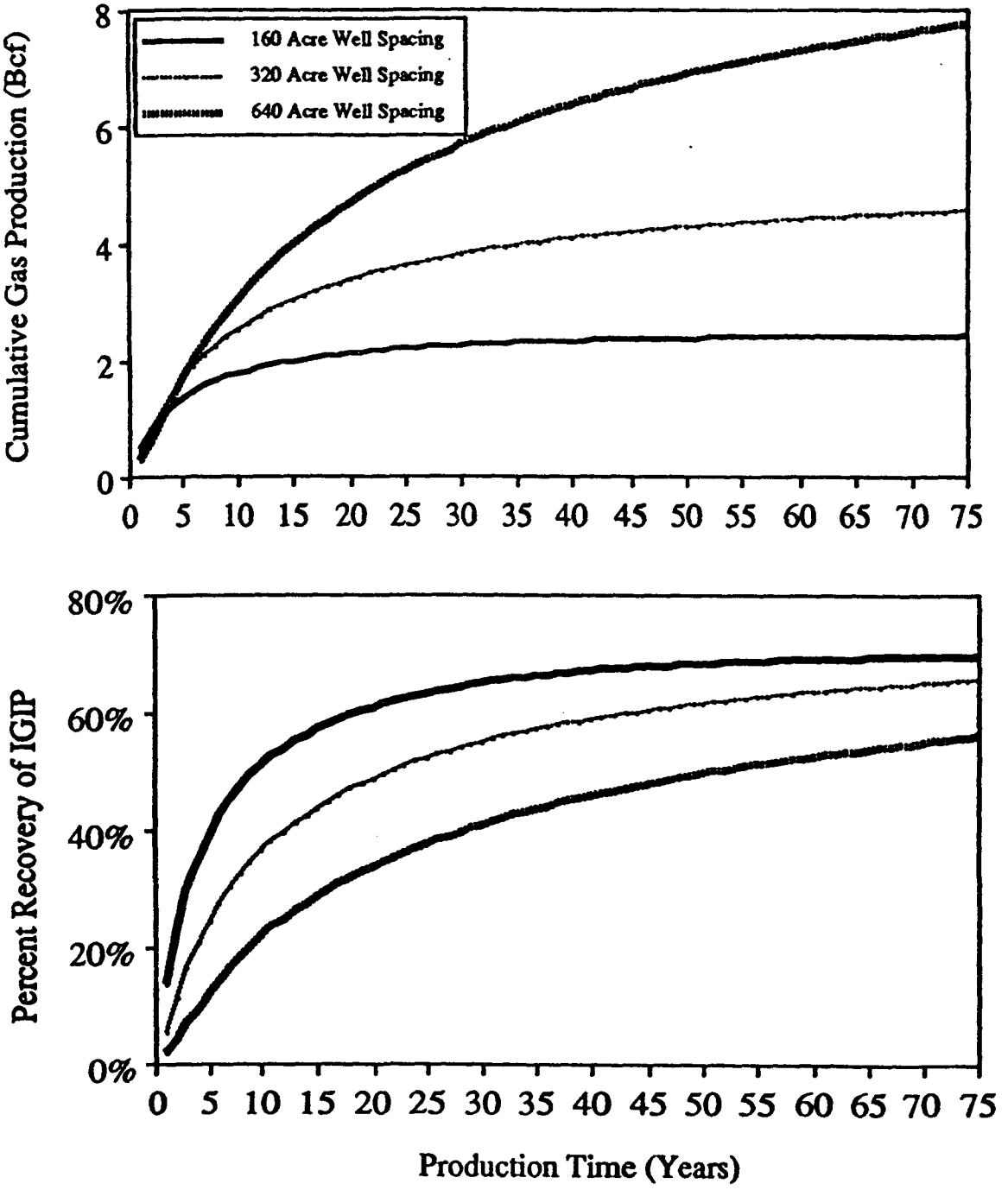

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Figure 6

San Juan Basin Sensitivity Analysis
Area 1 - Single Well Case

Water Production vs. Time

Ø=0.25%, k=5md, and Xf=300 Ft.

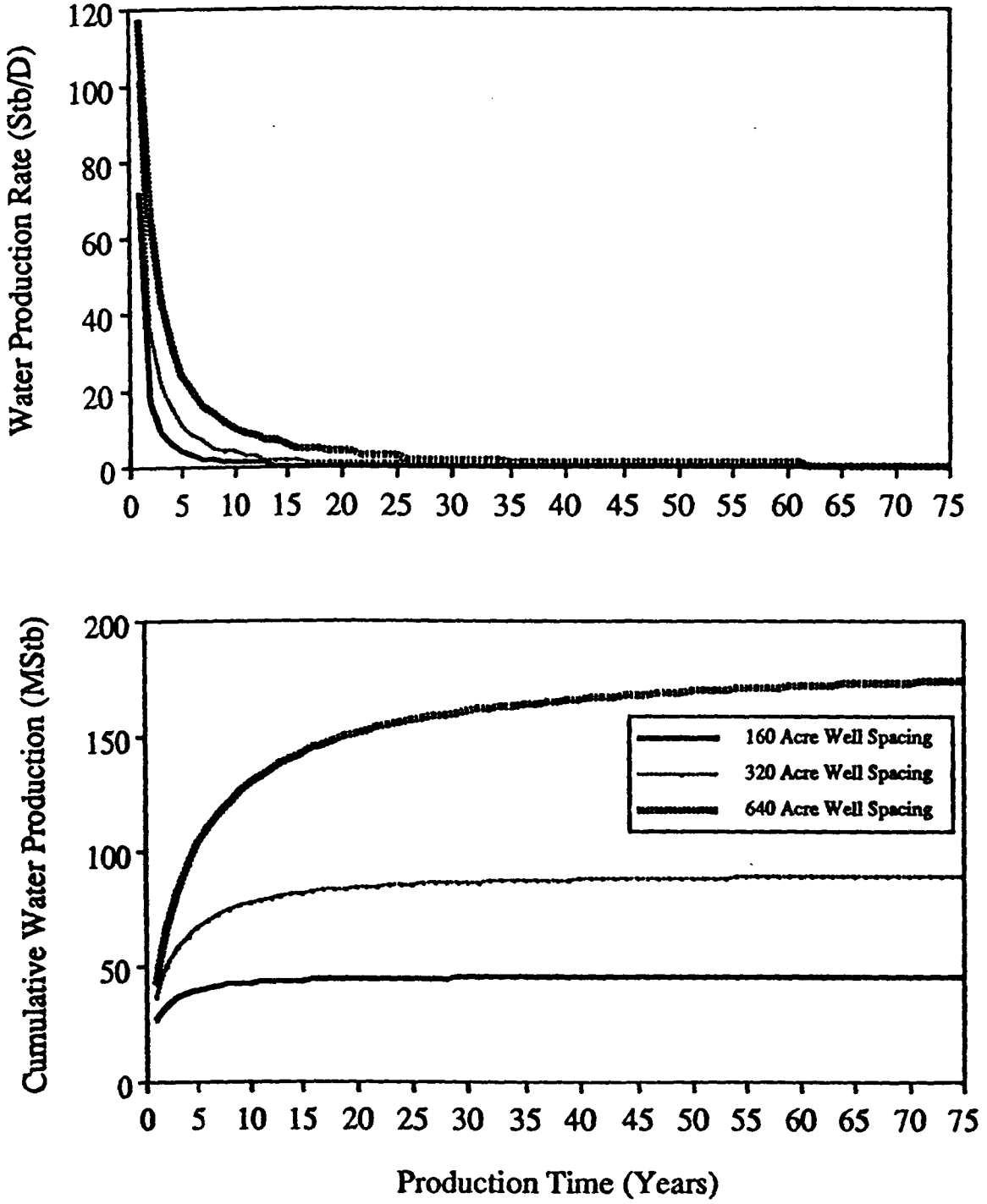

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Figure 7

San Juan Basin Sensitivity Analysis
Area 1 - Single Well Case

Gas Production vs. Time

Ø=0.25%, k=10md, and Xf=300 Ft.

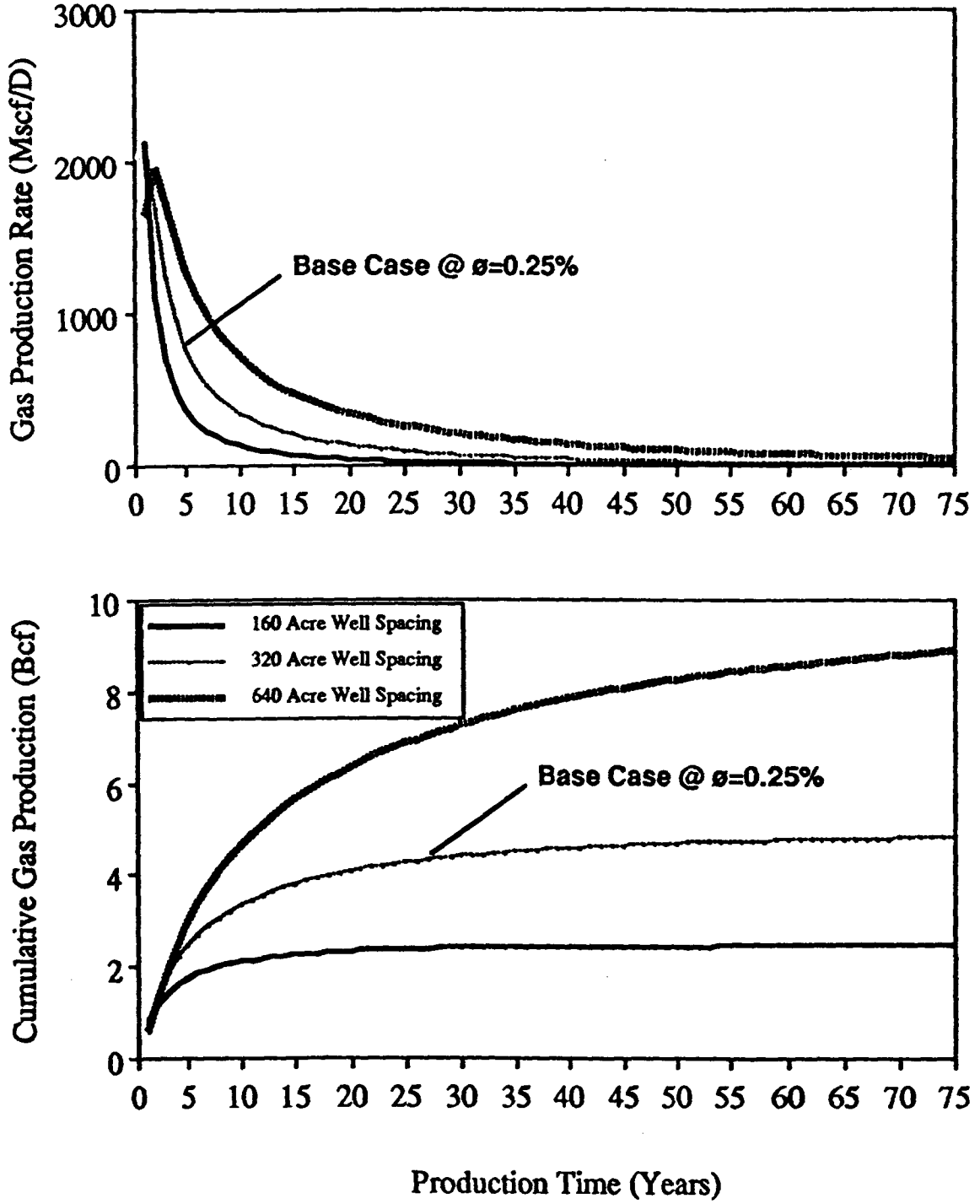

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Figure 8

San Juan Basin Sensitivity Analysis
Area 1 - Single Well Case

Gas Recovery vs. Time

Ø=0.25%, k=10md, and Xf=300 Ft.

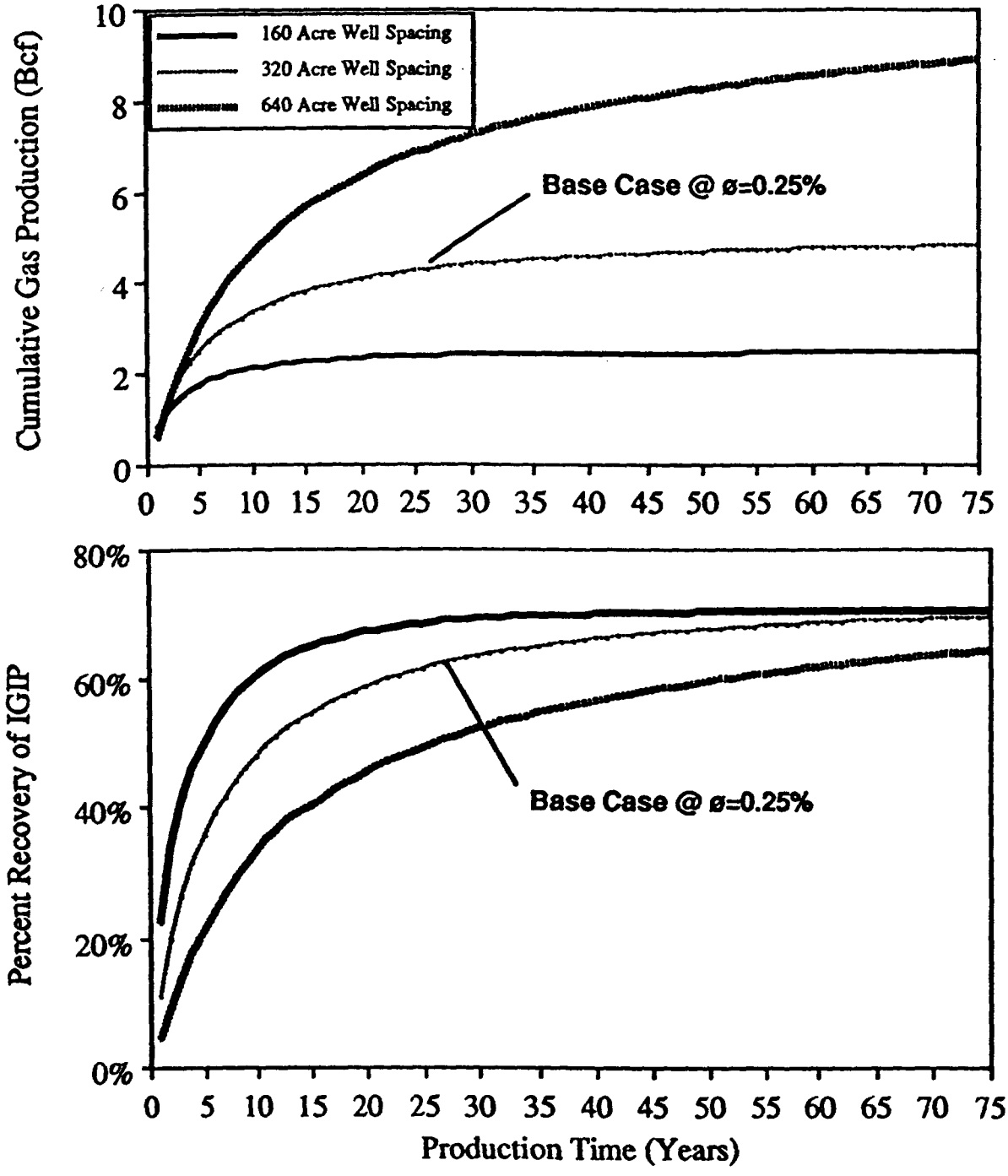

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Figure 9

San Juan Basin Sensitivity Analysis
Area 1 - Single Well Case

Water Production vs. Time

Ø=0.25%, k=10md, and Xf=300 Ft.

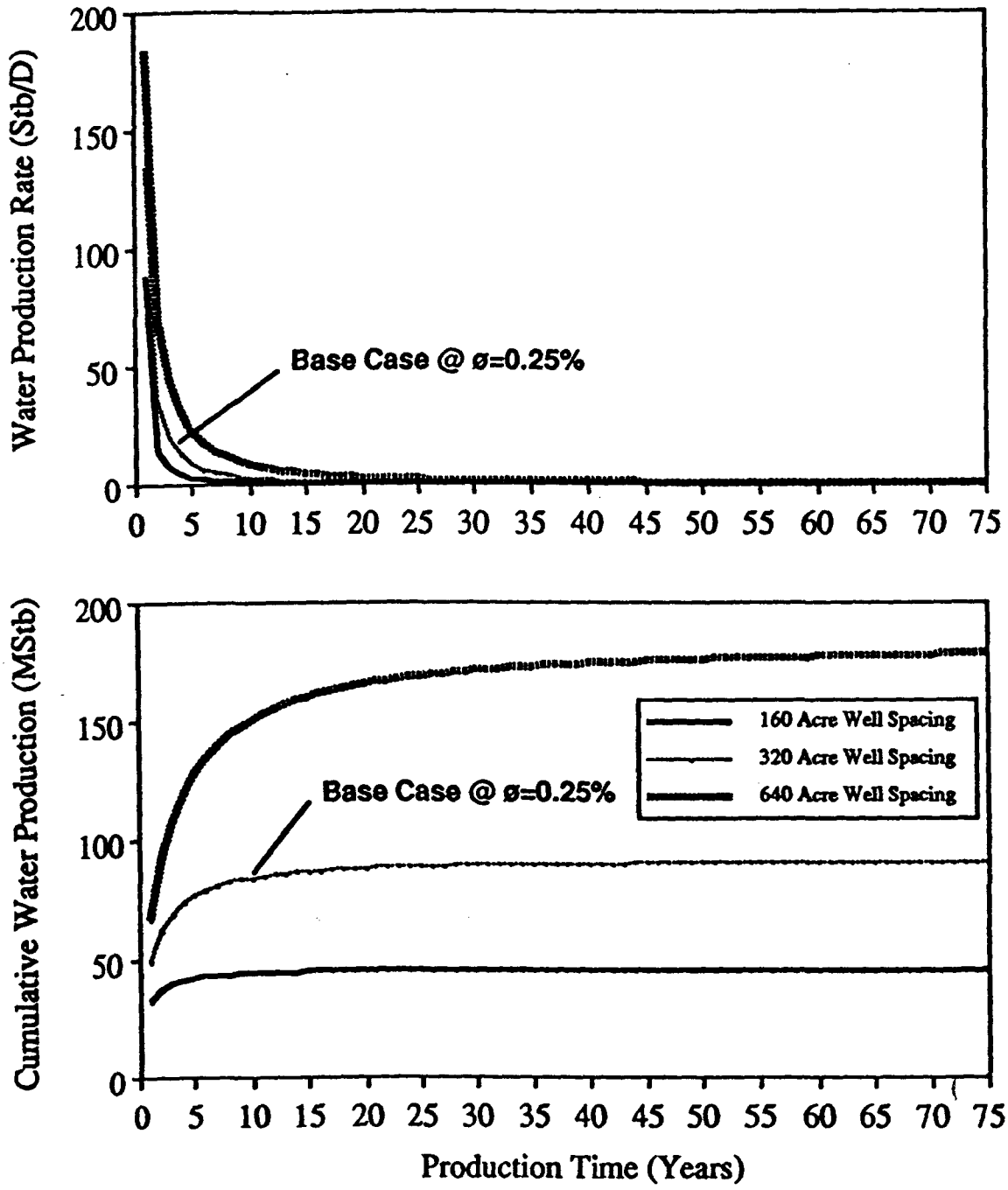

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Figure 10

San Juan Basin Sensitivity Analysis
Area 1 - Single Well Case

Gas Production vs. Time

Ø=0.25%, k=50md, and Xf=300 Ft.

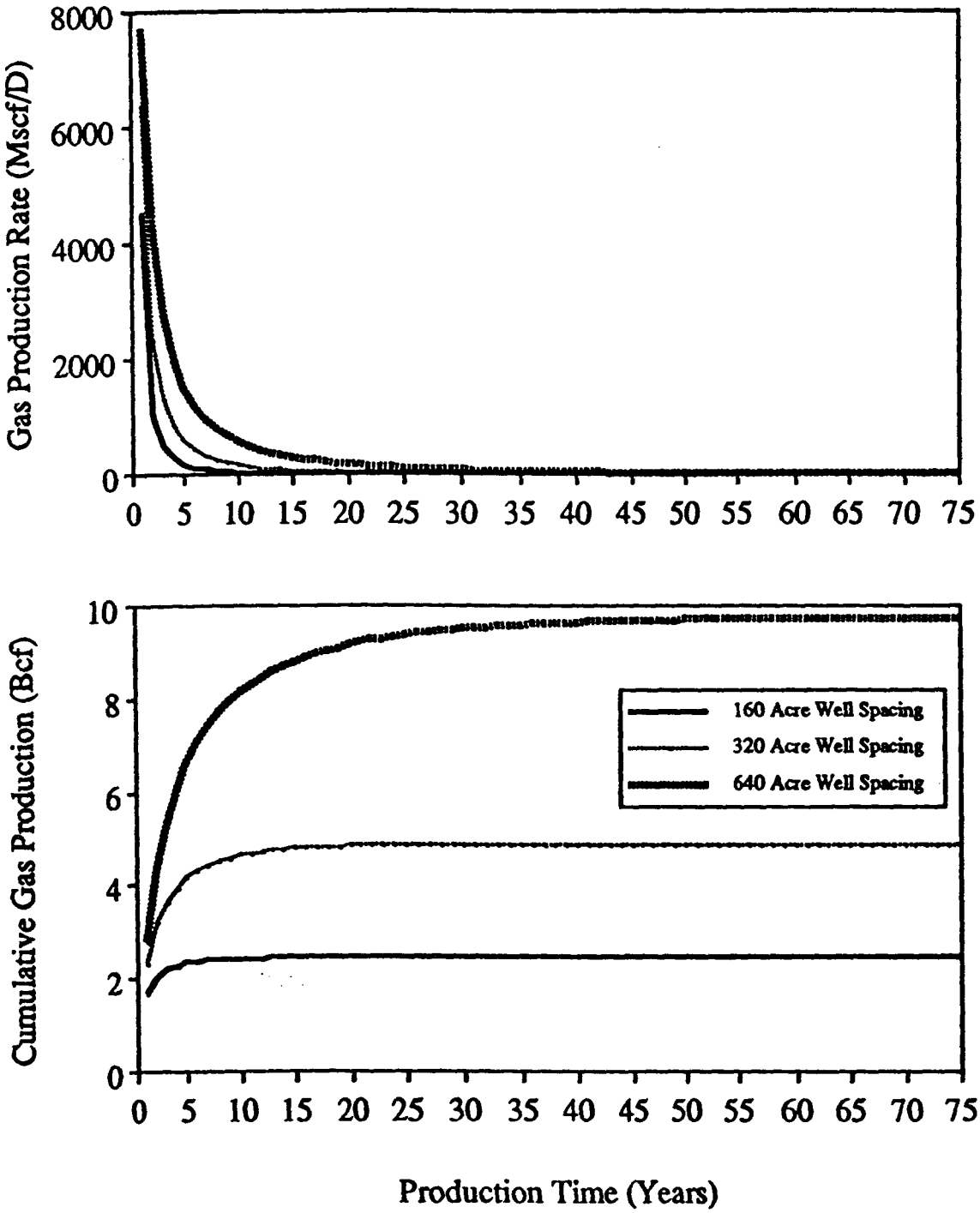

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Figure 11

San Juan Basin Sensitivity Analysis
Area 1 - Single Well Case

Gas Recovery vs. Time

Ø=0.25%, k=50md, and Xf=300 Ft.

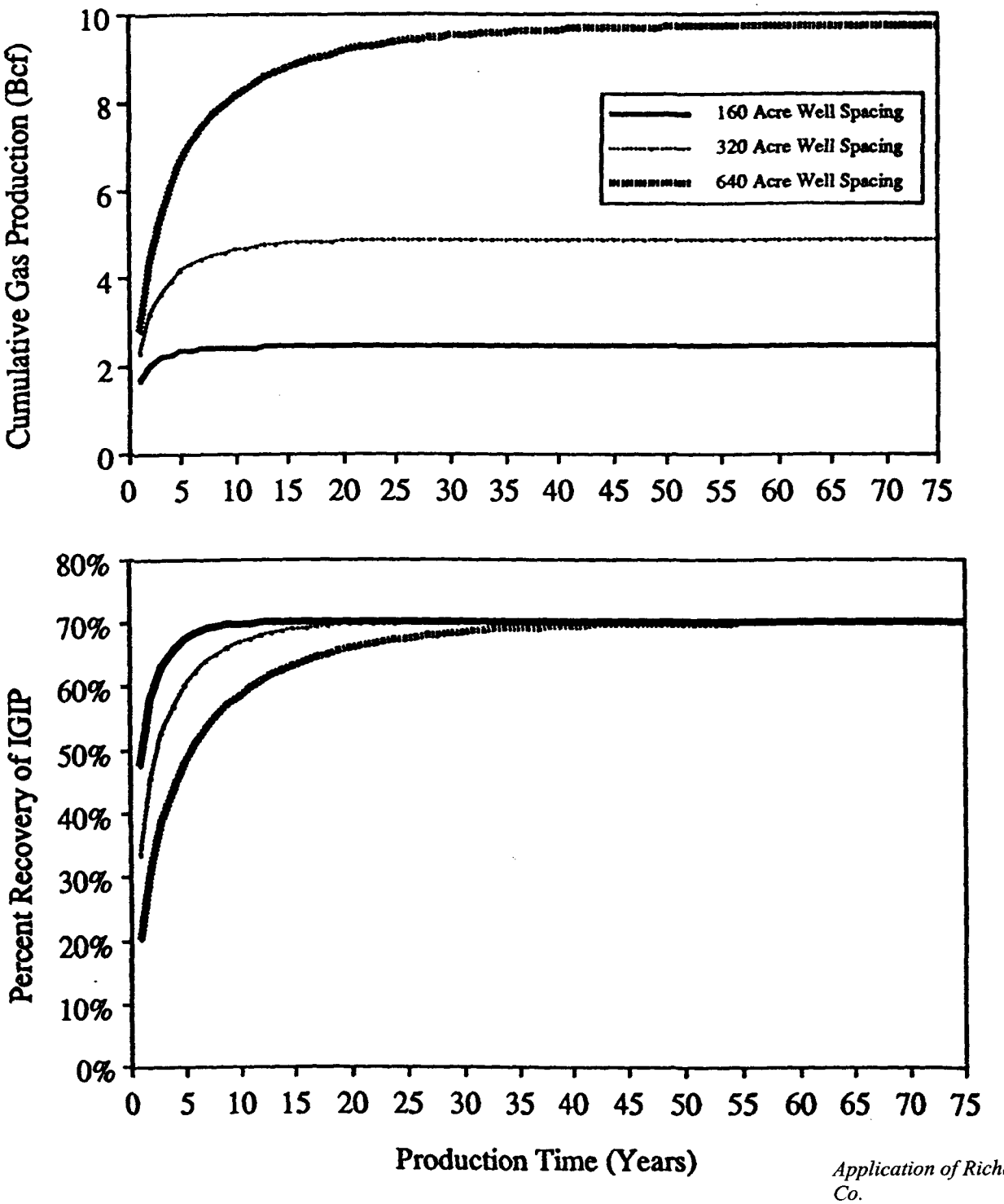

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Figure 12

San Juan Basin Sensitivity Analysis
Area 1 - Single Well Case

Water Production vs. Time

Ø=0.25%, k=50md, and Xf=300 Ft.

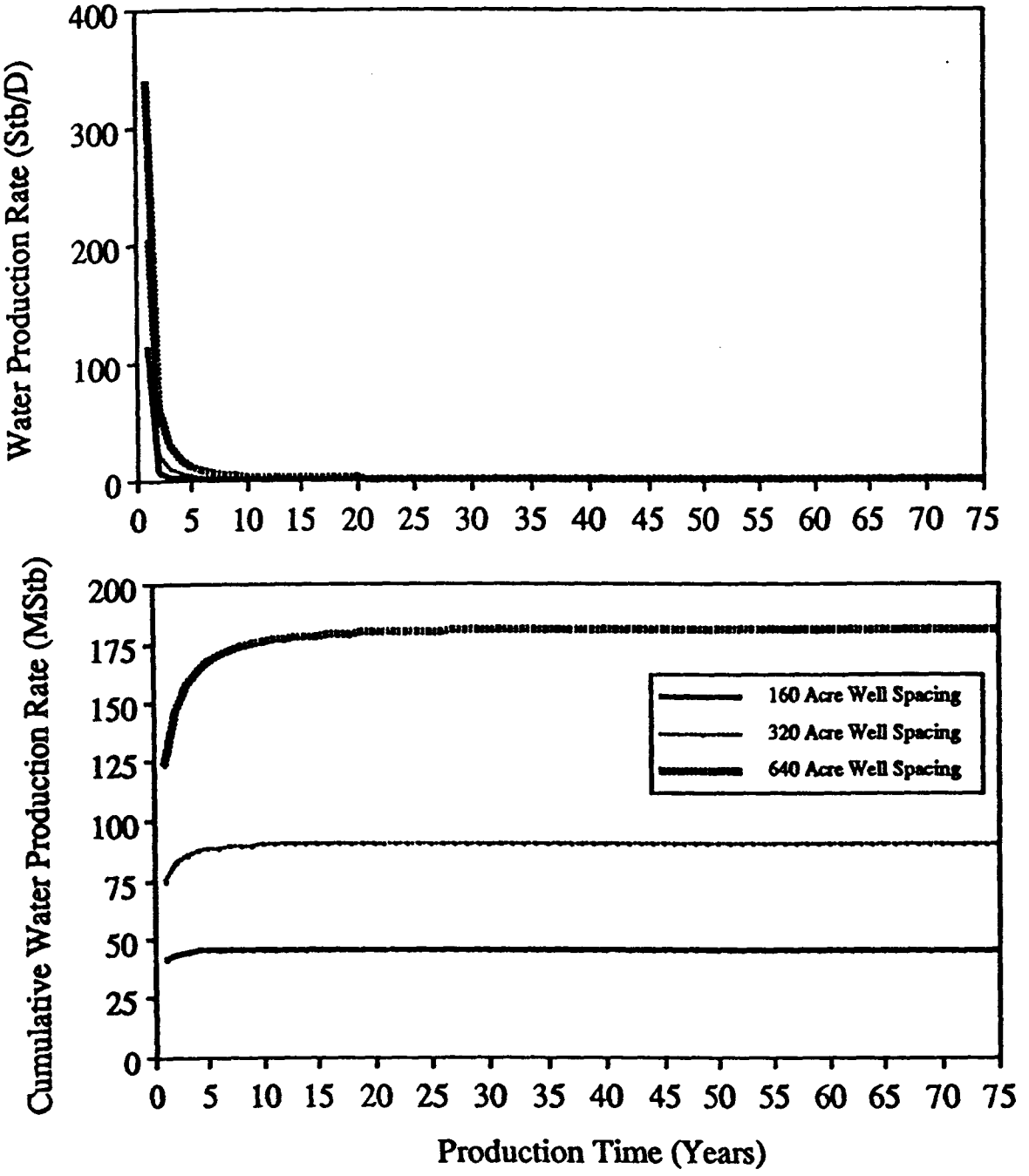

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Figure 13

San Juan Basin Sensitivity Analysis
Area 1 - Full Section Case

Gas Production vs. Time

Ø=0.25%, k=1md, and Xf=300 Ft.

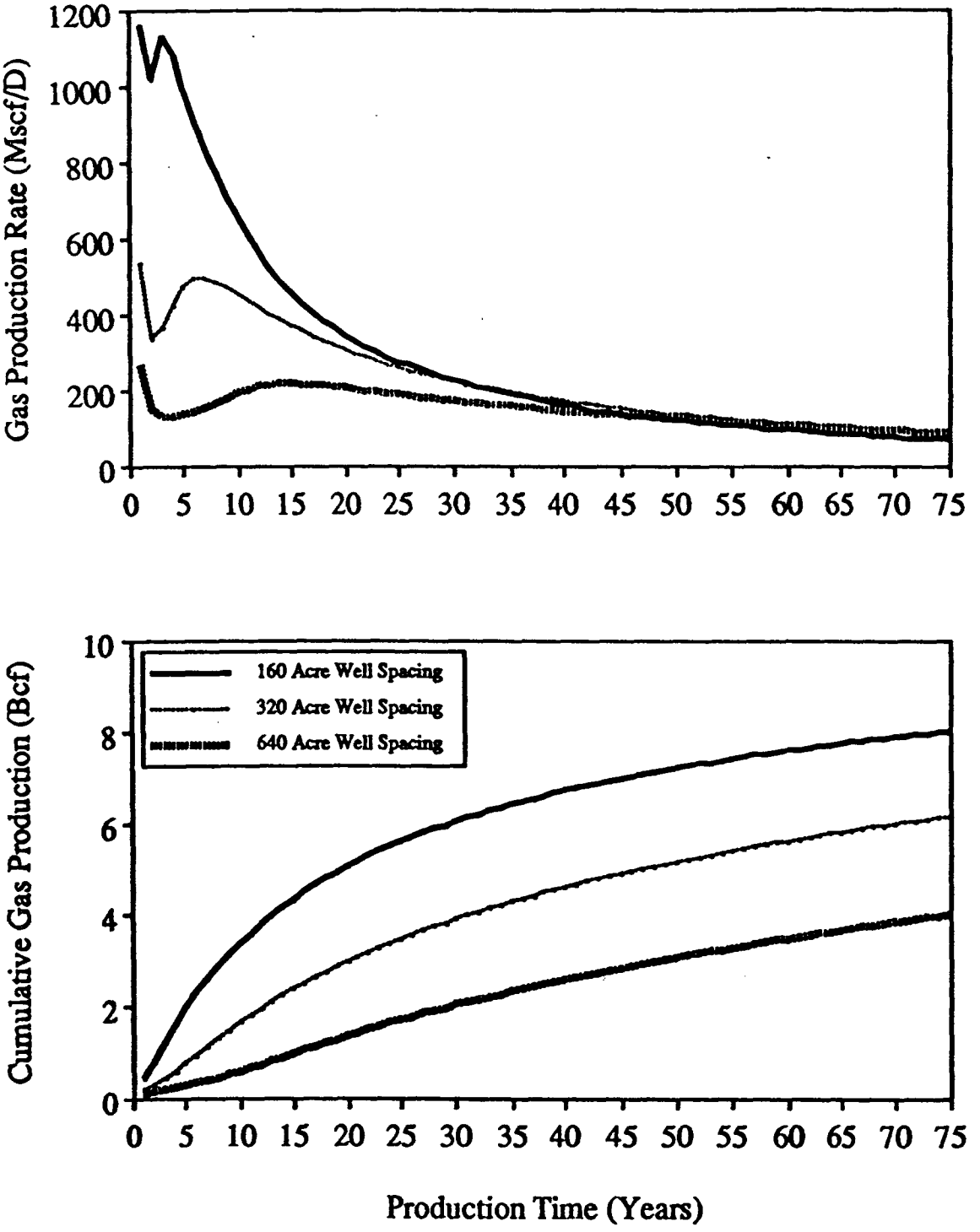

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Figure 14

San Juan Basin Sensitivity Analysis
Area 1 - Full Section Case

Gas Recovery vs. Time

Ø=0.25%, k=1md, and Xf=300 Ft.

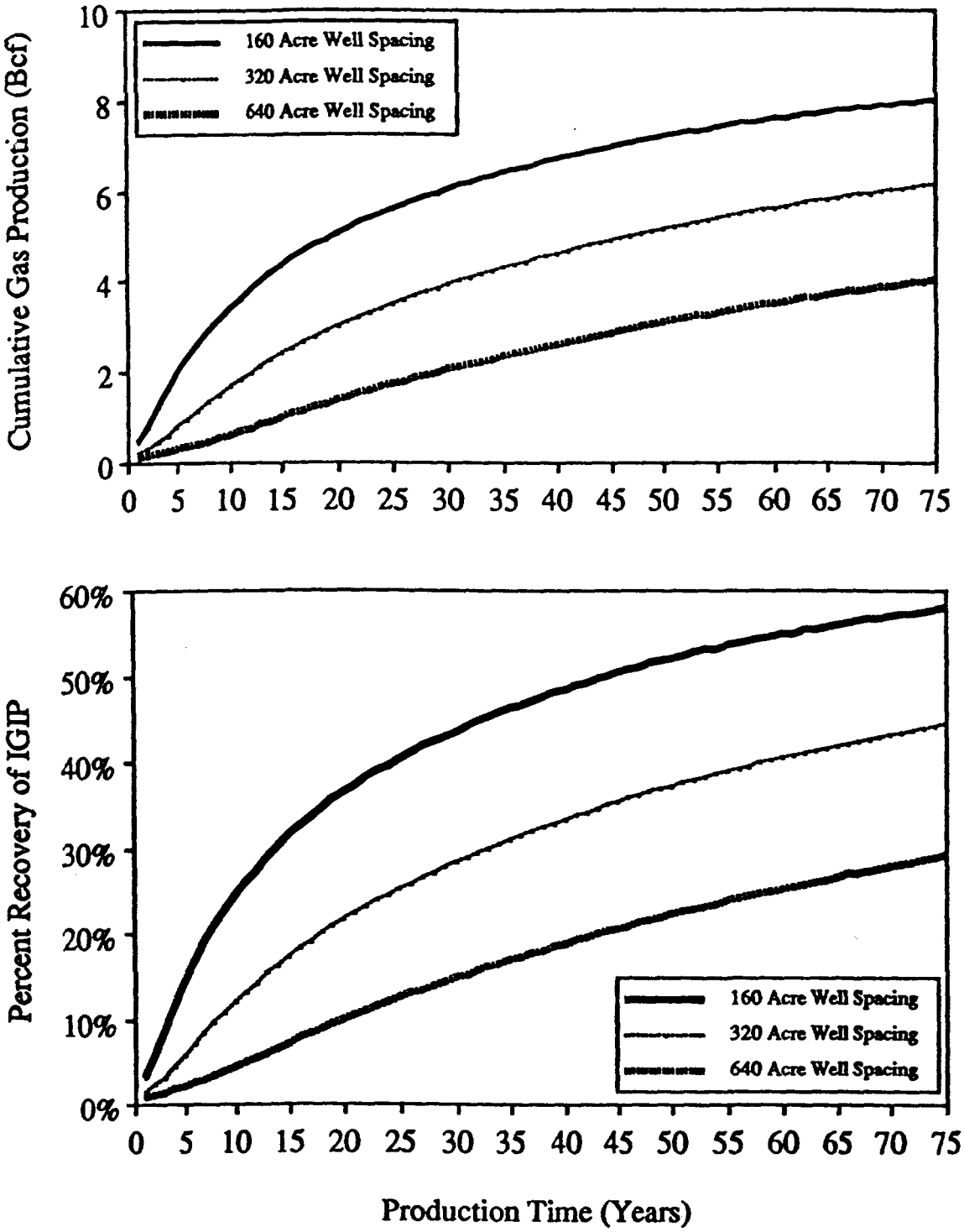

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Figure 15

San Juan Basin Sensitivity Analysis
Area 1 - Full Section Case

Water Production vs. Time

Ø=0.25%, k=1md, and Xf=300 Ft.

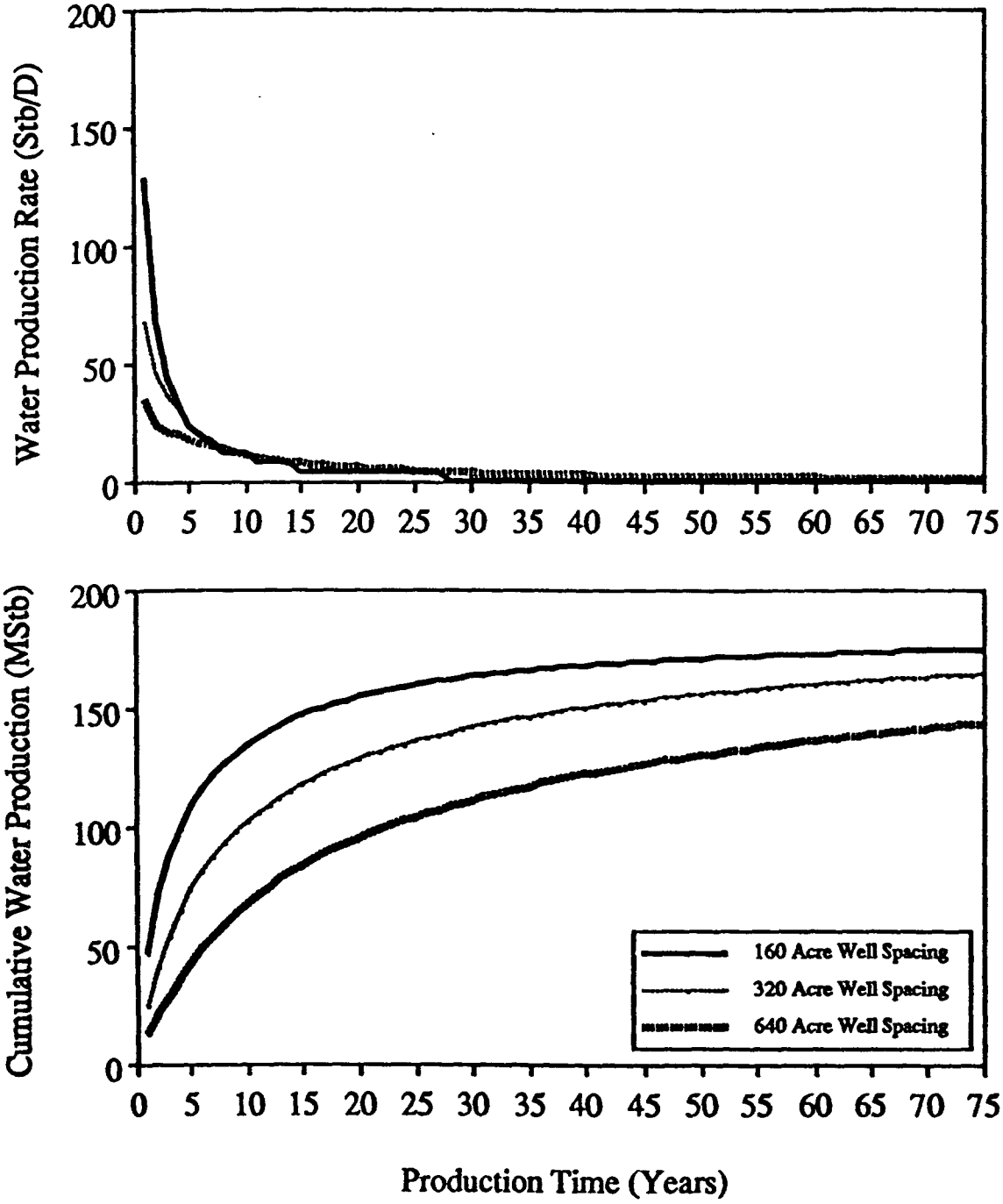

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Figure 16

San Juan Basin Sensitivity Analysis
Area 1 - Full Section Case

Gas Production vs. Time

Ø=0.25%, k=5md, and Xf=300 Ft.

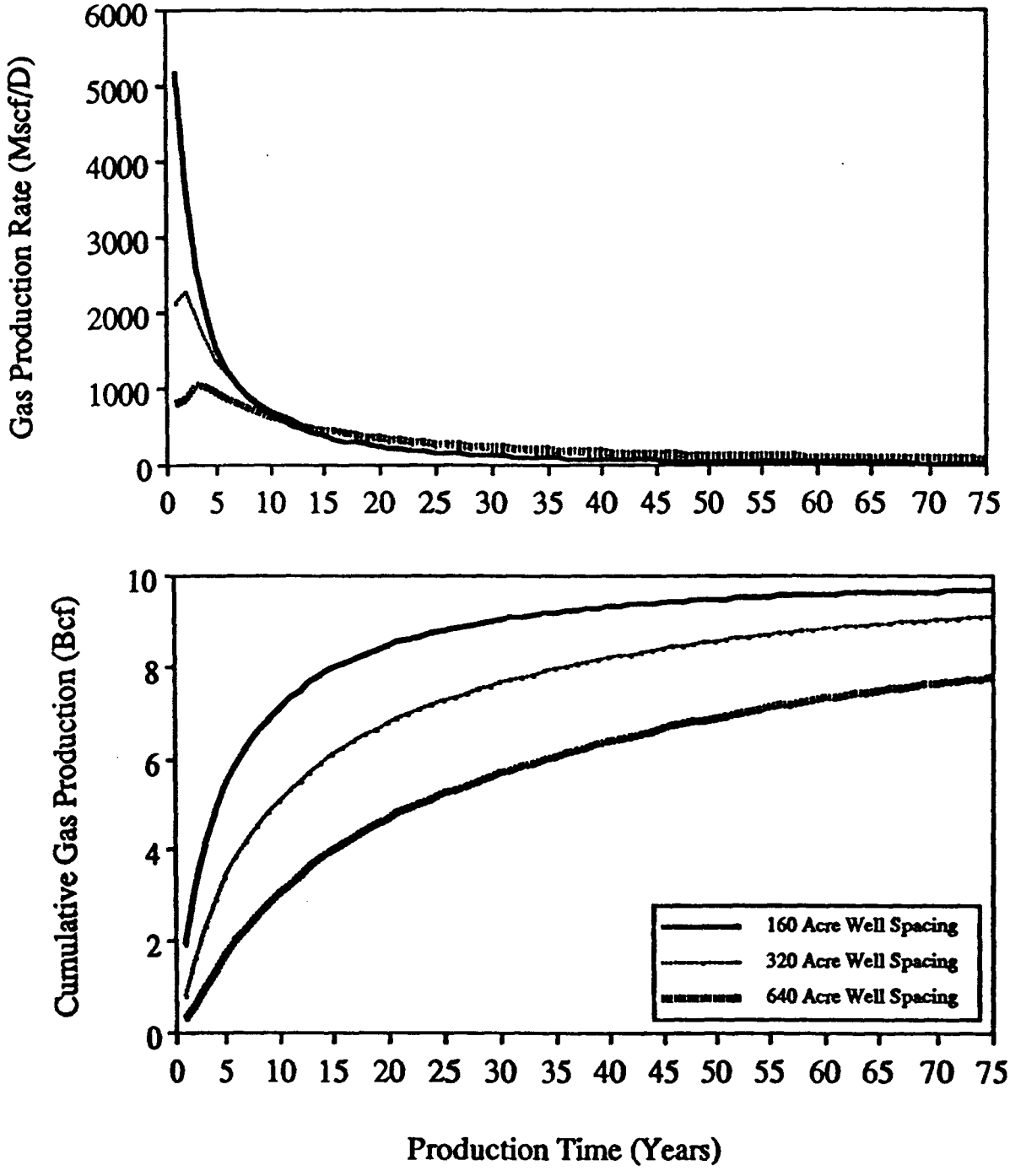

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Figure 17

San Juan Basin Sensitivity Analysis
Area 1 - Full Section Case

Gas Recovery vs. Time

Ø=0.25%, k=5md, and Xf=300 Ft.

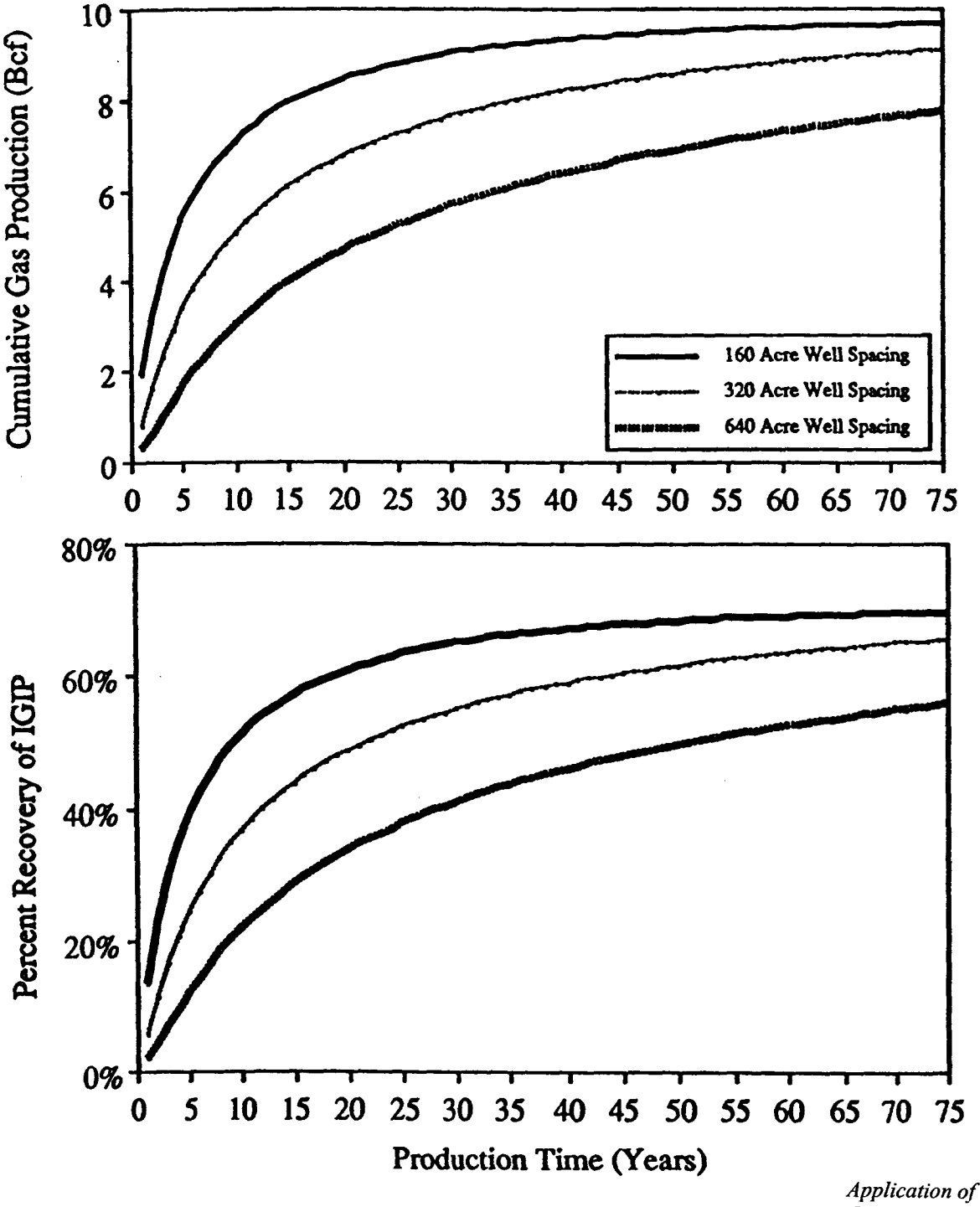

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Figure 18

San Juan Basin Sensitivity Analysis
Area 1 - Full Section Case

Water Production vs. Time

Ø=0.25%, k=5md, and Xf=300 Ft.

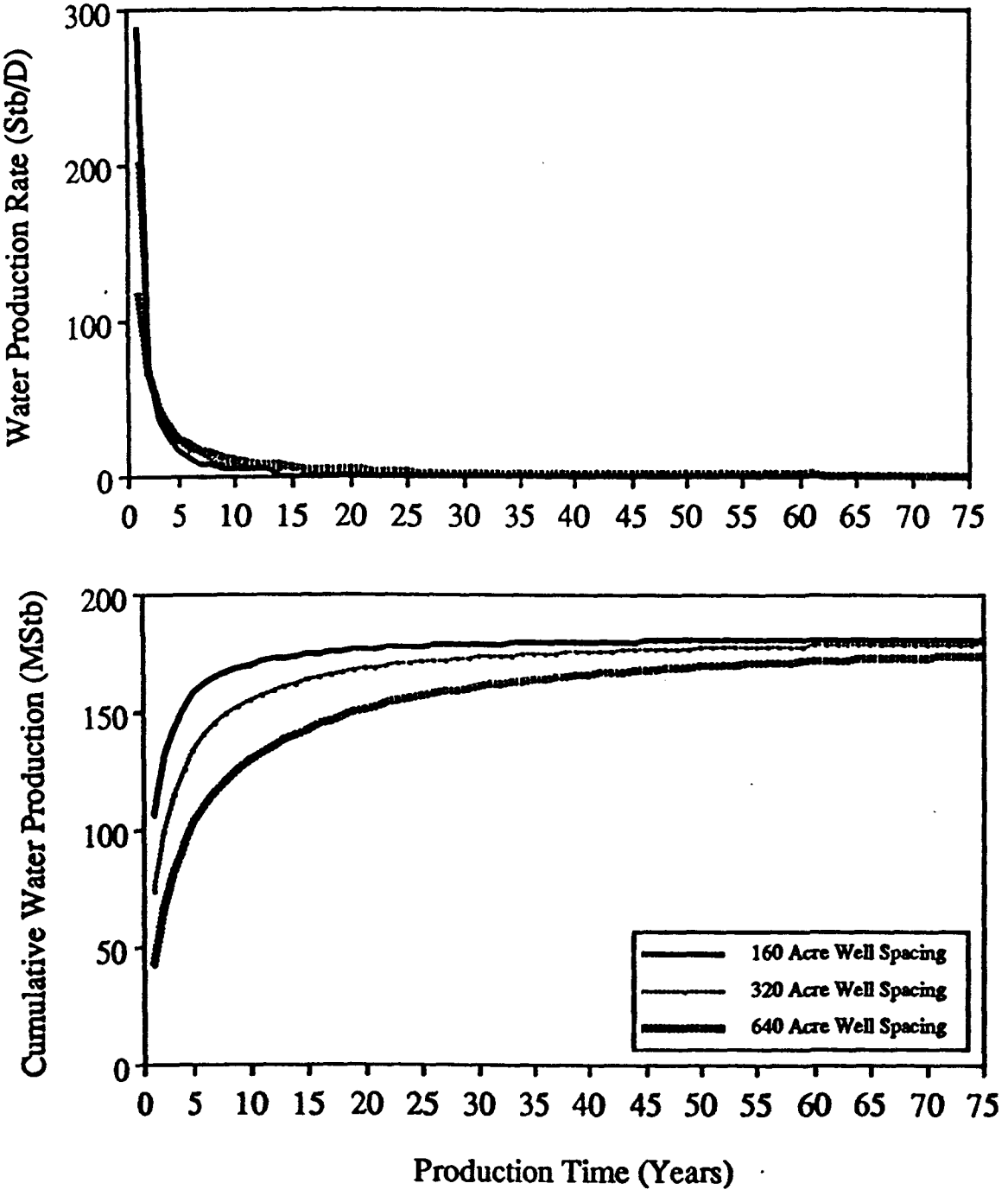

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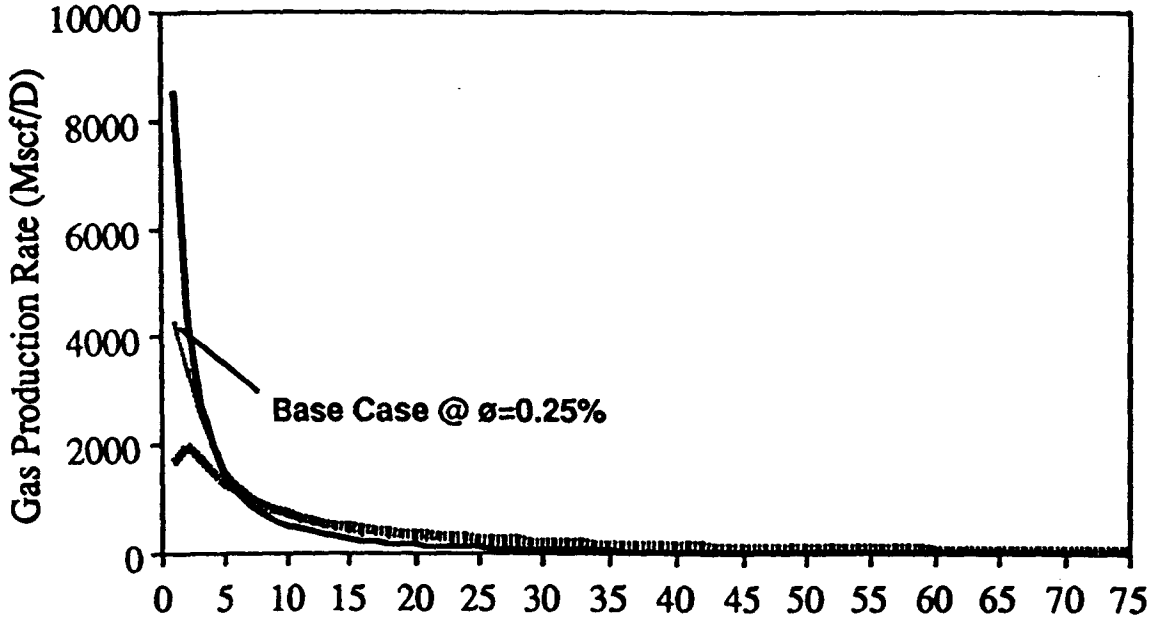
Figure 19

San Juan Basin Sensitivity Analysis
Area 1 - Full Section Case

Gas Production vs. Time

Ø=0.25%, k=10md, and Xf=300 Ft.



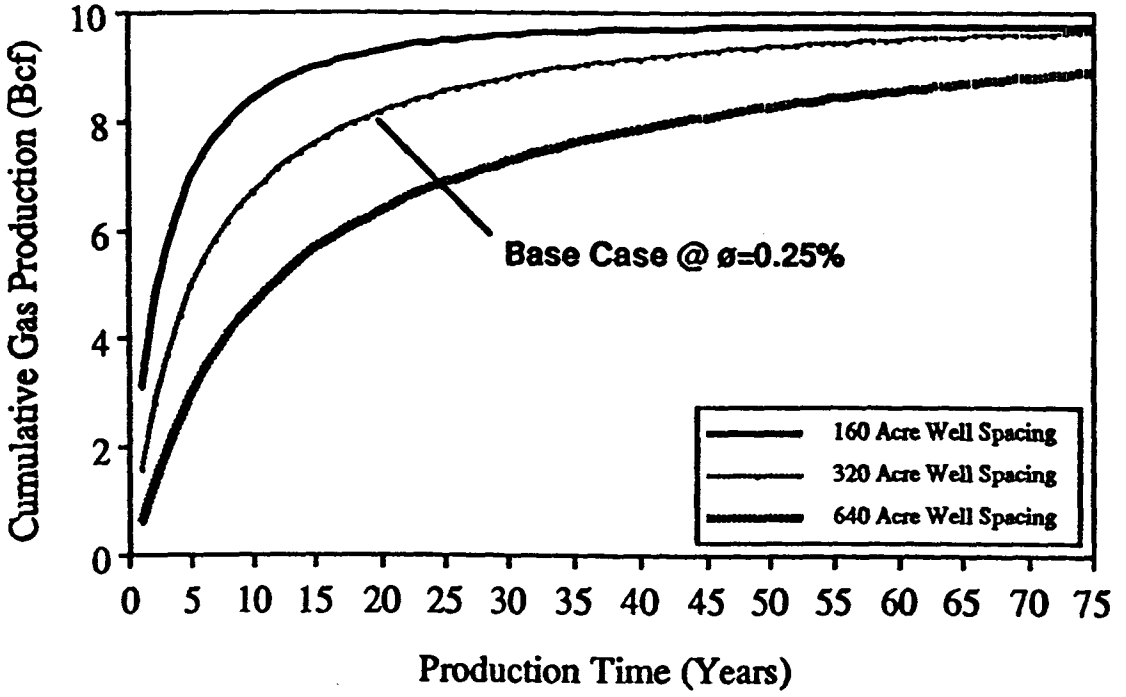


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Figure 20

San Juan Basin Sensitivity Analysis
Area 1 - Full Section Case

Gas Recovery vs. Time

Ø=0.25%, k=10md, and Xf=300 Ft.

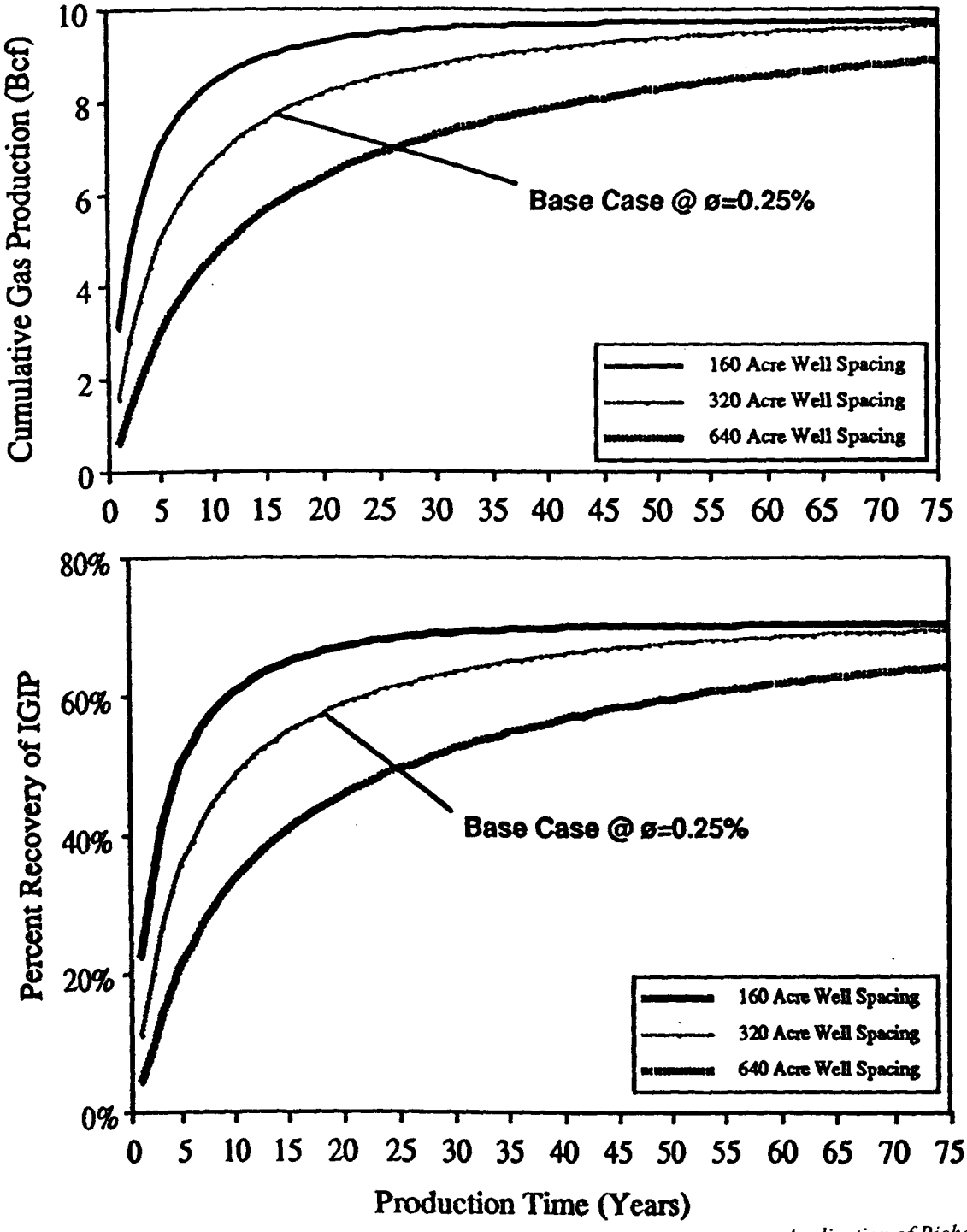

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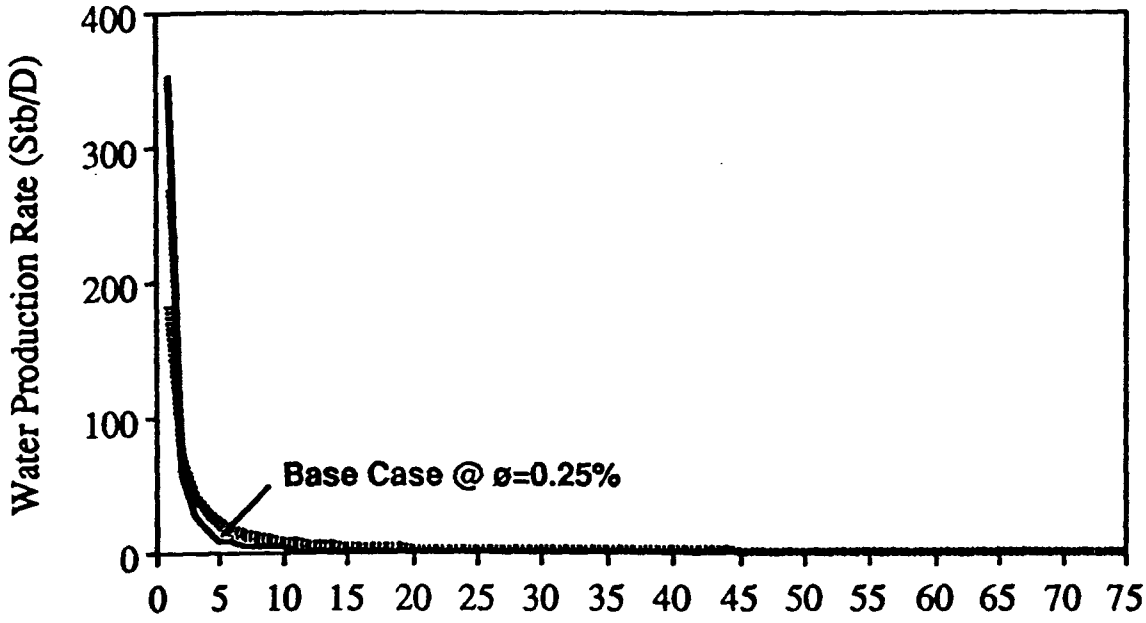
Figure 21

San Juan Basin Sensitivity Analysis
Area 1 - Full Section Case

Water Production vs. Time

Ø=0.25%, k=10md, and Xf=300 Ft.



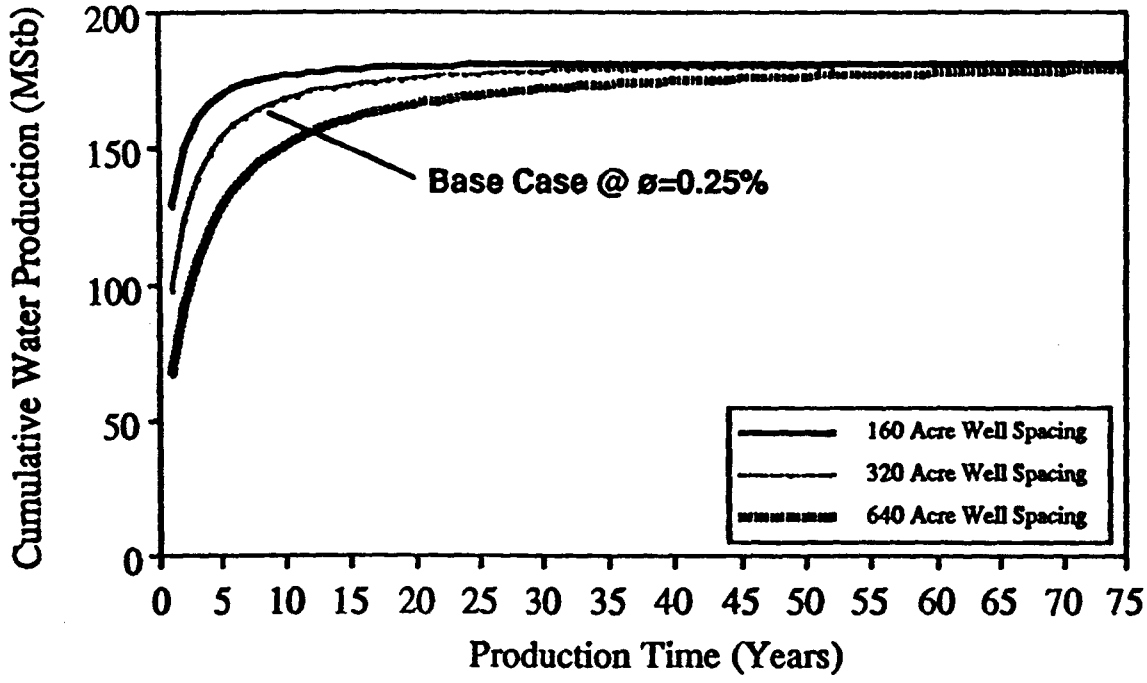


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Figure 22

San Juan Basin Sensitvity Analysis
Area 1 - Full Section Case

Gas Production vs. Time

Ø=0.25%, k=50md, and Xf=300 Ft.

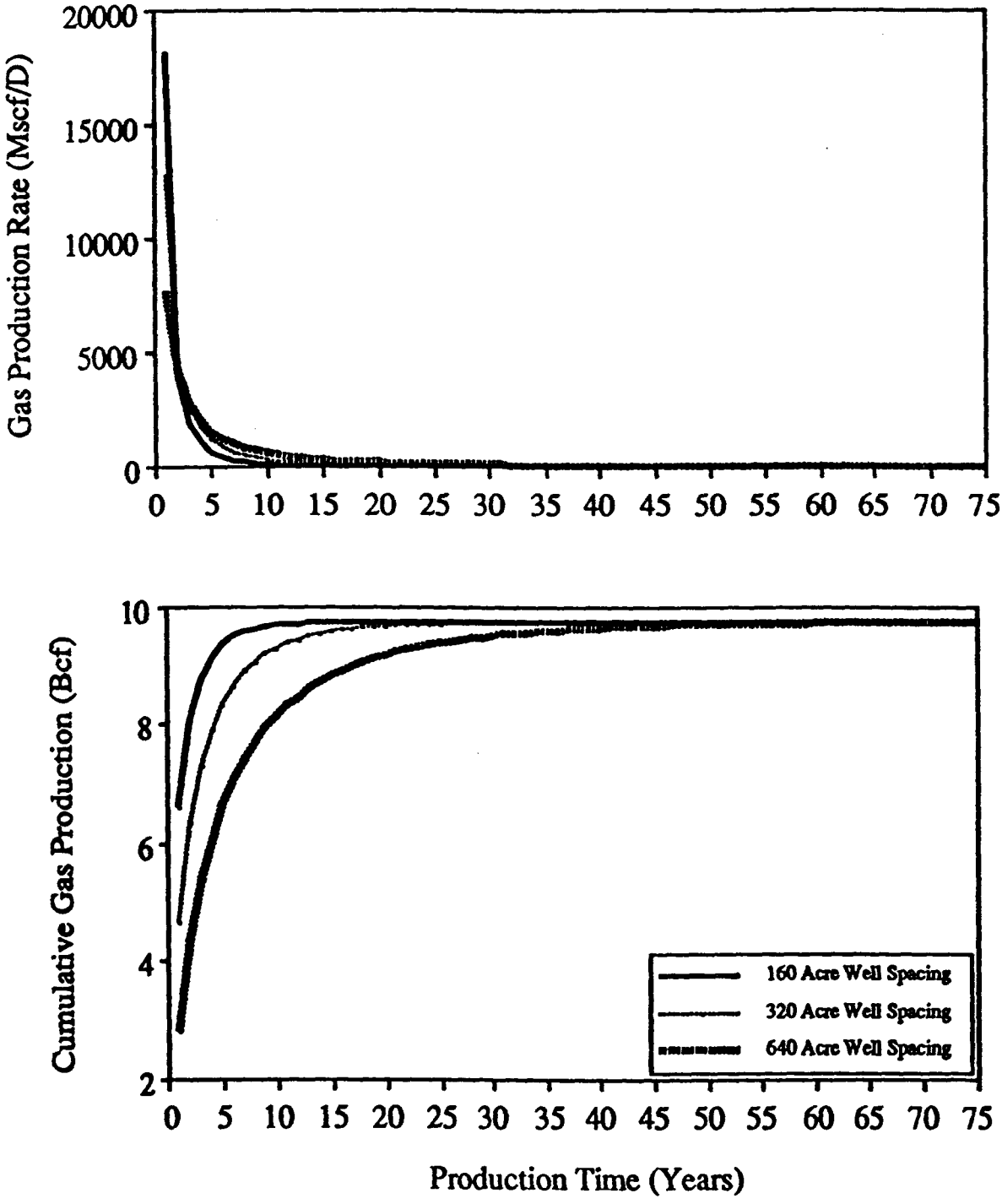

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Figure 23

San Juan Basin Sensitivity Analysis
Area 1 - Full Section Case

Gas Recovery vs. Time

Ø=0.25%, k=50md, and Xf=300 Ft.

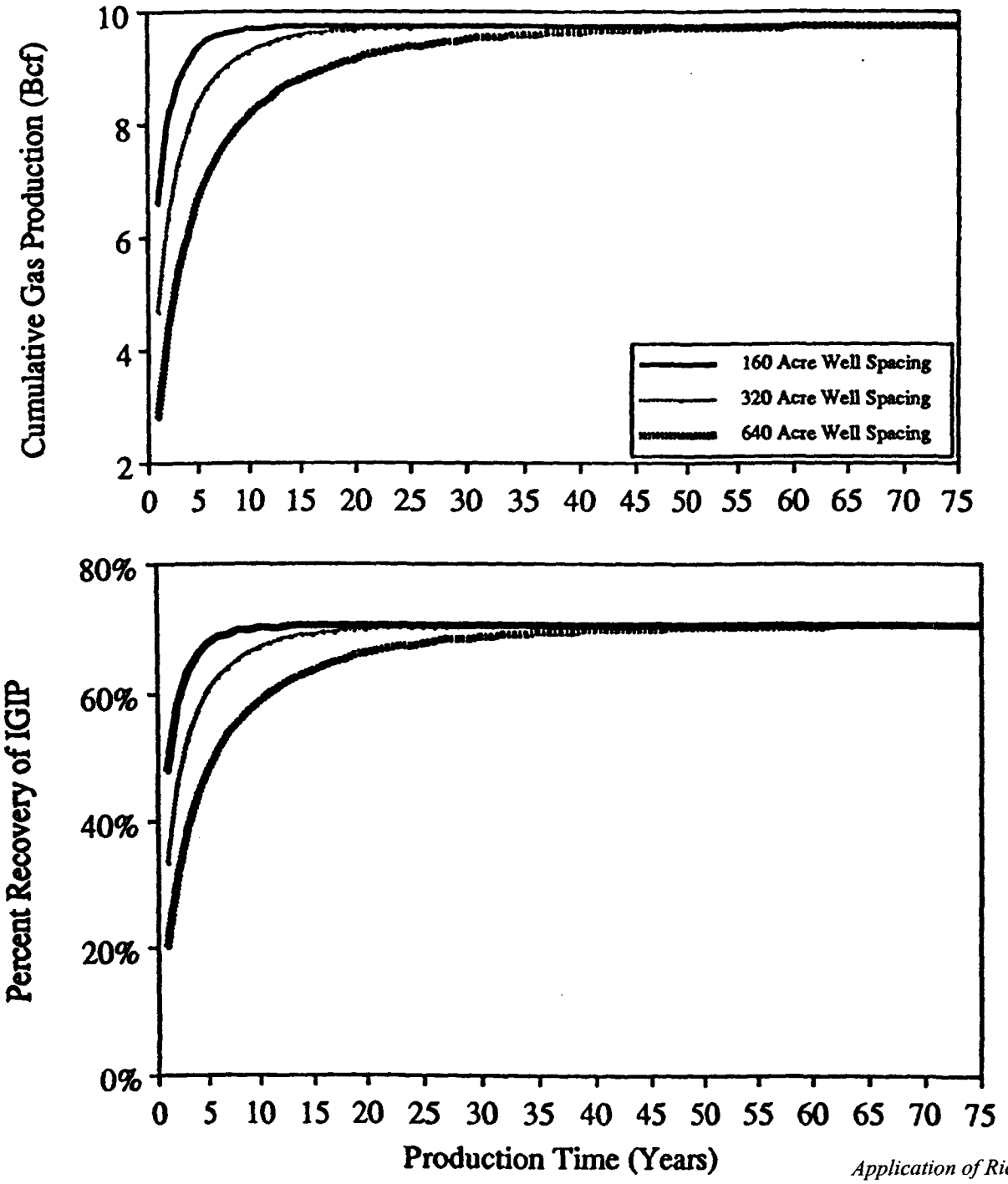

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Figure 24

San Juan Basin Sensitivity Analysis
Area 1 - Full Section Case

Water Production vs. Time

Ø=0.25%, k=50md, and Xf=300 Ft.

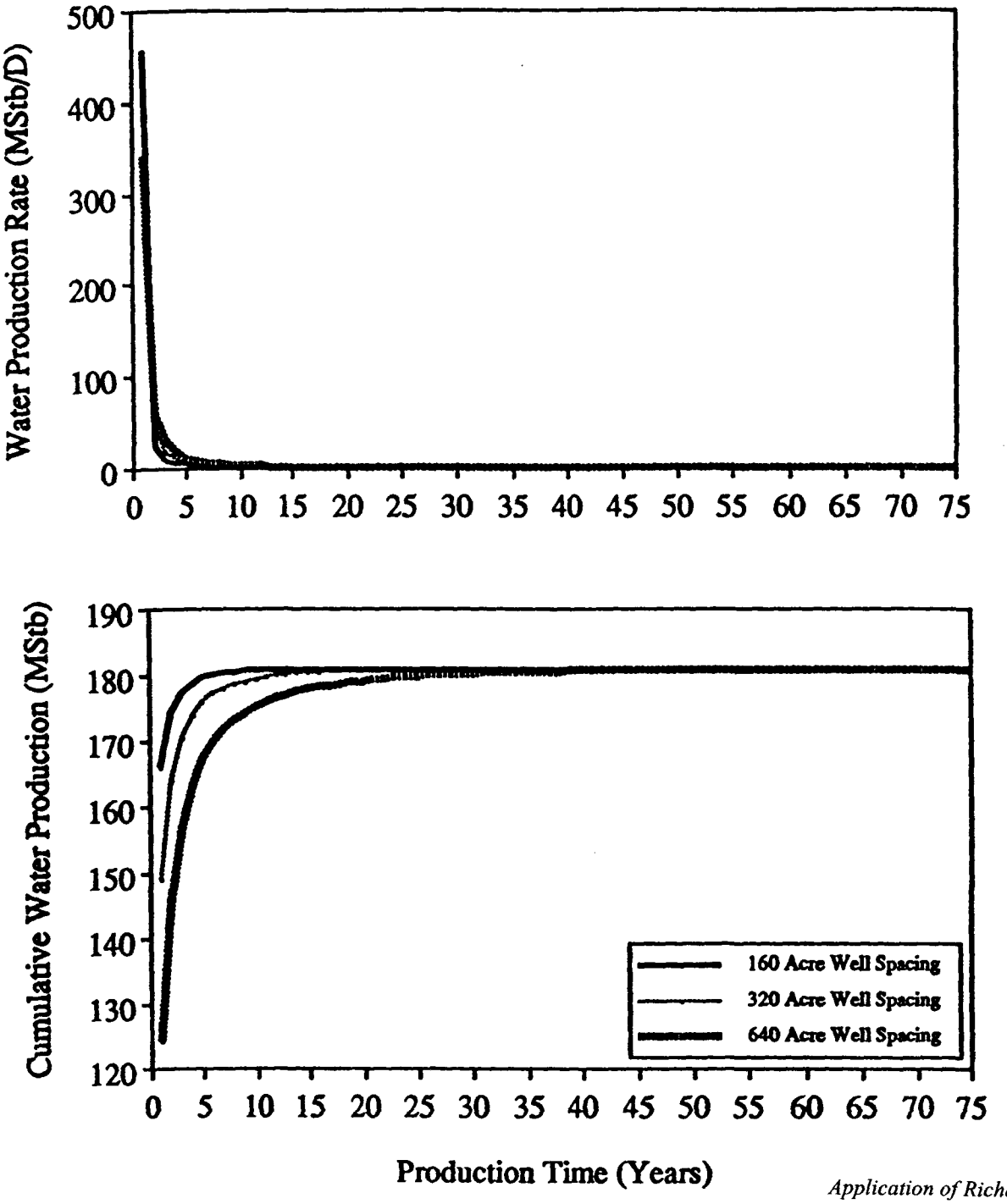

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Figure 25

San Juan Basin Area 1 Sensitivity Analysis
Abandonment Rate Plot for Ø= 0.25%, k= 1md and Xf=300 Ft

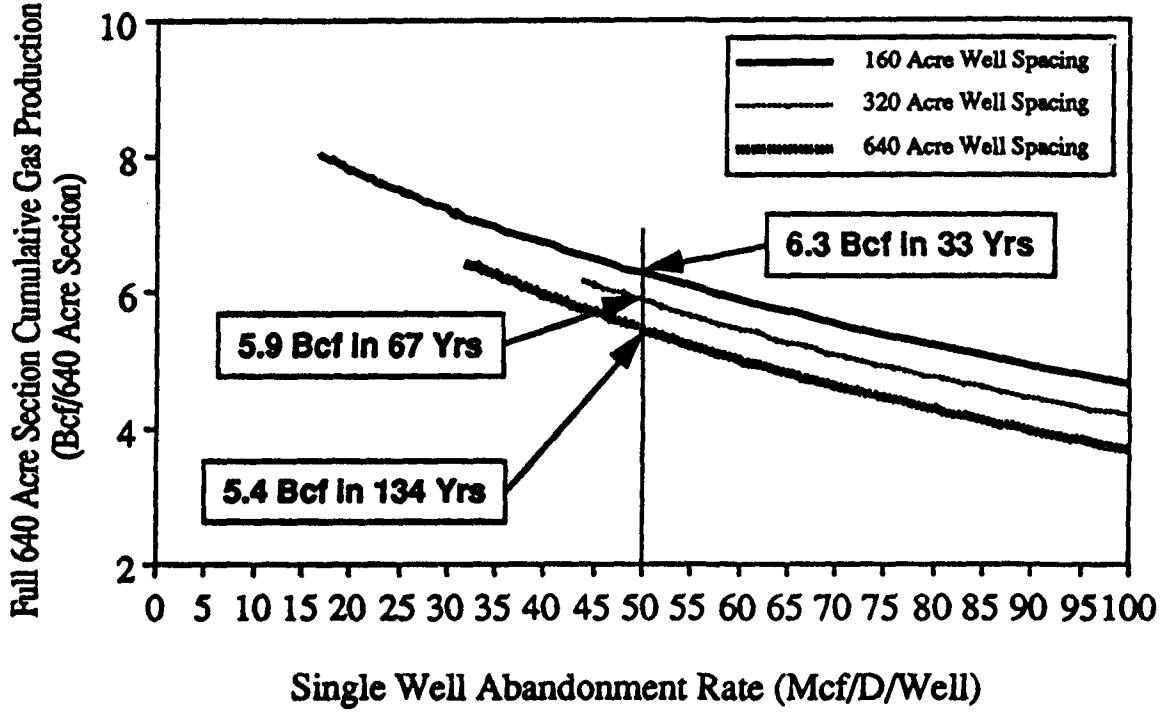

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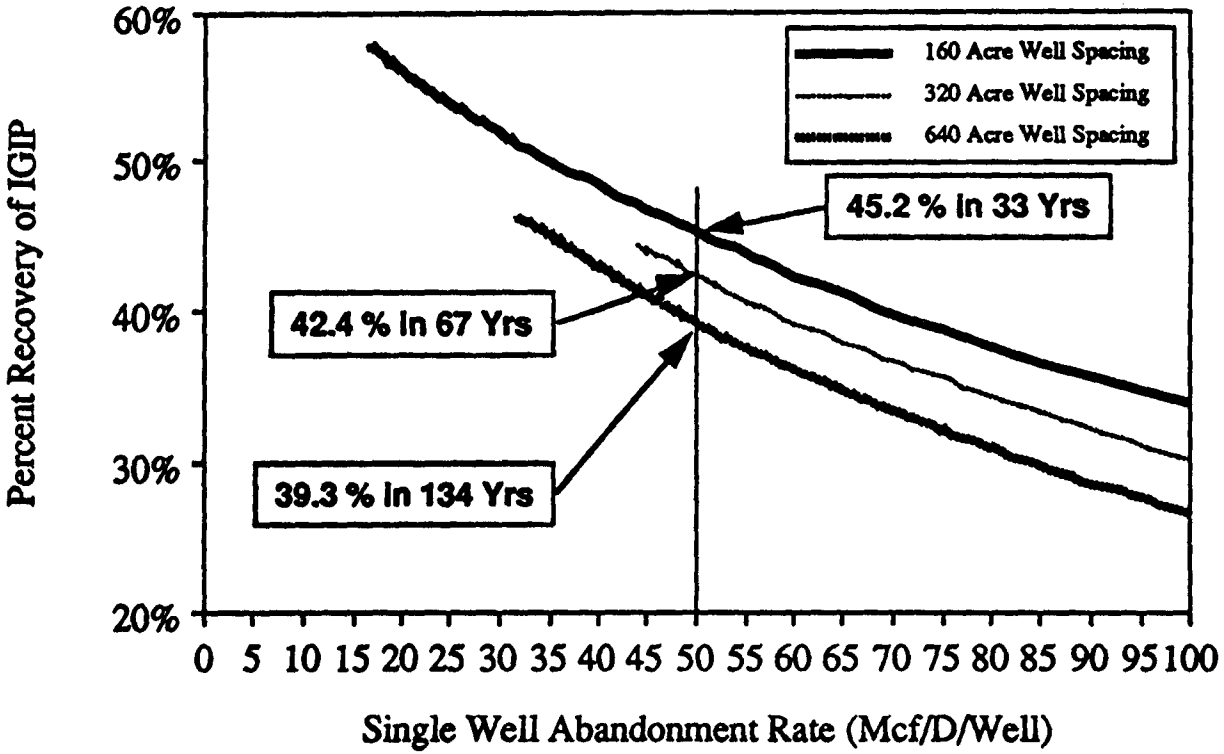
Figure 26

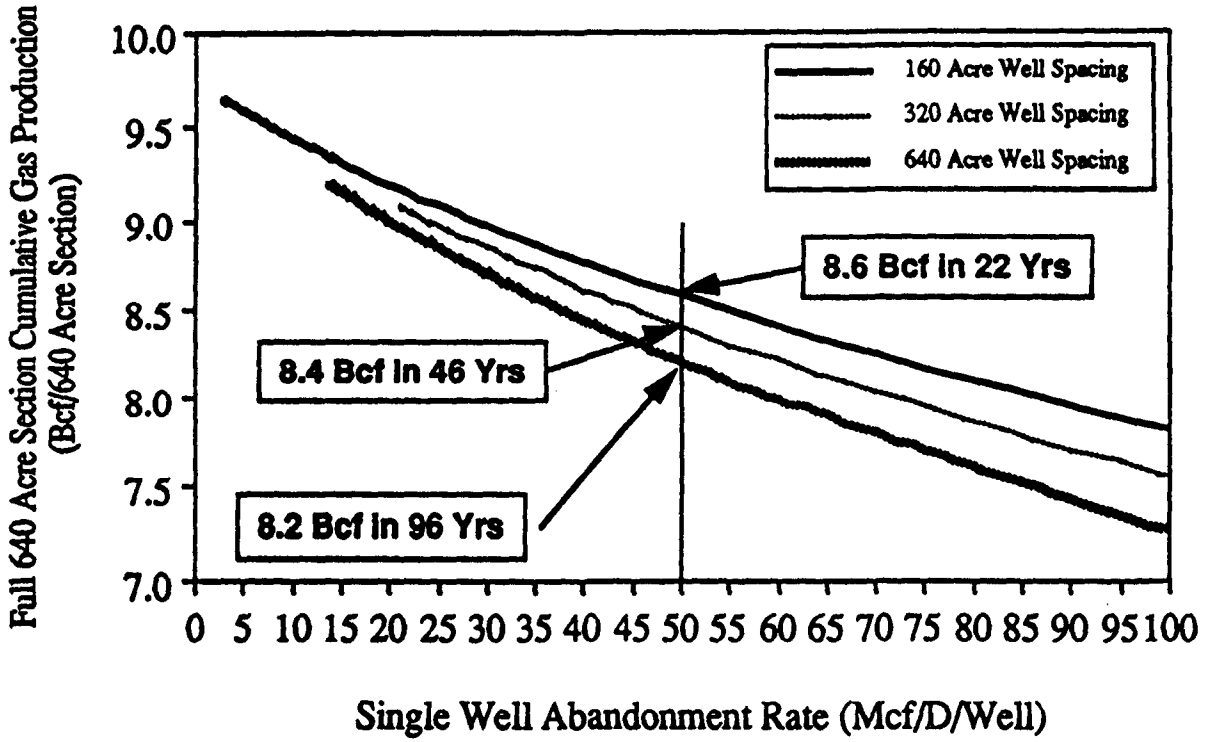
San Juan Basin Area 1 Sensitivity Analysis
Abandonment Rate Plot for Ø= 0.25%, k= 1md and Xf=300 Ft



Application of Richardson Operating Co.
Record on Appeal, 1699.

Figure 27

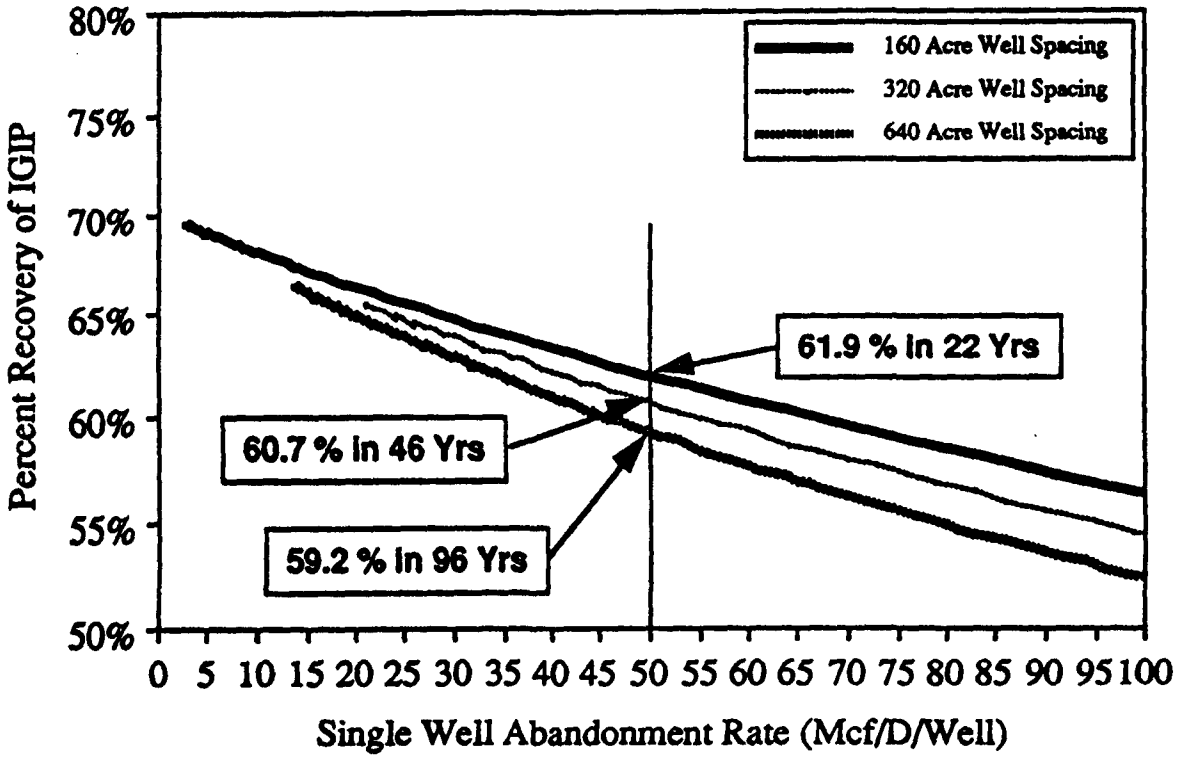
San Juan Basin Area 1 Sensitivity Analysis
Abandonment Rate Plot for Ø= 0.25%, k= 5 md and Xf=300 Ft



Application of Richardson Operating Co.
Record on Appeal, 1700.

Figure 28

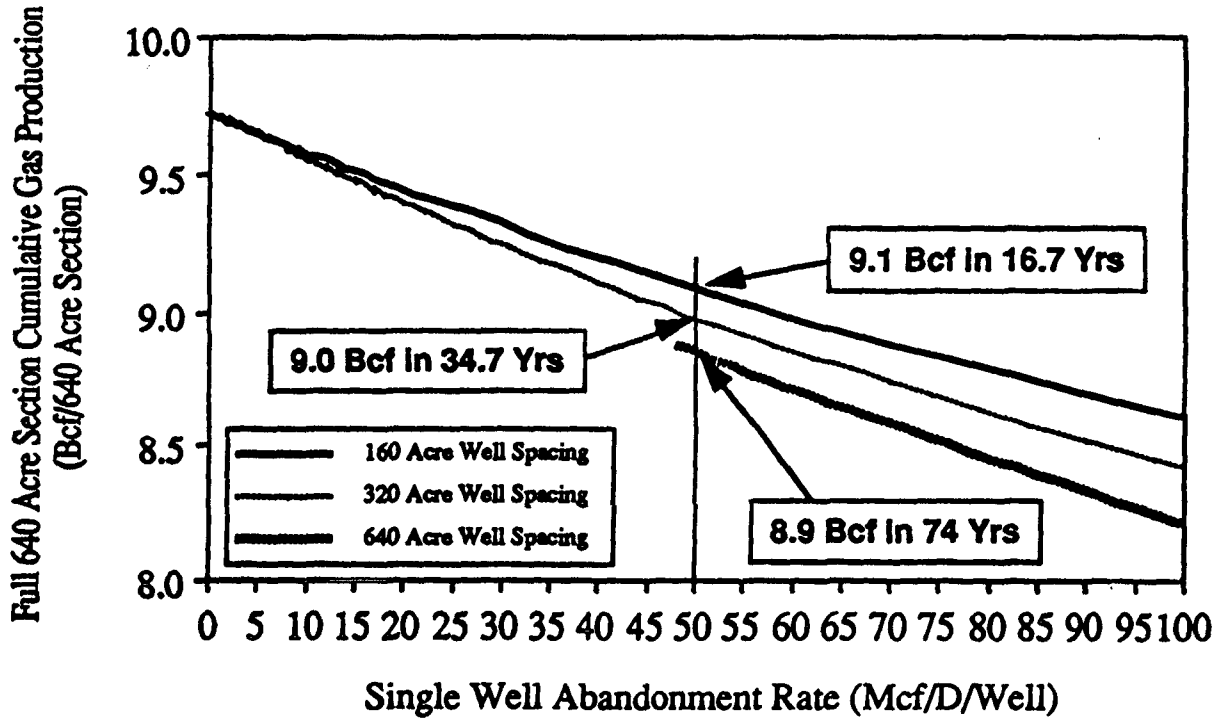
San Juan Basin Area 1 Sensitivity Analysis
Abandonment Rate Plot for Ø= 0.25%, k= 5 md and Xf=300 Ft



Application of Richardson Operating Co.
Record on Appeal, 1701.

Figure 29

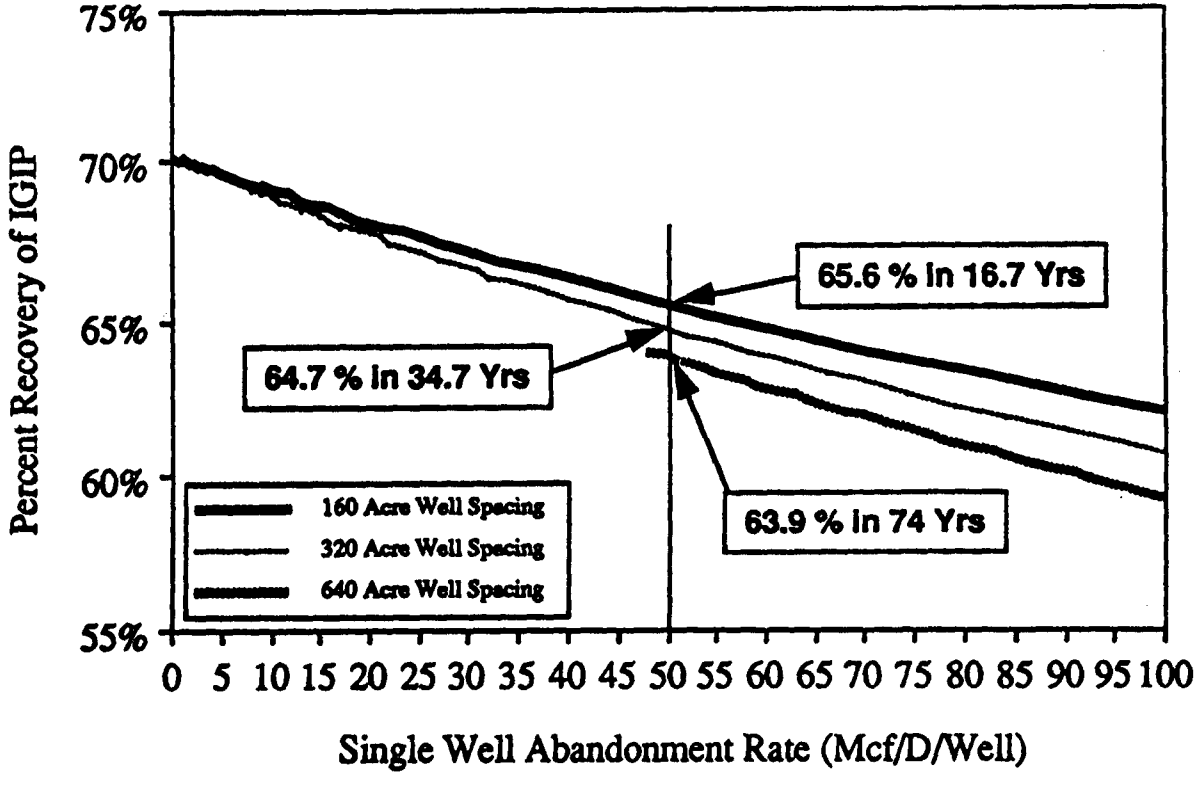
San Juan Basin Area 1 Sensitivity Analysis
Abandonment Rate Plot for Ø= 0.25%, k= 10 md and Xf=300 Ft



Application of Richardson Operating Co.
Record on Appeal, 1702.

Figure 30

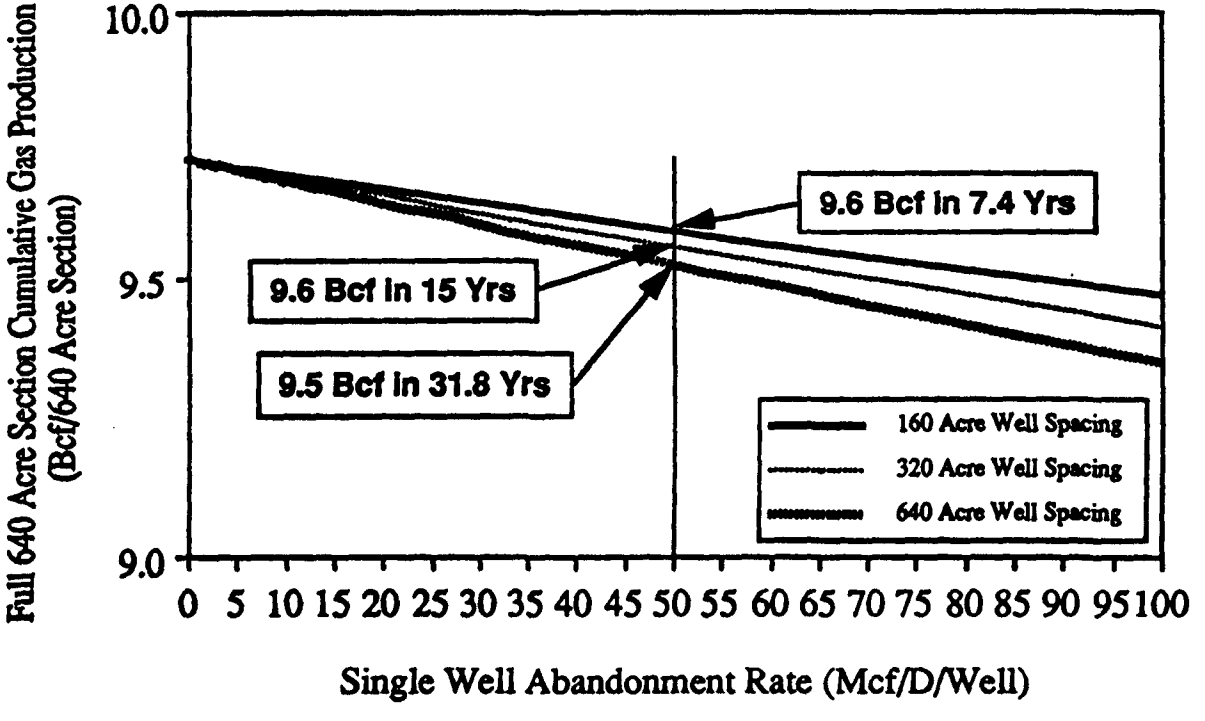
San Juan Basin Area 1 Sensitivity Analysis
Abandonment Rate Plot for Ø= 0.25%, k= 10 md and Xf=300 Ft



Application of Richardson Operating Co.
Record on Appeal, 1703.

Figure 31

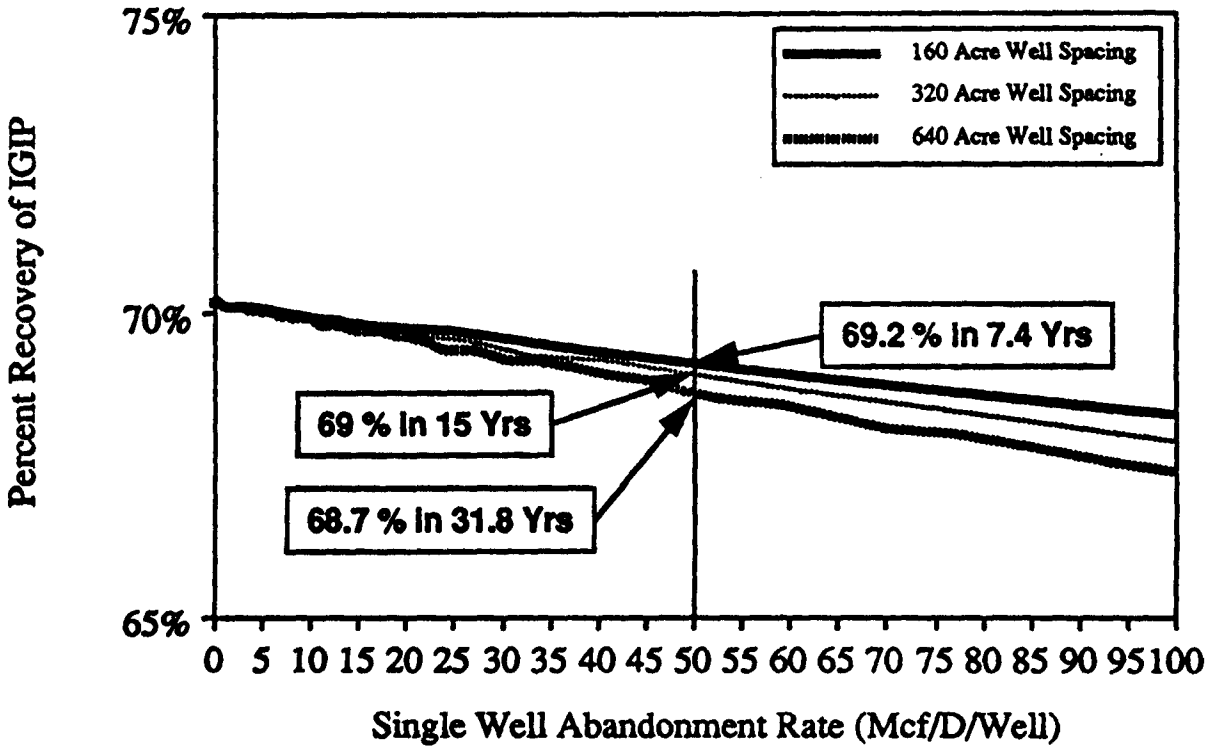
San Juan Basin Area 1 Sensitivity Analysis
Abandonment Rate Plot for Ø= 0.25%, k= 50 md and Xf=300 Ft



Application of Richardson Operating Co.
Record on Appeal, 1704.

Figure 32

San Juan Basin Area 1 Sensitivity Analysis
Abandonment Rate Plot for Ø= 0.25%, k= 50 md and Xf=300 Ft



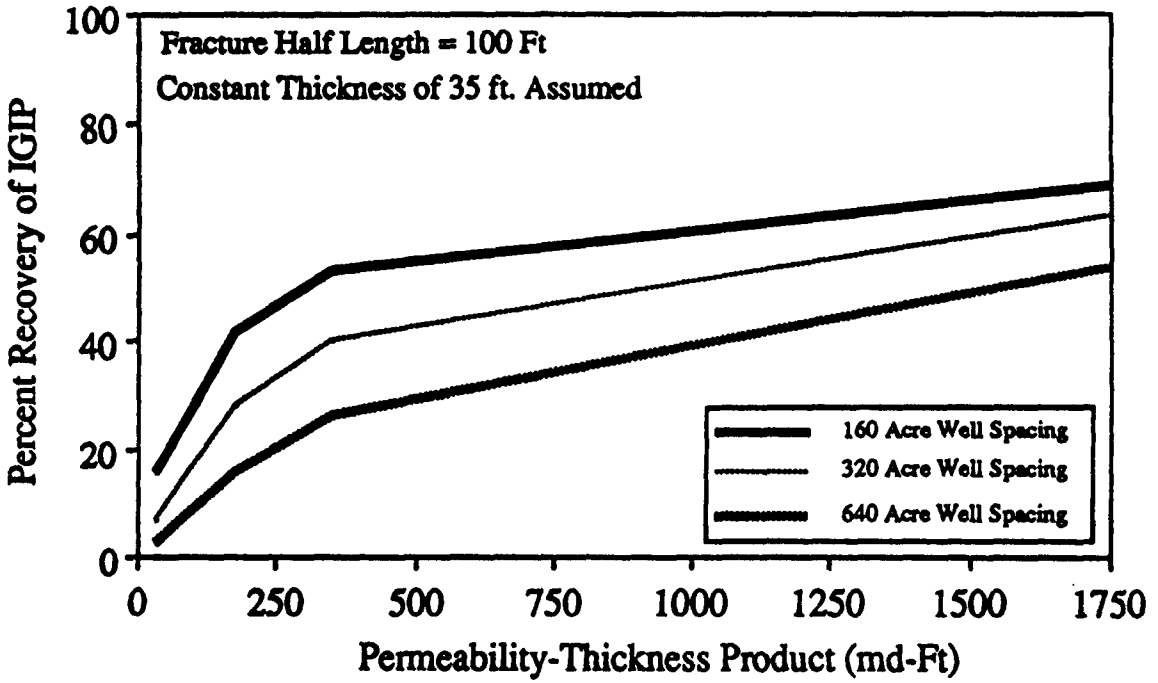
Application of Richardson Operating Co.
Record on Appeal, 1705.

Figure 33

San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs. kh for ø=0.25%

10 Year Simulation



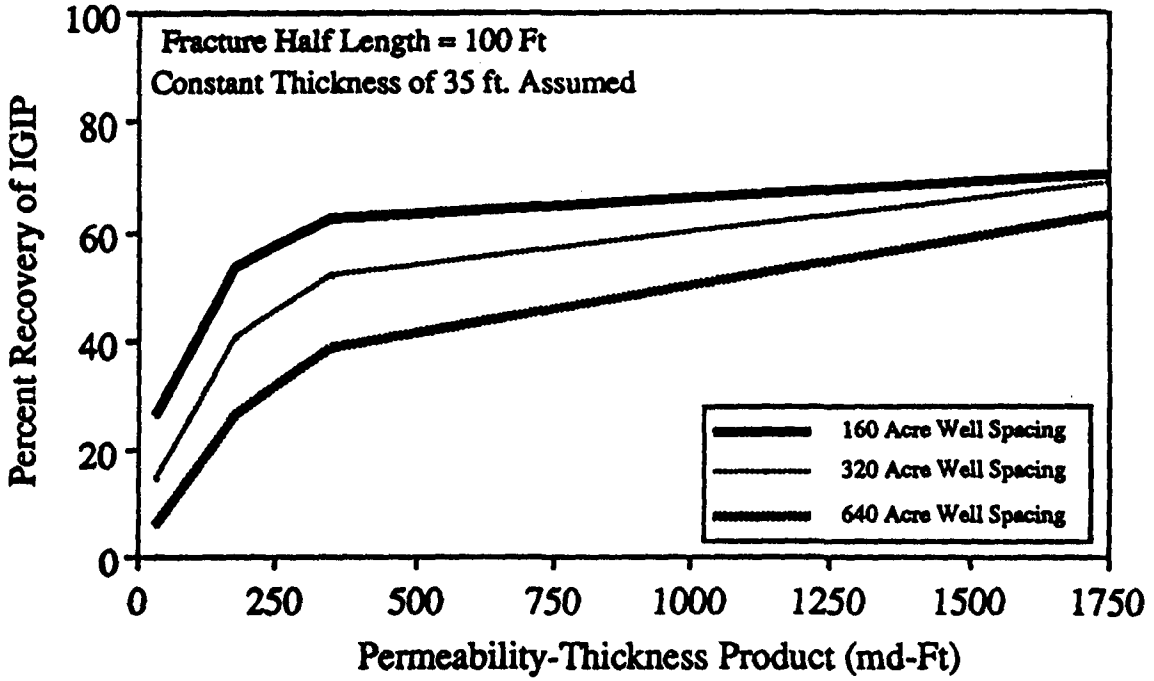
Application of Richardson Operating Co.
Record on Appeal, 1706.

Figure 34

San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs. kh for ø=0.25%

20 Year Simulation



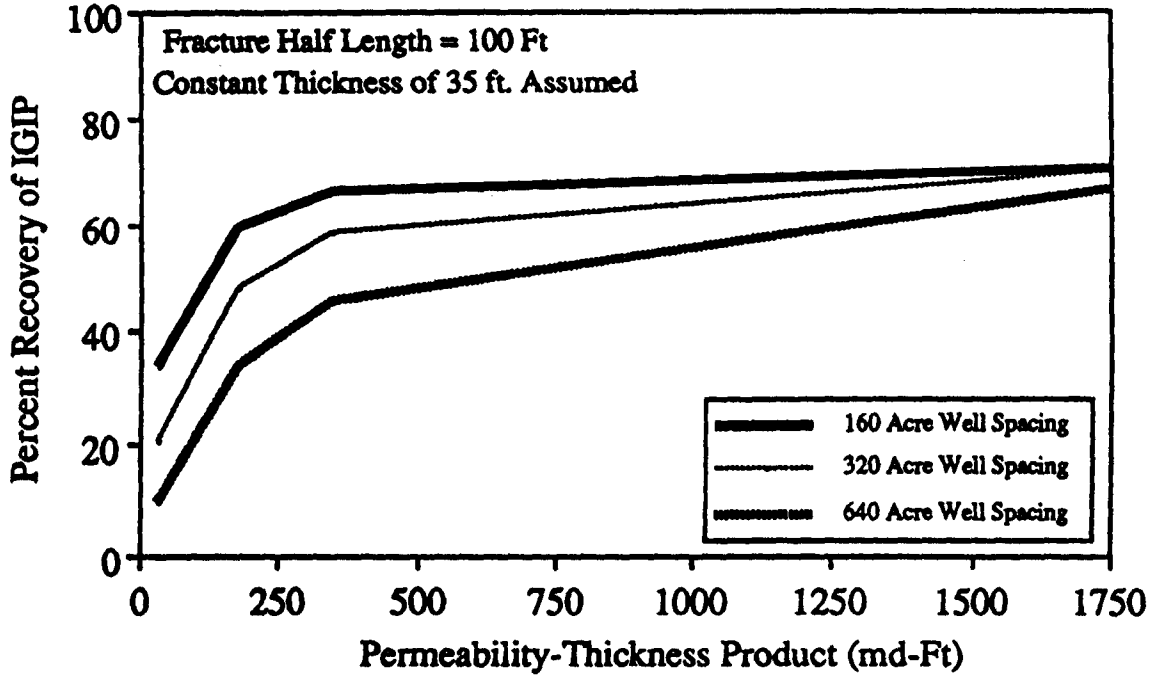
Application of Richardson Operating Co.
Record on Appeal, 1707.

Figure 35

San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs. kh for ø=0.25%

30 Year Simulation



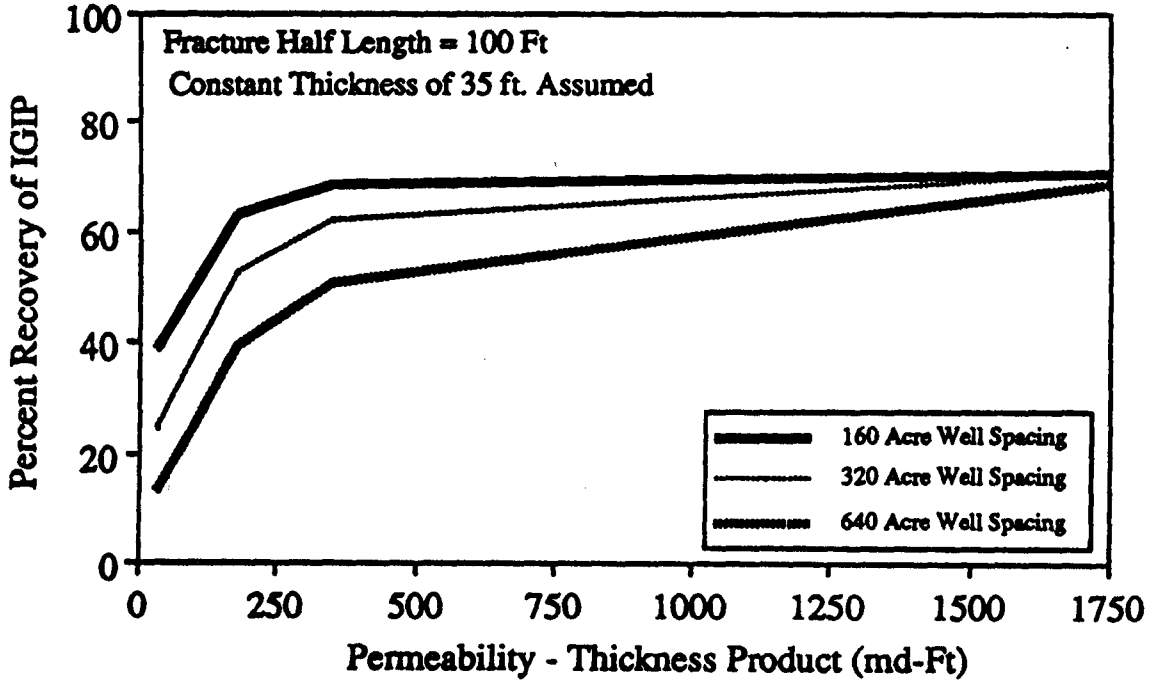
Application of Richardson Operating Co.
Record on Appeal, 1708.

Figure 36

San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs. kh for ø=0.25%

40 Year Simulation



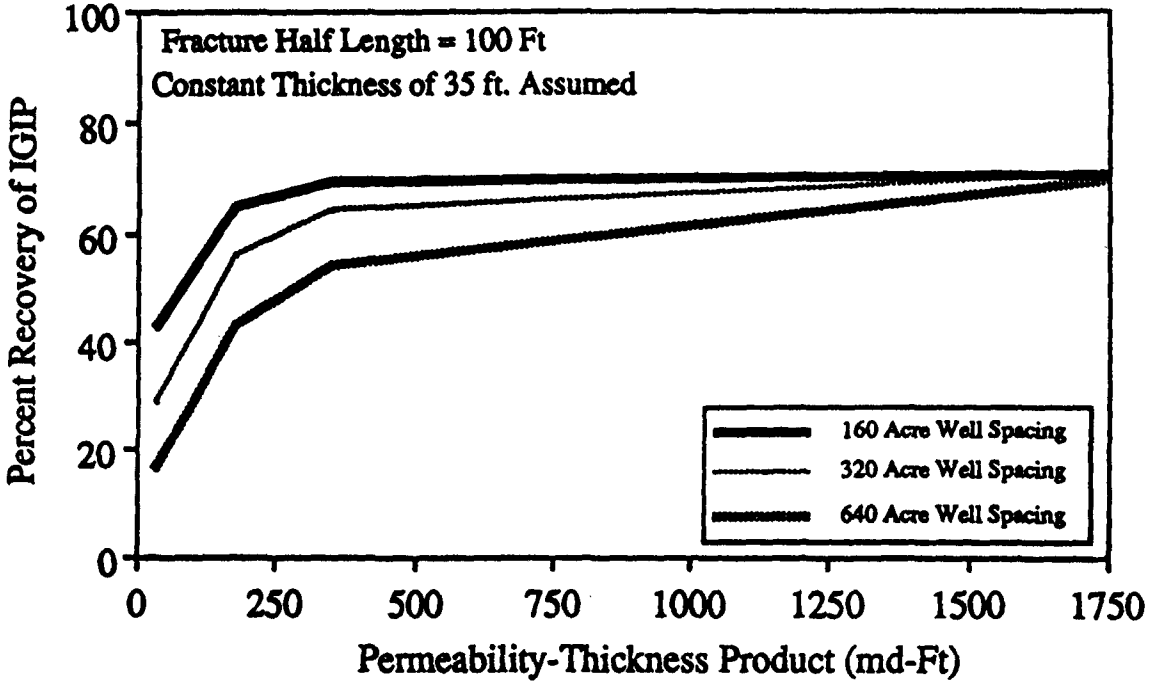
Application of Richardson Operating Co. Record on Appeal, 1709.

Figure 37

San Juan Basin Area 1 Sensitivity Analysis

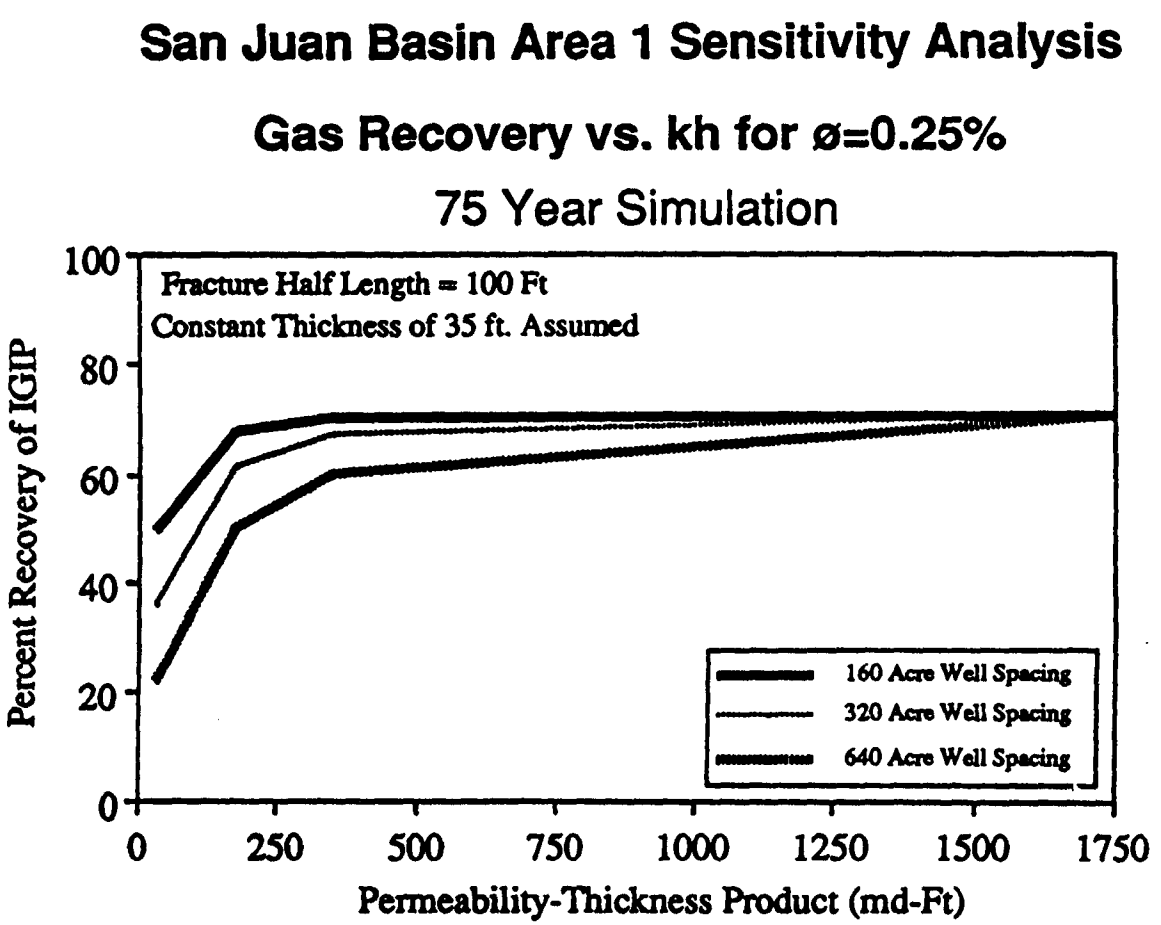
Gas Recovery vs. kh for ø=0.25%

50 Year Simulation



Application of Richardson Operating Co.
Record on Appeal, 1710.

Figure 38



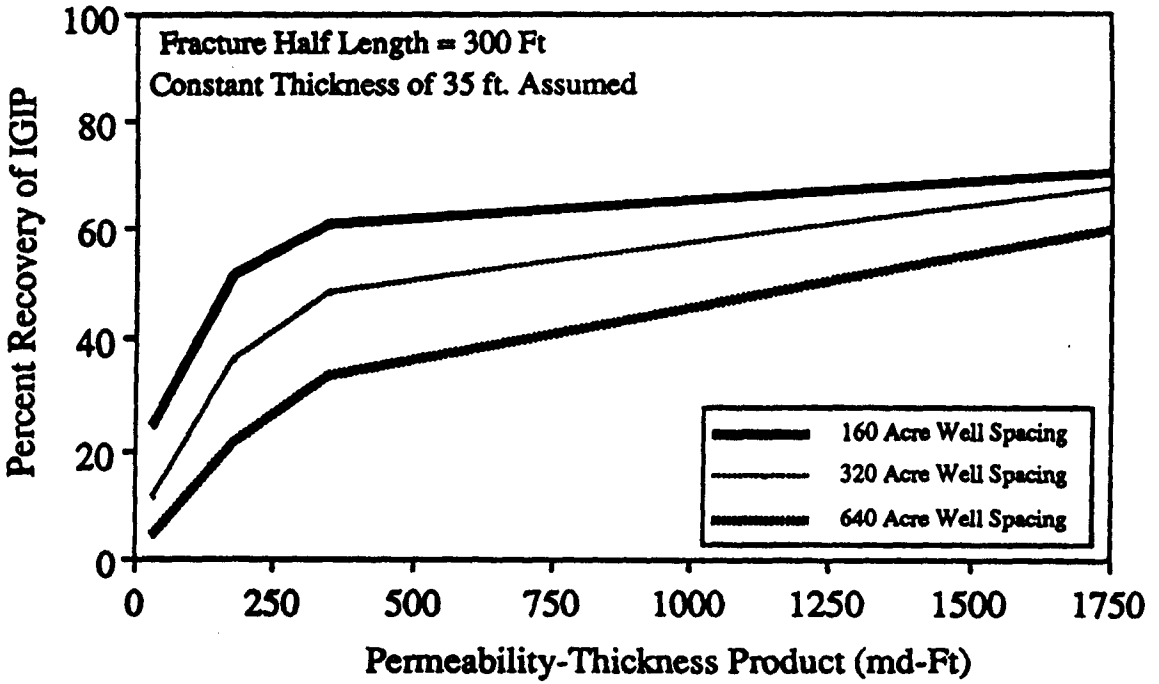
Application of Richardson Operating Co.
Record on Appeal, 1711.

Figure 39

San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs. kh for ø=0.25%

10 Year Simulation



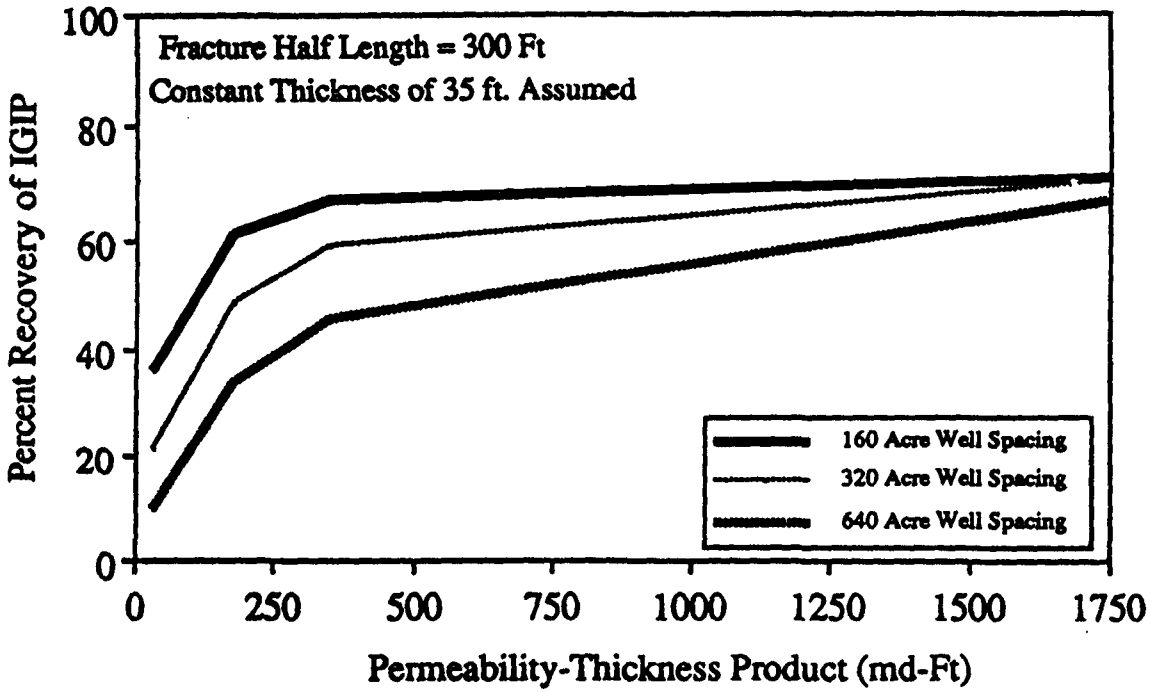
Application of Richardson Operating Co.
Record on Appeal, 1712.

Figure 40

San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs. kh for ø=0.25%

20 Year Simulation



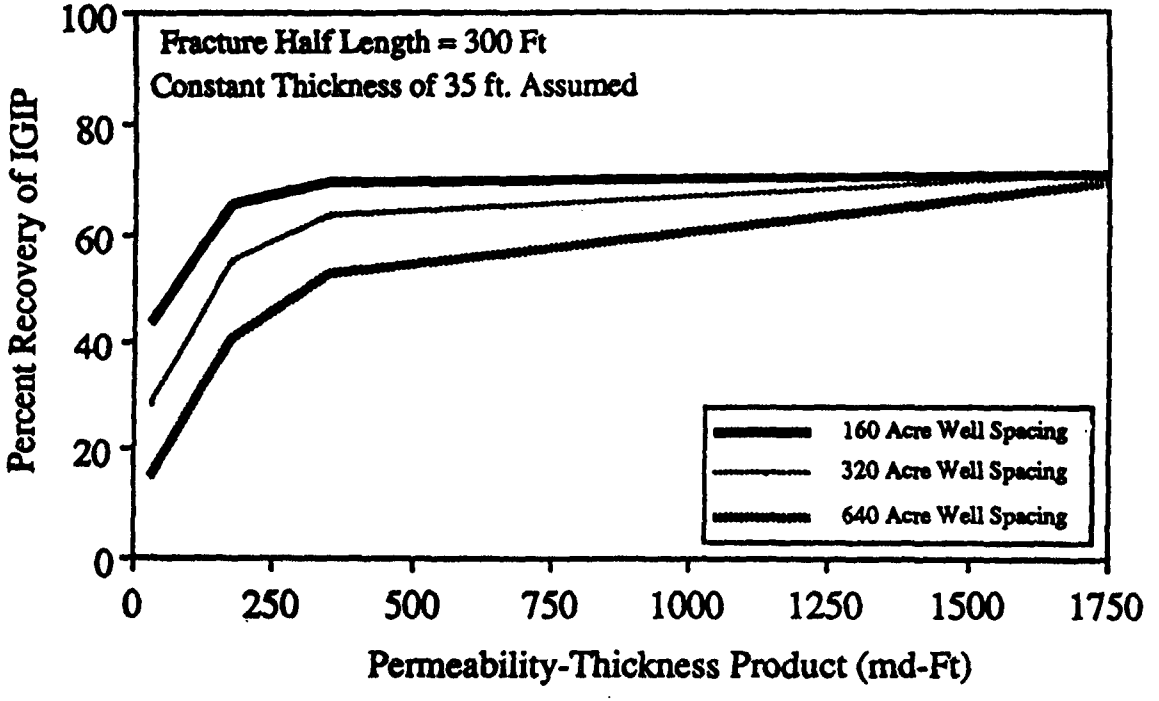
Application of Richardson Operating Co.
Record on Appeal, 1713.

Figure 41

San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs. kh for ø=0.25%

30 Year Simulation



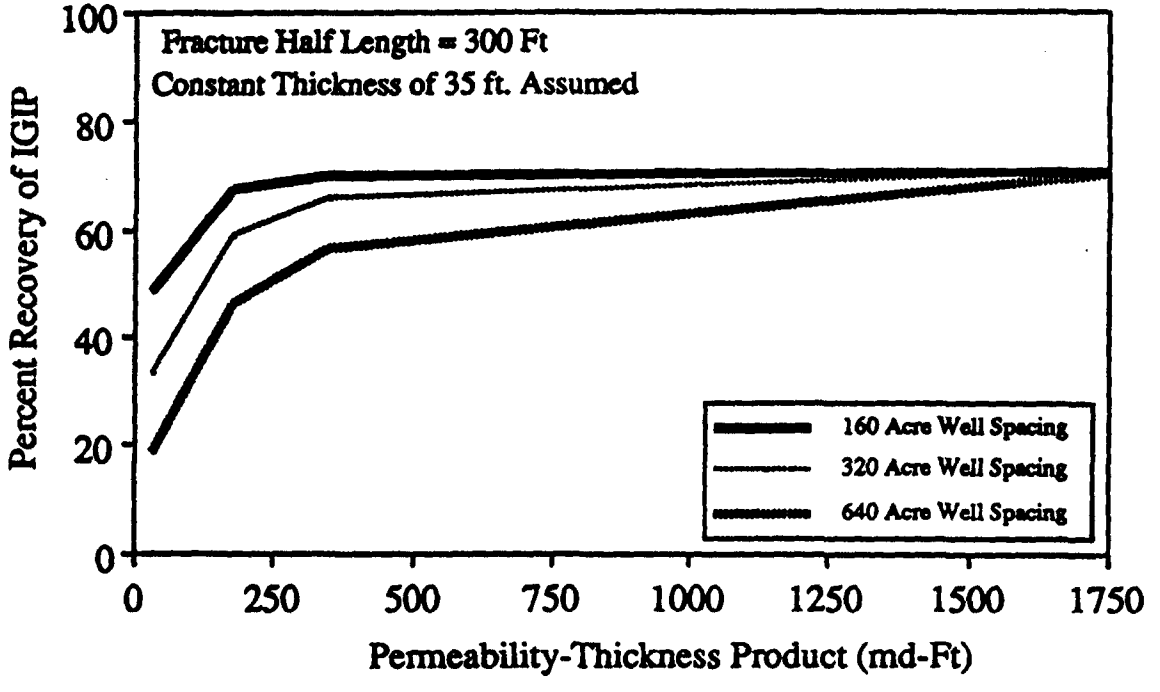
Application of Richardson Operating Co.
Record on Appeal, 1714.

Figure 42

San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs. kh for ø=0.25%

40 Year Simulation



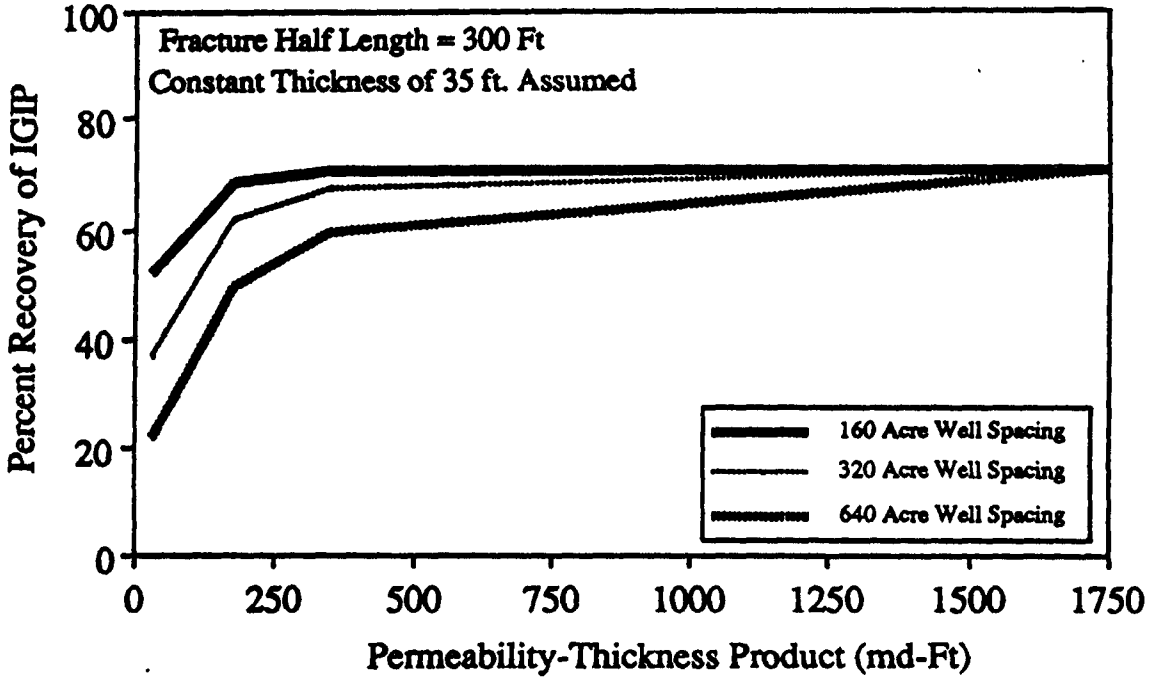
Application of Richardson Operating Co.
Record on Appeal, 1715.

Figure 43

San Juan Basin Area 1 Sensitivity Analysis

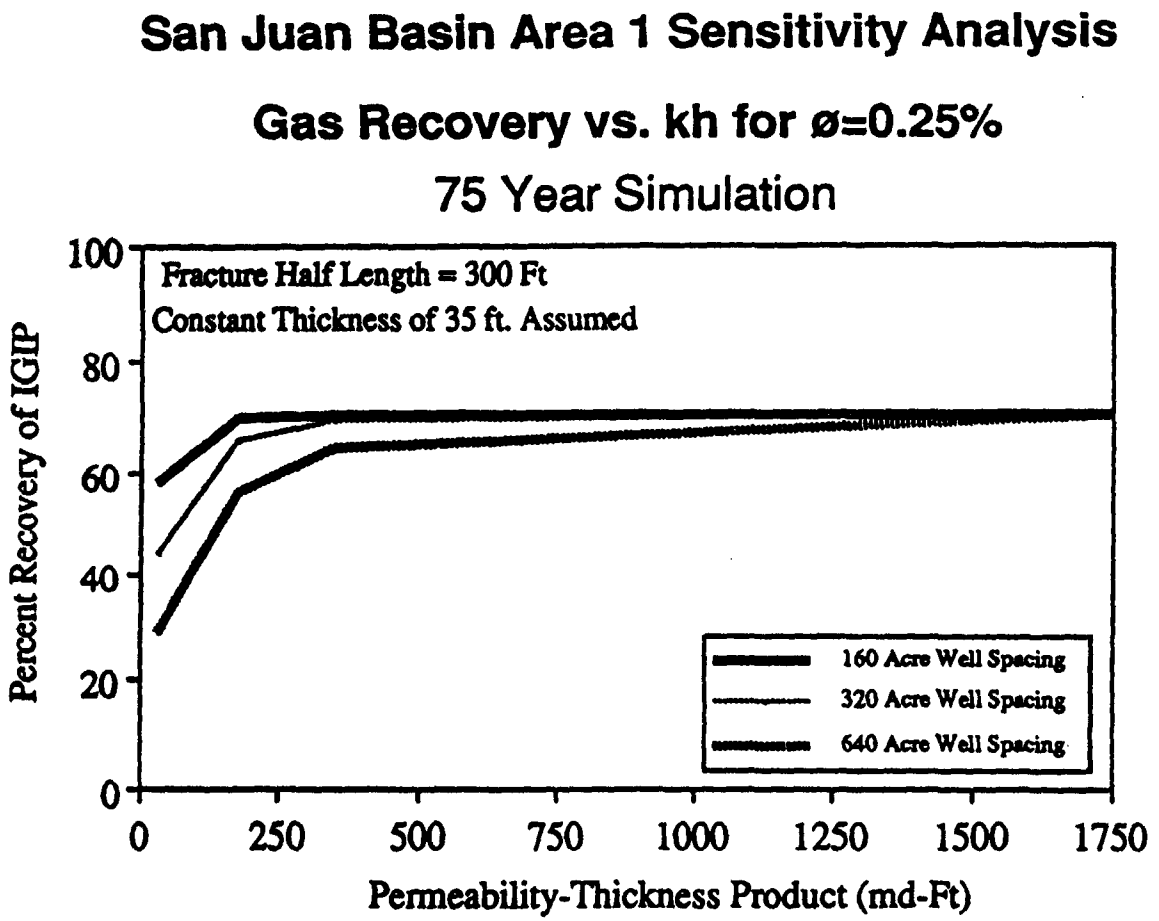
Gas Recovery vs. kh for ø=0.25%

50 Year Simulation



Application of Richardson Operating Co.
Record on Appeal, 1716.

Figure 44



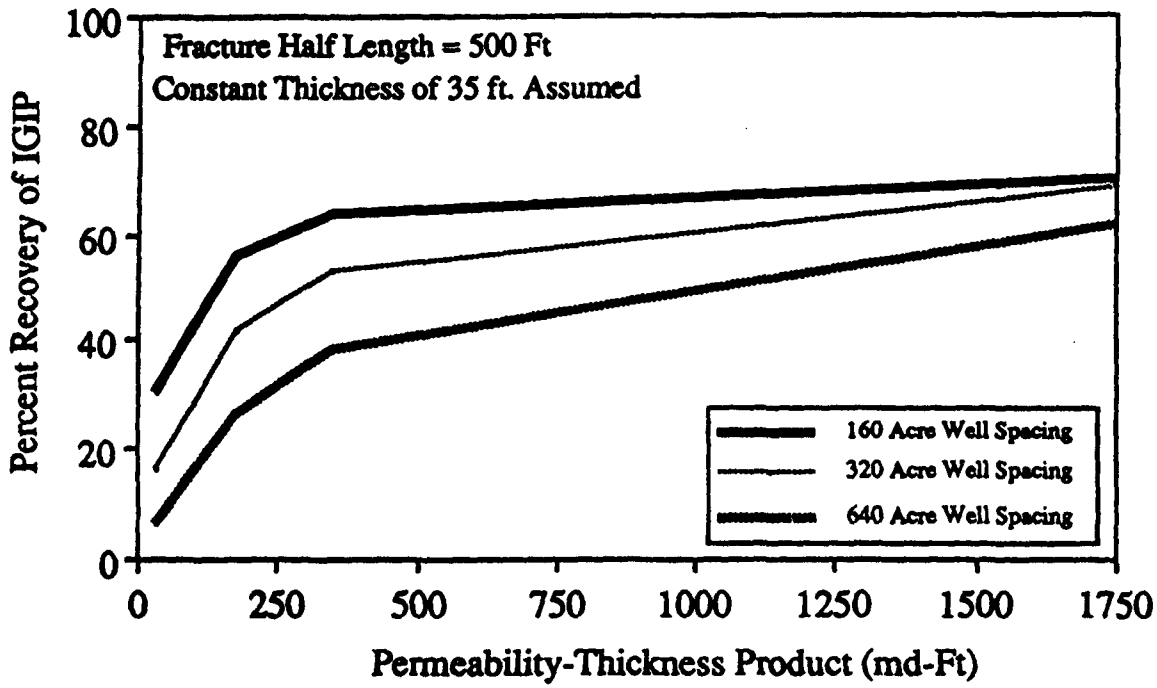
Application of Richardson Operating Co.
Record on Appeal, 1717.

Figure 45

San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs. kh for ø=0.25%

10 Year Simulation



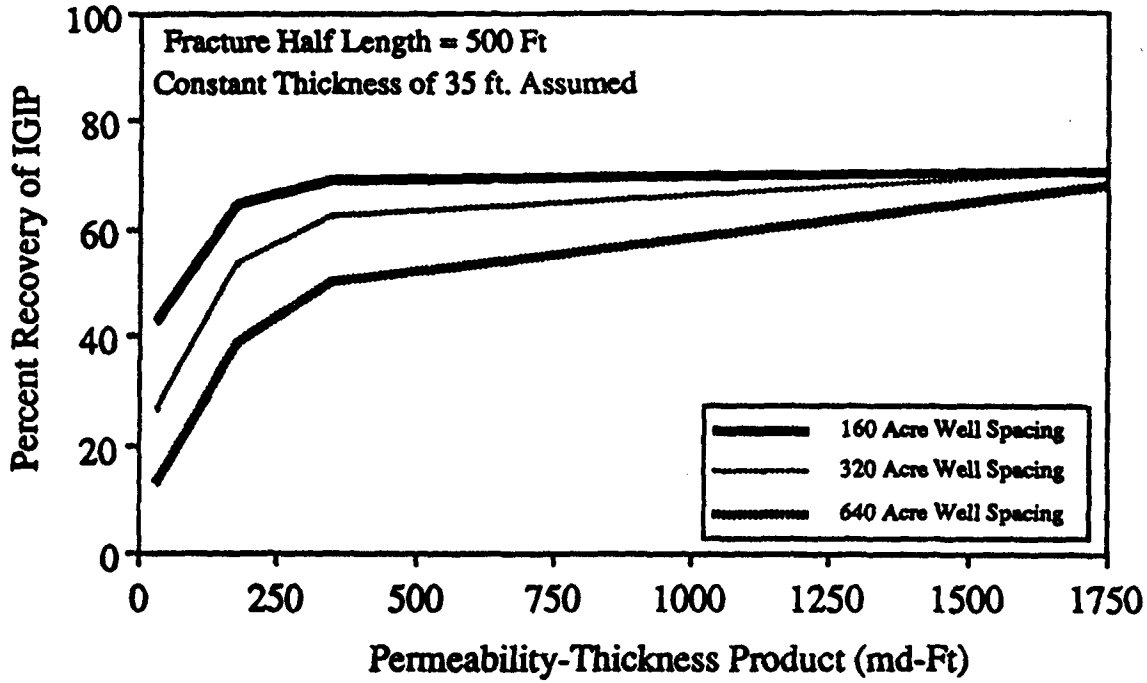
Application of Richardson Operating Co.
Record on Appeal, 1718.

Figure 46

San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs. kh for ø=0.25%

20 Year Simulation



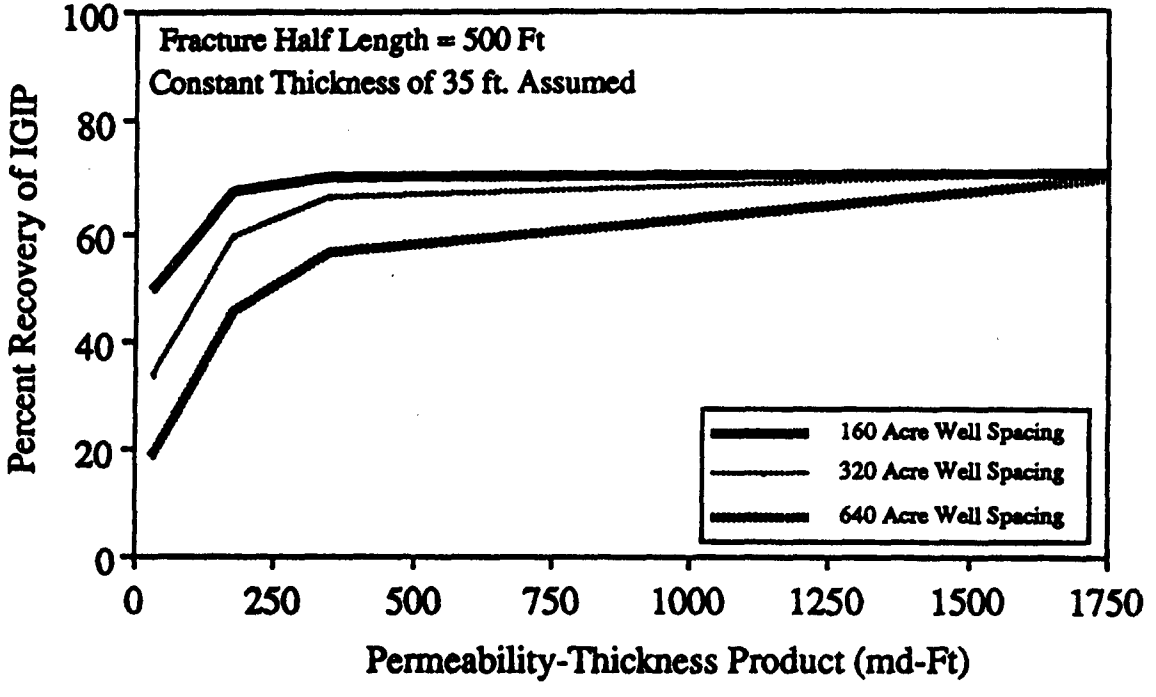
Application of Richardson Operating Co.
Record on Appeal, 1719.

Figure 47

San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs. kh for ø=0.25%

30 Year Simulation



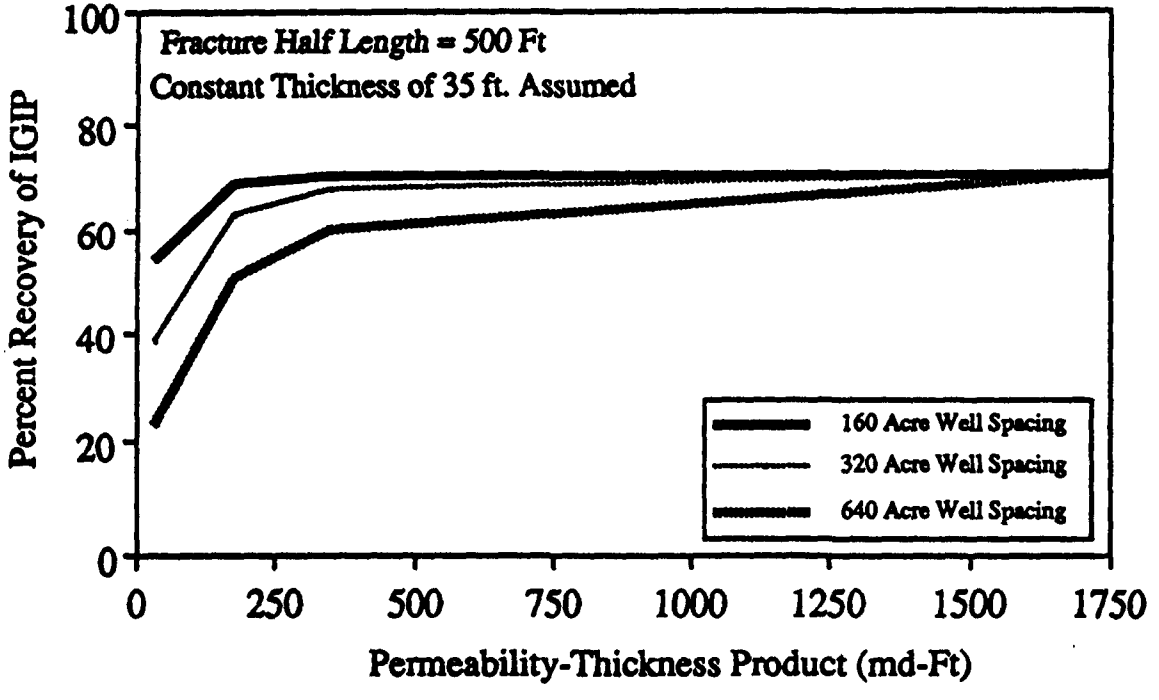
Application of Richardson Operating Co.
Record on Appeal, 1720.

Figure 48

San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs. kh for ø=0.25%

40 Year Simulation



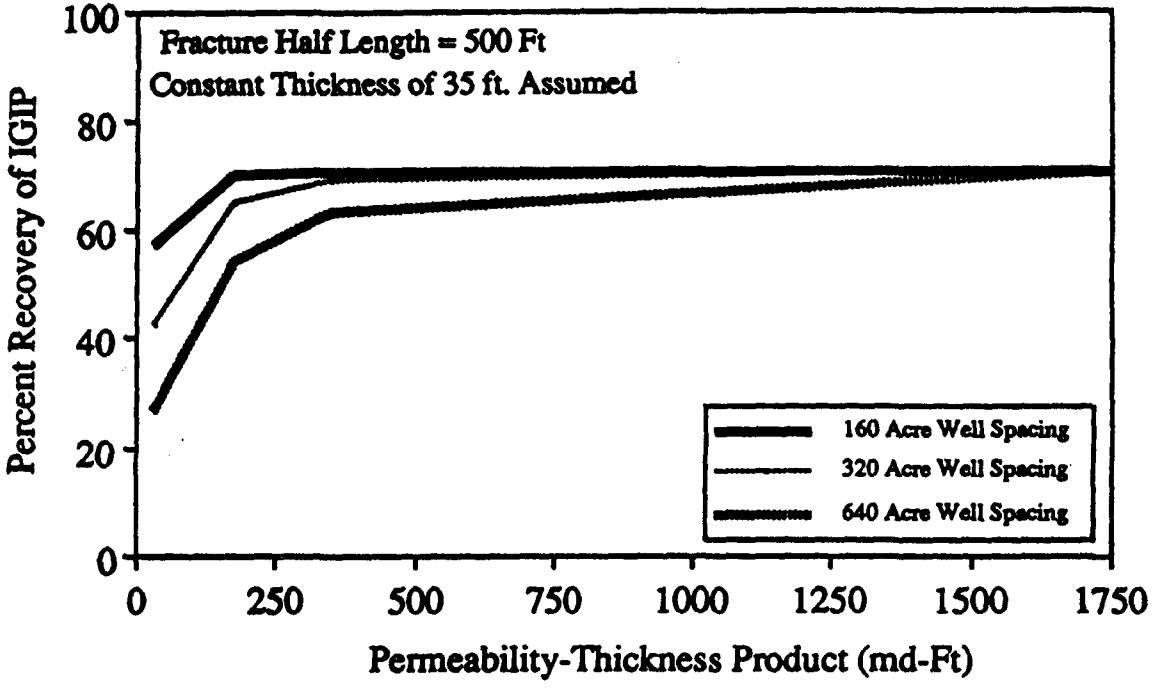
Application of Richardson Operating Co.
Record on Appeal, 1721.

Figure 49

San Juan Basin Area 1 Sensitivity Analysis

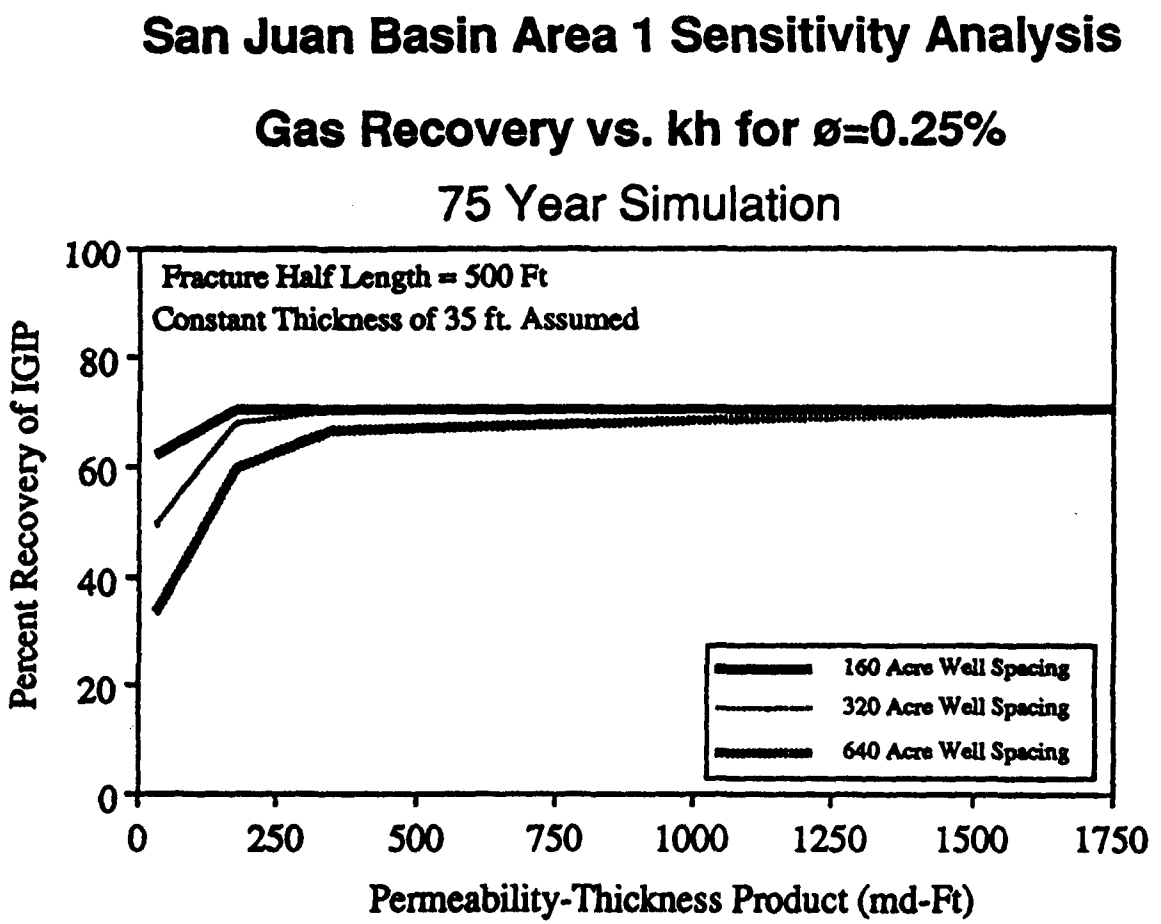
Gas Recovery vs. kh for ø=0.25%

50 Year Simulation



Application of Richardson Operating Co.
Record on Appeal, 1722.

Figure 50

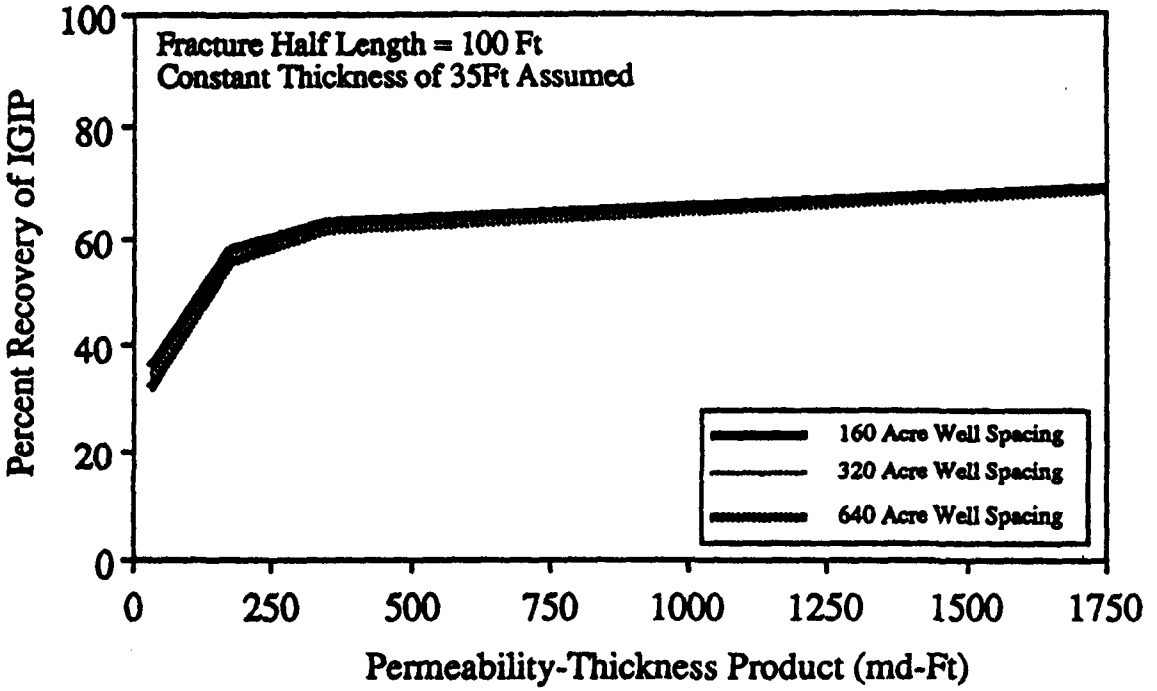


Application of Richardson Operating Co.
Record on Appeal, 1723.

Figure 51

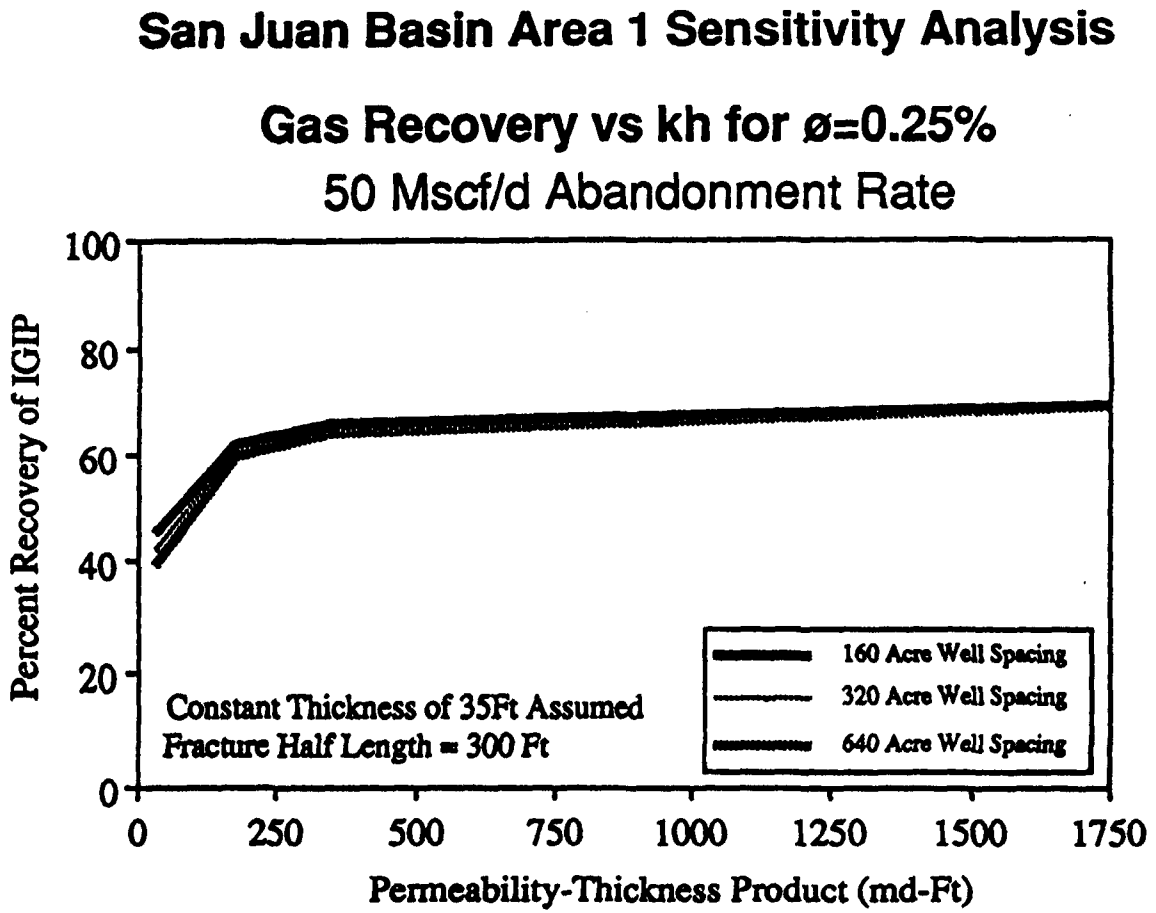
San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs kh for ø=0.25%
50 Mscf/d Abandonment Rate



Application of Richardson Operating Co.
Record on Appeal, 1724.

Figure 52



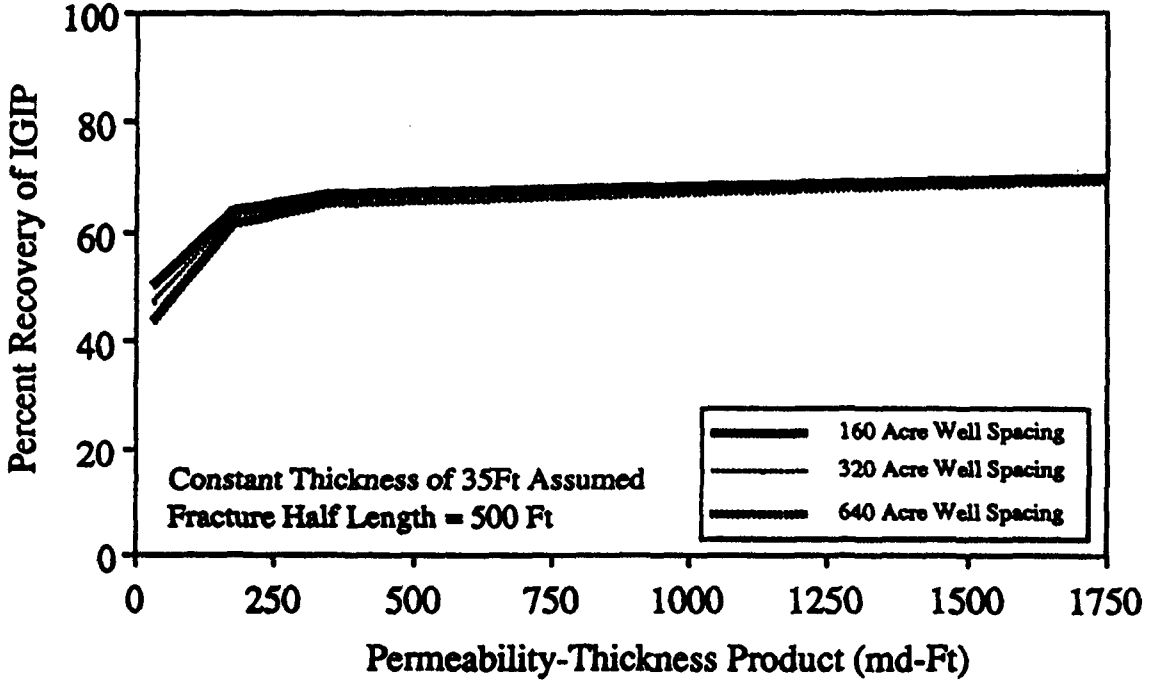
Application of Richardson Operating Co.
Record on Appeal, 1725.

Figure 53

San Juan Basin Area 1 Sensitivity Analysis

Gas Recovery vs kh for ø=0.25%

50 Mscf/d Abandonment Rate

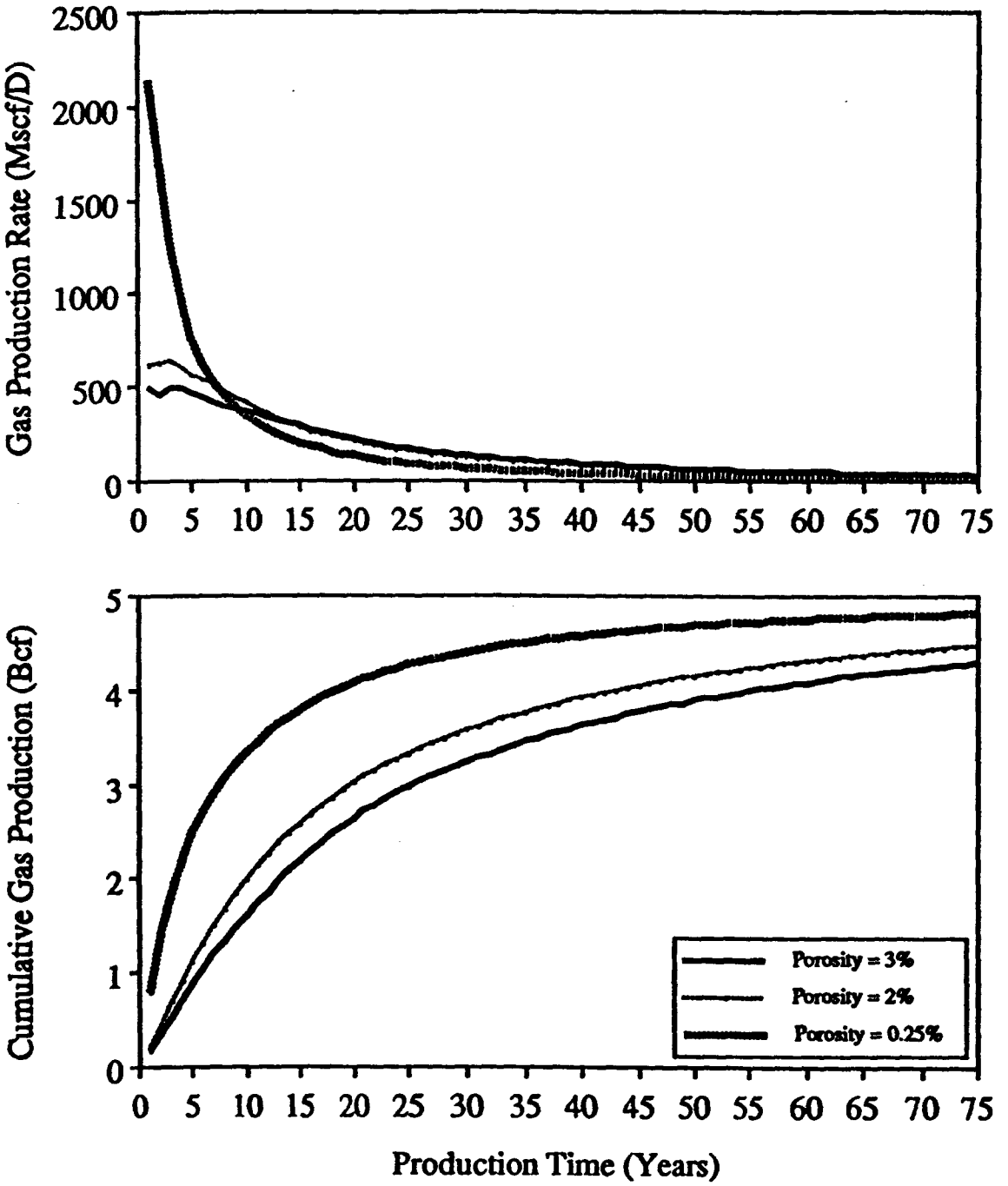


Application of Richardson Operating Co.
Record on Appeal, 1726.

Figure 54

San Juan Basin Sensitivity Analysis
Area 1 Type Reservoir
Base Case Variation in Porosity

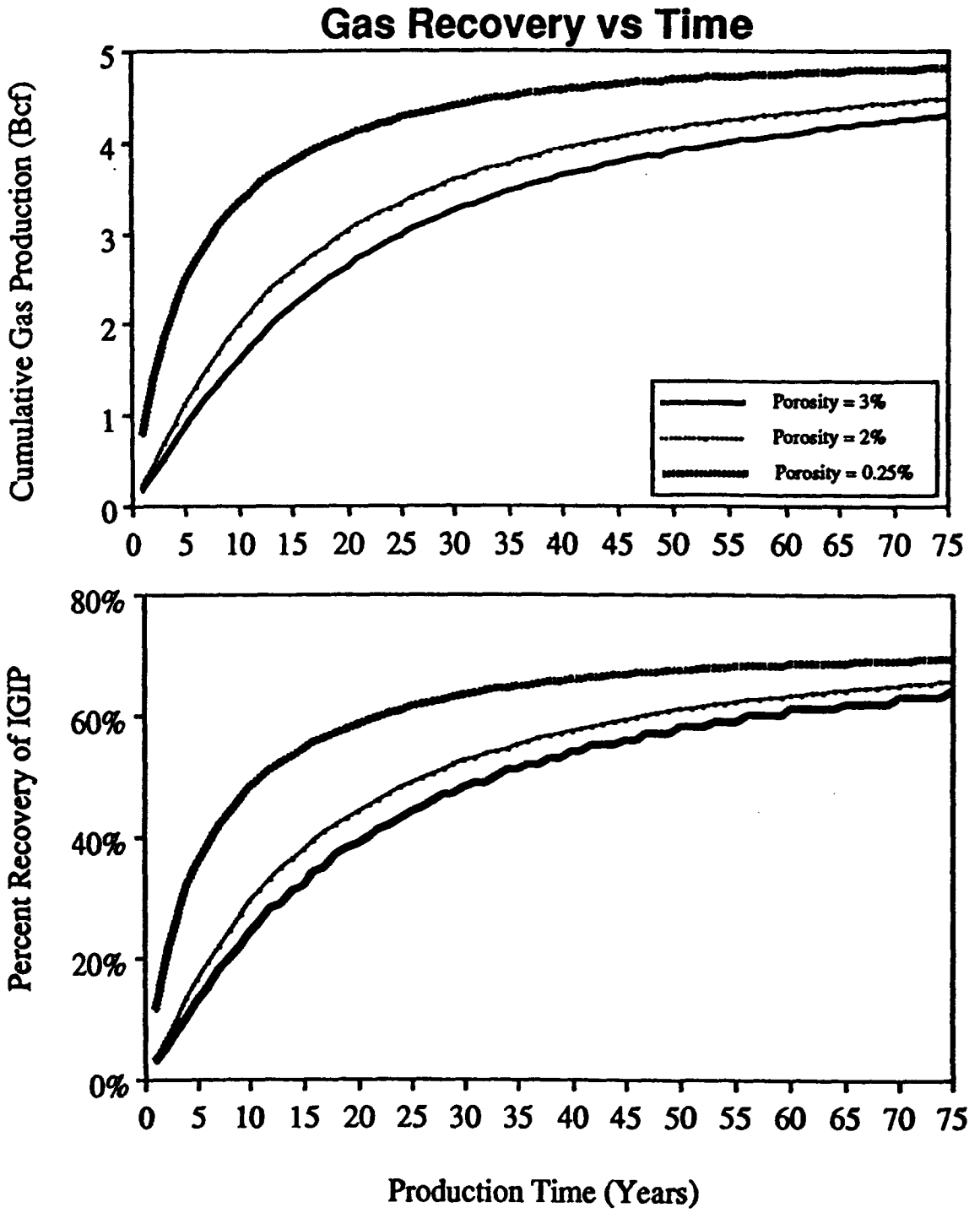
Gas Production vs Time



Application of Richardson Operating Co.
Record on Appeal, 1727.

Figure 55

San Juan Basin Sensitivity Analysis
Area 1 Type Reservoir
Base Case Variation in Porosity

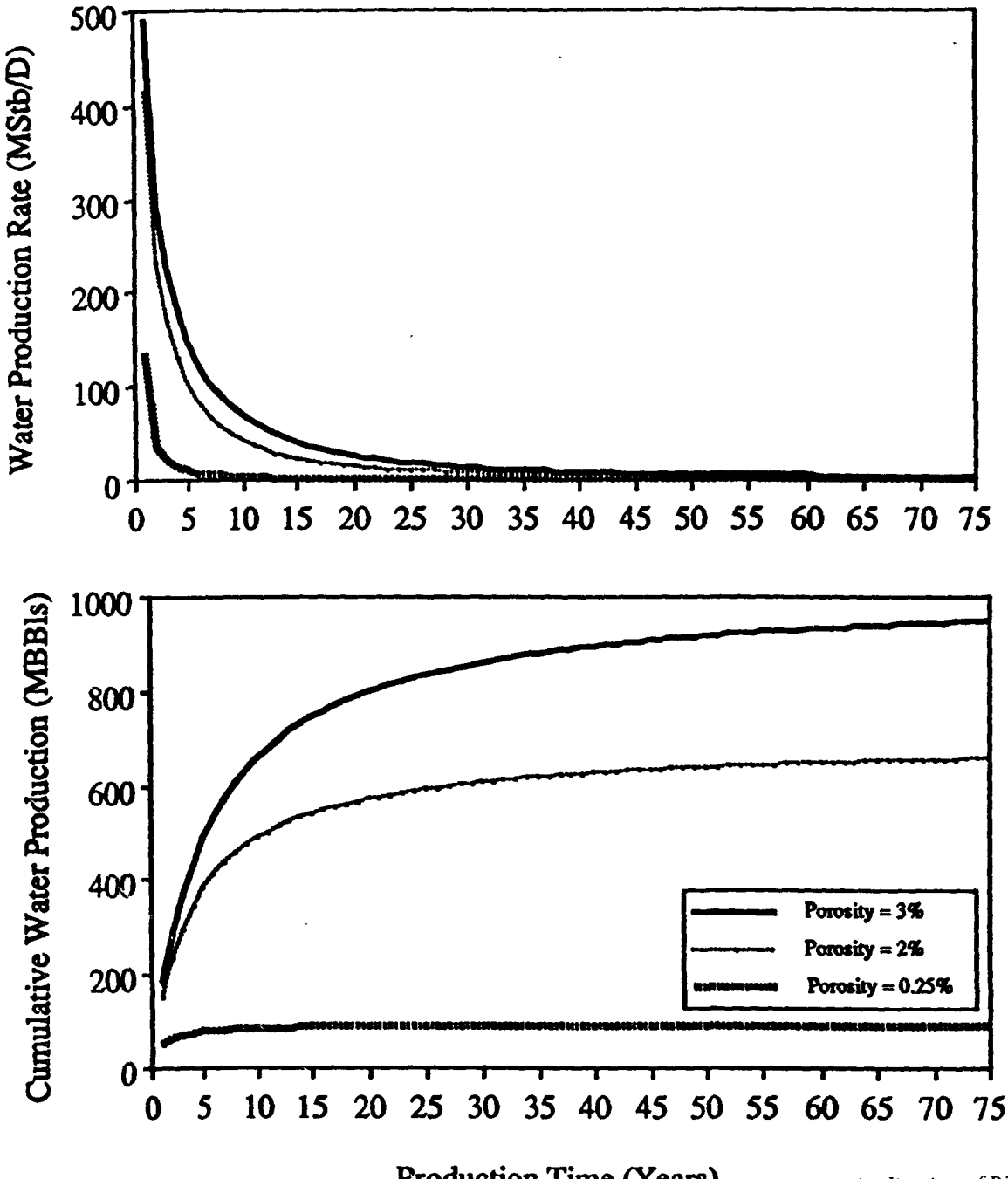


Application of Richardson Operating Co.
Record on Appeal, 1728.

Figure 56

San Juan Basin Sensitivity Analysis
Area 1 Type Reservoir
Base Case Variation in Porosity

Water Production vs Time



Application of Richardson Operating Co.
Record on Appeal, 1729.