PREDICTION OF NON-DARCY FLOW EFFECTS ON FLUID FLOW THROUGH POROUS MEDIA BASED ON FIELD DATA

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ABSTRACT

PREDICTION OF NON-DARCY FLOW EFFECTS ON FLUID FLOW THROUGH POROUS MEDIA BASED ON FIELD DATA

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The objective of this dissertation is to investigate the non-Darcy flow effects on field base data by considering gas viscosity, gas deviation factor and gas density as variables. To achieve it, different correlations from the literature and field data have been combined to Sawyer-Brown Method, thus a contribution has been achieved. Production history of selected gas field has been implemented to a numerical simulator. To find out non-Darcy effects quantitatively, Darcy flow conditions have also been run in the simulator for each scenario in addition to non-Darcy flow correlation runs. Extracted data from simulation runs have been analyzed on the basis of Sawyer-Brown Method by introducing several correlations to consider gas viscosity, gas deviation factor and gas density as variables. Engineering and scientific research on non-Darcy flow is still being conducted in order for better understanding the nonlinear flow behavior of fluids through porous media. The deviations from Darcy's Law are attributed to the occurrence of all or alternating combinations of factors that can be categorized as the anisotropy of porosity and permeability, multi-phase flow of fluids in varying phases, magnitude of pressure drop and the subsequent phase change in fluids, and the change in flow regime at elevated rates of flow in porous media. Throughout this dissertation, the factors causing deviations from Darcy flow behavior have been investigated.

Keywords: Porous Media, Fluid Flow, Fluid Phase, Non-Darcy Flow, Viscous Forces.

ÖZ

SAHA VERİLERİ TEMELİNDE GÖZENEKLİ ORTAMDA DARCY-DIŞI AKIŞ ETKİLERİNİN SAPTANMASI

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Bu tezin amacı gaz viskozitesini, gaz sapma faktörünü ve gaz yoğunluğunu değişkenler olarak ele alıp Darcy-dışı akış etkilerini saha verileri temelinde incelemektir. Bunu başarabilmek için literatürden ve saha verilerinden farklı korelasyonlar, Sawyer-Brown Metoduna ilave edilmiş ve katkı sağlanmıştır. Seçilen gaz sahasının üretim tarihçesi bir nümerik simülatöre girilmiştir. Darcy-dışı akış etkilerini nicel olarak bulabilmek için, Darcy-dışı akış korelasyonlarına ilave olarak Darcy akış koşulları da her senaryo için simüle edilmiştir. Gaz viskozitesini, gaz sapma faktörünü ve gaz yoğunluğunu değişken olarak kullanabilmek için Sawyer-Brown Metoduna farklı korelasyonlar eklenerek simülasyondan elde edilen sonuçlar çözümlenmiştir. Gözenekli ortamda akışkanların doğrusal olmayan akış davranışlarını daha iyi anlayabilmek için Darcy-dışı akış üzerine mühendislik ve bilimsel araştırmalar halen devam etmektedir. Darcy Yasasından sapmalar gözenekli ortamda gözeneklilik ve geçirgenlik anizotropisi, değişken fazlarda akışkanların çok fazlı akışı, basınç düşümü büyüklüğüne bağlı olarak akışkanların faz değiştirmesi, ve gözenekli ortamda yüksek hızlı akıştan ötürü akış rejiminin değişmesi şeklinde sınıflanabilir. Bu doktora tezinde Darcy akışı davranışından sapmalara neden olan faktörler incelenmiştir.

Anahtar Kelimeler: Gözenekli Ortam, Akışkan Akışı, Akışkan Fazı, Darcy-Dışı Akış, Viskoz Kuvvetler.

Dedicated to my father and mother Musa and Üner Alp who were my first teachers,
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TABLE OF CONTENTS

CHAPTERS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Latin:

Symbol	Description	Dimension	Unit
p	pressure	M/L^2	psi
x	distance	L	cm, ft, in
k	permeability (absolute)	L^2	cm2, m2, D, mD
Q	fluid flow rate	L^3/T	cm3/sec, bbl/day
A	cross sectional area of flow zone	L^2	cm^2, ft^2, in^2
k_o	effective oil permeability	L^2	cm^2, m^2, D, mD
k_w	effective water permeability	L^2	cm^2, m^2, D, mD
k_g	effective gas permeability	L^2	cm^2, m^2, D, mD
k_{ro}	relative oil permeability	L^2/L^2	Dimensionless
k_{rw}	relative water permeability	L^2/L^2	Dimensionless
k_{rg}	relative gas permeability	L^2/L^2	Dimensionless
k_v	vertical permeability	L^2	cm^2, m^2, D, mD
k_h	horizontal (lateral) permeability	L^2	cm^2, m^2, D, mD
g	earth gravity coefficient		
S	saturation	L^3/L^3	Dimensionless
S_o	oil saturation	L^3/L^3	Dimensionless

S_g	gas saturation	L^3/L^3	Dimensionless
S_w	water saturation	L^3/L^3	Dimensionless
M	mobility ratio	$[L^3T/M]/[L^3T/M]$	Dimensionless
c	compressibility	LT^2/M	Dimensionless
z	gas deviation factor	L^3/L^3	Dimensionless

Greek:

Symbol	**Description**	**Dimension**	**Unit**
ν	superficial velocity	L/T	cm/s, ft/s
δ	differential sign		
μ	dynamic (absolute) viscosity	M/LT	cP (centi-Pois)
μ_o	effective oil viscosity	M/LT	cP (centi-Pois)
μ_g	effective gas viscosity	M/LT	cP (centi-Pois)
μ_w	effective water viscosity	M/LT	cP (centi-Pois)
Ø	porosity	L^3/L^3	Percentage
τ	tortuosity	L/L	Dimensionless
ρ	density	M/L^3	kg/m^3, gr/cm^3, ppg
υ	specific volume	L^3/M	m^3/kg, cm^3/gr, gpp
γ_s	specific weight	M/L^3	gr/cm^3, N/m^3
β	non-Darcy flow coefficient	1/L	cm^{-1}
σ	shear stress	M/LT^2	psi

$\delta u/\delta y$	shear rate	$1/T$	s^{-1}
ν	kinematic viscosity	L^2/T	cm^2/sn, stoke
γ	absolute mobility	L^3T/M	cm^2/cP, m^2/cP, D/cP, mD/cP
γ_o	oil mobility	L^3T/M	cm^2/cP, m^2/cP, D/cP, mD/cP
γ_g	gas mobility	L^3T/M	cm^2/cP, m^2/cP, D/cP, mD/cP
γ_w	water mobility	L^3T/M	cm^2/cP, m^2/cP, D/cP, mD/cP
c	compressibility	LT^2/M	Dimensionless
z	gas deviation factor	L^3/ L^3	Dimensionless

Subscripts:

$_o$	oil
$_g$	gas
$_w$	water
$_r$	relative
$_c$	connate
$_i$	irreducible
$_s$	specific
$_v$	verticle
$_h$	horizontal

LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
D	Darcy (Unit description of permeability)
mD	Mili Darcy (Unit description of permeability)
HC	Hydro Carbon

CHAPTER 1

INTRODUCTION

Fluid flow through a porous medium has been described by Darcy in 1856 [1].

1.1. Darcy Flow

Darcy has described the fluid flow with following equation known as Darcy's Law:

$$\nu = -(k/\mu)(\delta p/\delta x) \qquad \text{(Eq. 1.1)}$$

This is a unidirectional, linear, differential relationship between laminar and single phase water (as a Newtonian fluid) flow through an isotropic aquifer as a porous and permeable medium, the dynamic viscosity of water and the pressure gradient. Here "ν" is the superficial velocity, "k" is permeability, δp is pressure differential, "μ" is viscosity, "δx" is dimension in x direction and "$\delta p/\delta x$" is pressure gradient. The minus sign at the right hand side of Eq. 1.1 indicates the flow direction from high pressure to low pressure.

The superficial velocity can be written as:

$$\nu = Q/A \qquad \text{(Eq. 1.2)}$$

where "Q" is the fluid flow rate and "A" is the cross sectional area of flow zone.

In Darcy's equation given in Eq. 1.1, the dynamic viscosity "μ" has a constant value due to linear relationship where shear stress (as dependent variable) changes by shear rates (as independent variable).

Fluid flow obeying Darcy's Law in Eq. 1.1 is called "Darcy Flow".

1.2. Non-Darcy Effects on Fluid Flow Through Porous Media

Some flow characteristics cause deviations from Darcy Flow as described in Eq.1.1.

Darcy has defined the fluid flow with a linear function as velocity (or rate across the cross-sectional area) versus pressure gradient in equation Eq. 1.1. As long as the flow rate goes higher, every incremental step in rate increase requires more (for shear thinning fluids) or less (for shear thickening fluids) energy (here pressure differential) than one step below. That means the relationship in rate versus pressure difference is not linear for non-Newtonian fluids. Drilling mud is an evidence for non-linear viscosity changes as a function of shear rate. In reservoirs, flowing fluid(s) are not always Newtonian type. That means the viscosity of the flowing fluid(s) are not constant at different flow rates, but the viscosity in Eq. 1.1 has been assumed as a constant value. Change in viscosity causes a deviation from Darcy flow as well.

At high flow rates or in non-Darcy flow conditions, the pressure differential of Eq.1.1 cannot predict the flow rate accurately. Thus, a deviation starts from Darcy flow behavior.

On the other hand, flow paths in the pore network are usually not straight. Such pore configuration is called tortuosity. Again, Eq.1.1 cannot accurately estimate the required pressure drop due to deviation from unidirectional flow and thus a deviation from Darcy Law takes place.

In gas reservoirs, flow rates are very high near wellbore regions. High flow rates may cause high pressure drops, and therefore condensation might start. Condensation during the flow is another source for a deviation in estimating pressure drop from Eq.1.1 due to changes in relative permeabilities.

Fluid flow which does not obey Darcy’s Law due to all or alternating combination of above mentioned reasons is called non-Darcy flow. Non-Darcy term has been introduced by Forchheimer [2] with the development of following equation:

$$-(\delta p/\delta x) = (\mu/k)\nu + \beta\rho\nu^2 \qquad \text{(Eq. 1.3)}$$

In Forchheimer equation (Eq.1.3.) the product of $\beta\rho v^2$ is an additional quantity to Darcy's equation (Eq.1.1). Here, "ρ" is the fluid density and β is the non-Darcy flow coefficient.

1.3. Description of The Problem

Defining non-Darcy flow coefficient (β in Eq.1.3) has led to numerous research studies that contributed a wealth of knowledge to the literature regarding fluid flow through porous media. Although many empirical and theoretical studies have been published in almost every decade of the last century, a clear definition of non-Darcy flow coefficient covering all affecting parameters has not been developed yet. Some attribute it to turbulence [3, 4], and some attribute it to inertial forces [5, 6, 7, 8 and 9].

In this study, the viscosity and gas deviation factors shall be considered as variables of pressure in finding non-Darcy flow effects.

1.4. The Importance of The Study

In gas reservoirs that produce from vertical wells, as the gas approaches radially to the well bore, the cross sectional area to flow becomes smaller with reducing distance, and consequently gas flow velocity increases. As a result, turbulent flow might initiate which is directly related with flow velocity and gas condensation might occur. Gas condensate causes a reduction in gas relative permeability, and thus gas production decreases. This mechanism is important for converted underground gas storage reservoirs during their production phases.

1.5. The Objective and the Methodology of The Study

The objective of this study is to investigate the non-Darcy flow effects by considering gas viscosity, gas deviation factor and gas density as variables.

To achieve the objective, first the theory and some basic concepts on fluid flow through porous media have been emphasized, and then the literature on non-Darcy fluid flow has been reviewed. On the basis of mentioned theory, concepts and literature, a new model has been developed by combining several correlations.

To verify the model, the field data of North Marmara (Kuzey Marmara) Underground Gas Storage offshore reservoir located at North West of Turkey have been implemented to the model, and the model results have been checked against the field data. This underground gas storage is already depleted gas reservoir and converted to underground gas storage.

1.6. Outline of The Study

To realize the above mentioned objective and methodology, the basic concepts on fluid flow through porous media has been emphasized in Chapter 2. The literature survey on non-Darcy fluid flow has been submitted in Chapter 3. The Statement of the Problem takes place in Chapter 4 and the Theory in Chapter 5. Method of Solution is given in Chapter 6 and the Results and Discussions including case study as implementation of the case study data into the model has been given in Chapter 7. In Chapter 8 the Conclusions of the study and in Chapter 9 the Recommendations for new studies are submitted. The list of references is placed following Chapter 9, and Appendices following the References.

CHAPTER 2

BASIC CONCEPTS

Fluid flow through porous media can categorically be investigated in following outline.

2.1. Medium Properties

The media subject to this dissertation is fluid saturated, sedimentary, overlain and underlain by impermeable layers, porous and permeable reservoirs.

2.1.1. Rock Properties

In terms of petrophysics and hydrocarbon (HC) exploration, sedimentary rocks can be sandstones or carbonate rocks. Here, carbonate rocks can be either calcite ($CaCO_3$) or dolomite ($CaMgCO_3$) type. In sandstones, the electrical load of solid surface is negatively charged while in carbonates it is positively charged. Major rock properties defining the fluid flow can be acknowledged as below.

2.1.1.1. Porosity

The average void fraction (in percentage) of the reservoir's bulk volume is called porosity. Porosity defines the fluid storage capacity of the reservoir rock. Dimension of porosity is L^3/L^3. Pore space has no any definitive geometrical shape and size. The distribution of pore space in reservoir rock is not homogeneous. In addition, pores are interconnected each other by capillary channels. Where the pores are not connected to each other, they are called 'dead pores'. The connected porosity of well drainage areas can be estimated quantitatively by means of well pressure interference tests [10], and also by lab tests on the core plugs taken from the reservoir. It is important not to forget that porosity is field wise averagely estimated datum.

2.1.1.2. Permeability

Fluid conductivity through a porous medium is achieved by capillary channels interconnecting the pores. The average conductivity of a reservoir is called permeability. Permeability is a tensor quantity. Capillary channels connecting the pore spaces in reservoirs are usually not straight, with inconstant diameter and their distribution in a reservoir is not homogeneous.

2.1.1.2.1. Absolute Permeability

The permeability is independent of the nature of the fluid where the pore volumes are totally saturated with a single phase fluid. Thus, it is called absolute permeability [11, 12]. Absolute permeability is denoted by Latin letter of "k", has the dimension of L^2.

2.1.1.2.2. Effective Permeability

Reservoirs are usually saturated with more than one immiscible fluid. These fluids can be oil, water and/or gas. Absolute permeability is independent of the nature of saturating fluid in single phase. In case of multiphase existence in the reservoir, the permeability value becomes a function of individually flowing phase saturation, and it is called Effective Permeability. Effective permeability is the product of absolute permeability (k) and the relative permeability of individual phase (k_{ro} for oil, k_{rw} for water and k_{rg} for gas) at certain saturation. Its dimension is L^2.

Effective permeability for oil (k_o) : $k_o = kk_{ro}$ (Eq. 2.1)

Effective permeability for water (k_w) : $k_w = kk_{rw}$ (Eq. 2.2)

Effective permeability for gas (k_g) : $k_g = kk_{rg}$ (Eq. 2.3)

2.1.1.2.3. Relative Permeability

Relative permeability is the ratio of effective permeability of a phase to the absolute permeability of the medium.

Relative permeability for oil (k_{ro}) : $k_{ro} = k_o/k$ (Eq. 2.4)

Relative permeability for water (k_{rw}) : $k_{rw} = k_w/k$ (Eq. 2.5)

Relative permeability for gas (k_{rg}) : $k_{rg} = k_g/k$ (Eq. 2.6)

Dimensionally, it is L^2/L^2 and dimensionless in unit.

Table 2.1 and Figure 2.1 shows the behavior of oil and water relative permeability versus water saturation. The data has been taken from Slider H.G. [12]. Here, it is notable that at a certain water saturation (S_w) the summation of oil relative permeability (k_{ro}) and water relative permeability (k_{rw}) does not yield one. On the other hand, relative permeability of water is zero in the same figure where water saturation is below 30 %. This is due to rock wettability and the level of connate water saturation. Similar effect can be observed for oil relative permeability behavior depending on oil saturation.

Table 2.1: Oil and water relative permeability behavior against water saturation.

S_w, %	30	40	60	80	90	100
k_{ro}	0.950	0.625	0.250	0.025	0.000	0.000
k_{rw}	0.000	0.020	0.060	0.300	0.600	1.000

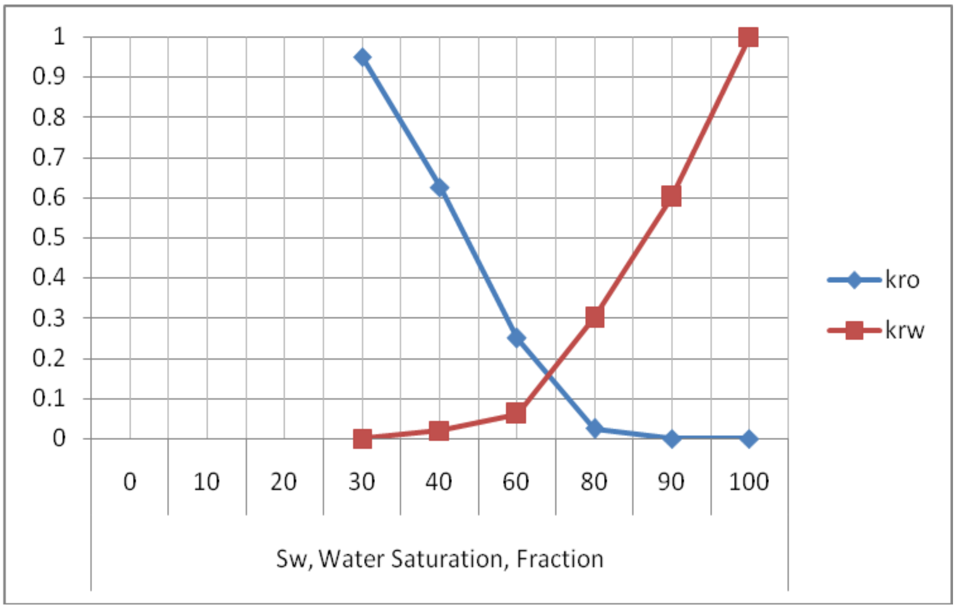

Figure 2.1: Relative permeability versus water saturation (Replotted from Slider, H.G. [12])

2.1.1.2.4. Vertical Permeability

Vertical permeability is the fluid conductivity perpendicular to the bedding plane of stratified reservoir rock. As well as other rock properties, vertical permeability values vary in micro scale in the reservoir. It is denoted by Latin letter of “k_v”. Dimensionally, it is L^2.

2.1.1.2.5. Horizontal (Lateral) Permeability

Horizontal (lateral) permeability is the fluid conductivity parallel to the bedding planes of stratified reservoir rock. Generally, horizontal permeability has higher values than vertical permeability. This sounds quite reasonable in terms of preferential migration paths. Unless otherwise is mentioned, always horizontal permeability is meant in calculating the rate of fluid production from reservoirs through wells. All definitions given above for absolute permeability, effective permeability and relative permeability mean horizontal ones. Horizontal permeability is denoted by Latin letter of “k_h”.

2.1.1.3. Tortuosity

Capillary channels connecting pores are not strait paths. Here, the ratio of the average path length (L’) to the average strait line distance in between pores (L) is called tortuosity [12].

$$\tau = L'/L \qquad \text{(Eq. 2.7)}$$

Tortuosity is denoted by Greek symbol of “τ”. Dimensionally, it is L/L and dimensionless in unit.

2.1.1.4. Wettability and Wetting

Wettability is a rock property although it can be observed when rock contacts with a fluid. Wetting is fluid property. When adhesive force (inner force between molecules of two different phases at the contact surface, such as solid and liquid) is higher than cohesive force (inner force between the molecules of a fluid) then fluid wets the solid surface. Therefore, wettability is not a function of fluid’s surface tension, but fluid’s surface tension is a function of adhesive force, and wettability is the result. On the other hand, the source of cohesive forces is the attraction between the molecules of a fluid. But the source of adhesive forces is defined with the interaction of contacting surface molecules of a solid with a fluid in contact. The force balance between adhesive and cohesive forces determines the degree of wetting [13].

2.1.2. Fluid Properties

2.1.2.1. Saturation

Porous media are sometimes filled with a single phase fluid but sometimes with multiphase fluids. The porosity percent occupied with any phase of the fluids is called the saturation for that phase, such as oil saturation (S_o), water saturation (S_w) and gas saturation (S_g).

Depending on the wettability character of the reservoir rock and fluid surface tension, some percent of a fluid saturation is naturally held by solid surface of the pores. Since this held fluid cannot be recovered without introducing additional energy into the medium, it is called Irreducible Saturation. Customarily, in oil wet reservoirs, it is called Irreducible or Residual Oil Saturation (S_{io}), and in water wet reservoirs it is called Irreducible or Residual Water Saturation (S_{cw}). Similarly, in gas reservoirs and in gas cap of oil reservoirs, some percent of gas can be held by the surface of pores, and this percent of gas saturation is called Irreducible Gas Saturation (S_{ig}) [12].

2.1.2.2. Density, Specific Volume, Specific Gravity, Specific Weight

Density is defined as the mass of unit volume, and it is dependent on temperature and pressure [14]. For liquids, density is decreased by increasing temperature, and increased by increasing pressure. Since liquids are assumed as incompressible fluids, the change in liquid density by pressure usually is ignored in practical engineering calculations. For gases, density increases by increasing pressure, but decreases by increasing temperature.

Density is denoted by Greek letter of "ρ". Dimensionally, density is M/L^3 and defined as:

$$\rho = m/V \qquad \text{(Eq.2.8)}$$

Reciprocal of density is Specific Volume, and it is defined as the volume of unit mass and is denoted by Greek letter of "υ". Dimensionally, it is L^3/M and balanced as:

$\upsilon = V/m$ (Eq.2.9)

Specific Gravity of gases is the ratio of the density of a gas at a given temperature and pressure to the density of air at the same temperature and pressure. Thus, it is independent of temperature and pressure whereas density is dependent where the gas obeys the ideal gas law. Therefore specific gravity is more commonly used than density [14]. Specific Gravity is balanced as:

$SG = \rho_{gas} / \rho_{air}$ (Eq.2.10)

2.1.2.3. Viscosity (Dynamic & Kinematic)

Viscosity is known as resistance of fluids against flow [15]. Driving mechanism of fluid flow is the shear stress. Moving molecules exerts an acceleration force. Viscosity is the ratio of change in shear stress over a change in shear rate under constant environmental conditions (such as constant pressure, temperature, etc.). Shear stress is defined by following equation:

$\sigma = \mu(\delta u/\delta y)$ (Eq.2.11)

Thus, viscosity is:

$\mu = \sigma / (\delta u/\delta y)$ (Eq.2.12)

Here, "μ" is dynamic (or absolute) viscosity with the dimension of M/LT, "σ" is shear stress with the dimension of M/L, and $\delta u/\delta y$ is shear rate (velocity gradient) with the dimension of 1/T.

The ratio of dynamic viscosity over density is called Kinematic Viscosity:

$\nu = \mu/\rho$ (Eq.2.13)

In Eq.2.13 "ν" is Kinematic Viscosity with the dimension of L^2/T.

For liquids, since they are assumed as incompressible fluids, pressure effect on dynamic and kinematic viscosities usually have been ignored in practical engineering solutions. Increasing pressure has a tendency to slightly raise the viscosity of liquids while increasing temperature cause an exponential decrease in liquids. Increasing temperature reduces cohesive force and increases molecular interchange. Reducing cohesive force reduces shear stress while increasing molecular interchange increases shear stress. Mathematically, temperature effect on liquid viscosity can be expressed as below [15]:

$$\mu = a10^{b/(T-c)} \qquad \text{(Eq.2.14)}$$

Here, “T” is absolute temperature, “a”, “b” and “c” are constants for each liquid and can be determined experimentally.

For gases, the pressure effect on dynamic viscosity has been assumed as negligible in practical engineering solutions, but kinematic viscosity has been considered due to compressibility of gasses by pressure. On the other hand, dynamic viscosities of gases are increased by increasing temperature. Since cohesive force of gases is low, its incremental contribution to reduce the gas viscosity by increasing temperature is lower than the incremental contribution of molecular interchange to increase the viscosity. Gas viscosity as a function of temperature can be calculated by:

$$\mu = (aT^{1/2})/(1+b/T) \qquad \text{(Eq.2.15)}$$

Here, “a” and “b” are experimentally determined constants and T is absolute temperature.

To summarize the temperature effect on liquid and gas viscosities:

Table 2.2: Temperature effect on liquid and gas viscosities.

Phases	**Inner Characteristics**	**Incremental effect of increasing temperature**	**Effect on shear stress**	**Effect on drag force**	**Viscosity change**
Liquid	Cohesive Forces	High reduction	High reduction	High reduction	Decrease
	Molecular Interchange	Low increase	Low increase	Low increase	
Gas	Cohesive Forces	Low reduction	Low reduction	Low reduction	Increase
	Molecular Interchange	High increase	High increase	High increase	

Depending on the shear stress behavior versus shear rate, fluids can be classified into two major groups: Newtonian Fluids and Non-Newtonian Fluids.

Newtonian Fluids have zero shear stress when there is no shear rate, and displays a linear shear stress behavior versus shear rate. Therefore, viscosities of Newtonian fluids have always constant values and Eq.2.12 applies.

Non-Newtonian Fluids might not have necessarily zero shear stress when there is no shear rate, and they have nonlinear shear stress behavior versus shear rate. Therefore, Non-Newtonian Fluids do not have necessarily always constant viscosity values and Eq.2.12 does not apply. For each one of these fluids, many empirical viscosity equations have been developed such as Bingham Plastic Viscosity, Power Law, etc. Mathematically, following empirical equation approach applies for shear stress of Non-Newtonian fluids:

$$\sigma = YP + \mu\,(\delta u/\delta y)^n \qquad \text{(Eq.2.16)}$$

$$\mu = \sigma/[(\delta u/\delta y)^n] - YP \qquad \text{(Eq.2.17)}$$

In Eq.2.16 and Eq.2.17 YP (Yield Point) and n values must be experimentally determined for each Non-Newtonian fluid, while in these equations YP = 0 and n = 1 for Newtonian fluids, the resulting equation becomes Eq.2.12.

2.1.2.4. Mobility and Mobility Ratio

Mobility of reservoir fluids (in porous medium) is the ratio of permeability over viscosity [11].

$\gamma = k/\mu$ (Eq.2.18)

Similar ratio is applied to find out effective mobility for oil, gas and water:

$\gamma_o = k_o/\mu_o$ (Eq.2.19)

$\gamma_g = k_g/\mu_g$ (Eq.2.20)

$\gamma_w = k_w/\mu_w$ (Eq.2.21)

In case of fluid displacement by another fluid, the ratio of displacing fluid effective mobility over displaced fluid effective mobility is called Mobility Ratio (M). As an example, if oil is displaced by water:

$M = \gamma_w/\gamma_o$ (Eq.2.22)

2.1.2.5. Compressibility

Volumes and thus densities of materials are dependent of temperature and pressure of their surrounding environment. As it is very well known by Boyle’s and Charles’ Laws [14], if the product of volume and pressure of an ideal gas is divided by its temperature, the result is always constant for that gas. Ideal gases obey following equation:

$pV = nRT$ (Eq.2.23)

Here, p is pressure, V is volume, n is the number of mole, R is universal gas constant and T is temperature of ideal gas.

Compressibility (c) as a term can be defined as at a constant temperature, the ratio of incremental volume change ($\Delta\upsilon$) to the initial volume (υ_0) under initial pressure (p_0) due to change in pressure Δp [16]:

$c = -(1/\upsilon_0)(d\upsilon/dp)_T$ (Eq.2.24)

Minus sign in Eq.2.24 is due to the increasing pressure change (or due to increasing volume if pressure reduces).

Since the incremental volume change for gases in practical engineering calculations is not small, gas compressibility values are always considered. In case of ideal gases, when the pressure is doubled, the volume is halved. But real gases such as natural hydrocarbon gases deviate from ideal gas compression behavior by a multiplier called gas deviation factor and usually denoted by “z”.

z = (Actual volume of n mole of gas at T and p)/(Ideal volume of n mole of gas at the same T and p)

This dimensionless quantity varies usually between 0.70 and 1.20, a value of 1.00 representing ideal behavior [11]. Thus, Eq.2.23 becomes:

$$pV = znRT \qquad \text{(Eq.2.25)}$$

In practical engineering calculations for solids and liquids, since the incremental volume change due to external pressure is small when compared with gases, compressibility of solids and liquids is generally assumed as negligible, but actually they are compressible, too. Hall [16] has experimentally showed that effective rock compressibility versus porosity of fluid saturated carbonate rocks and sand stones results almost similar function.

2.1.3. Fluid Saturated Rock Properties

On the base of basic concepts and theories on fluids and rocks, fluid saturated rocks are investigated as systems.

2.1.3.1. Surface Tension and Interfacial Tension Phenomena

Surface tension is a result of cohesive forces (inner forces) between molecules of a fluid independent of surrounding medium.

Interfacial tension is the result of adhesive forces in between two liquids at the contact surface. Here, the contact surface is not a geometrical two dimensional surface, but it has a thickness at molecular level.

Interfacial tension together with wettability of the rock, determine the relative permeability of a pore surface.

As a result of surface tension, liquids climb or sink by holding the walls of capillary solid channels depending on the degree of cohesive forces. This is known as capillary effect of surface tension.

CHAPTER 3

LITERATURE SURVEY OF NON-DARCY EFFECTS ON FLUID FLOW THROUGH POROUS MEDIA

Literature on fluid flow through porous media starts with empirical and unidirectional Darcy's Law [1]. Darcy's law as below is a linear relationship between laminar and single phase water (as a Newtonian fluid) flow through an isotropic porous medium, the dynamic viscosity of water and the pressure gradient:

$$u = -(K/\mu)(\delta p/\delta x) \qquad \text{(Eq. 3.1)}$$

where u is superficial velocity (L/T), K is permeability (L^2), p is pressure $M/(LT^2)$, μ is viscosity (M/LT), and x is dimension in x direction (L). In Darcy's equation given above the dynamic viscosity has a constant value due to assumed linear relationship where shear stress (as dependent variable) versus shear rates (as independent variable).

The deviations from Darcy's conditions have required numerous contributions to Darcy's law since quite early dates up to now.

The very first contribution to Darcy's Law has done by Jules Dupuit [17] known as Dupuit Assumption which states that ground water discharge is proportional to the saturated aquifer thickness.

The most significant and one of the earliest contributions to Darcy's Law due to deviations from Darcy's conditions has been made by P. Forchheimer [2] as below equation:

$$-(\delta p/\delta x) = (\mu/K)u + \beta\rho u^2 \qquad \text{(Eq. 3.2)}$$

where ρ is fluid density (M/L^3), and β is the non-Darcy coefficient (1/L). Here β coefficient has had different names in the literature such as turbulence factor, the coefficient of inertial resistance, the velocity coefficient, the non-Darcy flow coefficient, the non-Darcy coefficient, the Forchheimer coefficient, the beta factor, etc.

The deviations from Darcy's law categorically can be summarized as because of anisotropy in porous media (three dimensional changes in absolute permeability due to tortuosity, layers, fractures, etc.), multi phase flow such as gas, liquid and even sometimes solid flow due to drag forces (non-Newtonian fluid properties, relative permeability, saturation, wettability, gravity segregation, surface tension, interfacial tension, miscibility might become definitive), phase changes due to pressure drop (condensation and vaporization), and high flow rates (turbulence) in different geometries (linear, cylindrical, semispherical, etc).

In almost every decade of the last century many empirical and theoretical studies have been published but a clear definition of Non-Darcy flow coefficient covering all affecting parameters has not been developed yet. As a matter of fact, there is no common agreement on the causes of nonlinearity between the pressure gradient and velocity; some scientists attribute it to viscous forces [3], and some attribute it to inertial forces [4, 5, 6, 7 and 8]. It seems that non-Darcy effect on fluid flow due to viscous forces has not been adequately quantified yet. Especially, gas condensation near well bore regions due to turbulent raises the fluid viscosity which will increase the required pressure drop to flow, and consequently a non-Darcy effect in fluid flow occurs.

In the last decades, theoretical, numerical and experimental research and investigations have proceeded for better understanding non-Darcy effects in flow through porous media on the base of century old accumulated literature.

The survey in literature of non-Darcy flow has been grouped on the basis of non-Darcy flow effects in this part of the dissertation.

3. 1. Anisotropic Effects:

J.W. Cooper, et all [18] have developed a quantitative relationship between pore scale anisotropic parameters and non-Darcy flow coefficient, tortuosity and permeability by single phase and two phase flow experiments on carbonate and sand stone plugs in addition to numerical simulation. They have solved the connate water saturation effect on non-Darcy coefficient, and in terms of anisotropy, they have developed a relationship between the product of non-Darcy flow coefficient and permeability, and permeability tensor and non-Darcy coefficient tensor. In the study of J.W. Cooper, Klinkenberg effect and turbulence effect have been neglected. The practical applications of the solutions are to calculate the pressure drop of non-Darcy flow of gas, and to calculate non-Darcy flow coefficient in single phase and two phase flows. In case of no experimental data, non-Darcy flow coefficient can be estimated by submitted correlation. Absence of water saturation and relative permeability terms are the weakest points of this study.

F.R. Spena and A. Vacca [19] have investigated a potential formulation of non-linear models of flow through anisotropic porous media by non-linear filtration model to anisotropic tensor permeability, quadratic and cubic flow models, and inertial forces derived from dissipation potential. The problem solved by this study is to generalize one dimensional non-Darcy flow models to three dimensional through anisotropic porous media. As assumptions of the study, convex potential of dissipative forces as viscous and drag are definitive on inertial terms, and viscous forces are collinear with the form drag forces. Due to co-linearity between viscous and form drag forces, an anisotropic media in terms of porosity and permeability can be considered as isotropic in terms of inertial forces. The practical application of the solutions is to extend isotropic non-linear flow models to anisotropic porous media. The transition from linear Darcy regime to non-linear Forchheimer’s regime is gradual due to the convexity of mechanically dissipative potential of viscous and form drag forces, and thus from Forchheimer’s regime (local turbulence) to Frauds regime (turbulence dominated inertial terms) as well. The magnitude of collinear viscous forces and form drag forces depends on the non-negative scalar function of the magnitude of seepage velocity. A consistent and general non-linear anisotropic flow model has been obtained. Physical properties of the fluids in the reservoir are considered as constant. Phase behavior of fluids in the pore is not considered. What happens at the high level of Fraud regime? The disintegration of the rock! If so, submitted formulation can mathematically explain the mechanism of artificial fracturing of the reservoir. It can be extended for multiphase flow by implementing saturation and relative permeability terms. It can be applied to analyze the water influx into the reservoir to the conceptually analogical problems in different engineering disciplines.

C.A.P. Tavares, et al [33] have studied the combined effect of non-Darcy flow and formation damage on gas well performance of dual-porosity and dual-permeability reservoirs by analytical solution and finite difference 2D simulation for single well with cylindrical grid geometry. An interpretation of pressure drawdown, buildup and isochronal tests in dual-porosity and dual-permeability reservoirs with non-Darcy flow which causes high local velocities has been developed. Non-Darcy flow coefficient has been calculated by Jones' correlation [34]. Vertical and single well production and steady state radial flow have been assumed. The model is modifiable for other geometries. It has been seen that conventional interpretation of the early time data in dual-porosity and dual-permeability reservoirs with non-Darcy flow effect may lead errors. Combined effect of non-Darcy flow and physical skin damage as effective damage has expectedly been calculated higher than input physical damage. In high initial reservoir pressure systems, non-Darcy flow effect starts at high flow rates while in low initial reservoir pressure systems at low flow rates due to the higher gas densities in higher pressure systems. Non-Darcy flow effect is highly susceptible to physical skin damage. In all scenarios, at similar flow rates, calculated effective skin damages have been found higher than the input physical skin damages. Dual porosity cause higher calculated effective skin than dual permeability does.

3.2. Multi-phase and phase behavior effects:

M.I. Dickens, et al [26] have investigated the impact of gravity segregation on multiphase non-Darcy flow in hydraulically fractured gas wells. Reservoir simulation has been used under three situations: uniform influx flow conditions, long term water production due to an initial mobile water saturation, and cleanup of a gas well following hydraulic fracture stimulation. Geertsma's correlation [72] has been applied which has been applied to the case study took place in this dissertation and explained in “Theory in Modeling of the Problem” (Chapter 5). The study has been handled under the assumptions of steady state flow, homogenous reservoir, uniform water saturation, constant bottom hole pressure, the influx to the fracture by reservoir depletion rather than the forced influx when studying fractured gas well with production of mobile water, complete gravity segregation requiring low pressure drop in horizontal direction compared to the buoyancy forces in the vertical direction, the complete segregation as inconsistent with gas entry into the highly water saturated zone at the bottom, linear relative permeability in hydraulic fractures requiring zero residual water saturation, and Forchheimer equation satisfying to calculate gas resistance factor as a measure of non-Darcy effect. Assumptions do not consider pressure drop in the fracture which can cause condensation of gas phase and as a result it will create a third phase of condensate in addition to existing gas and water. Darcy or non-Darcy flow and linear and non-linear relative permeability have been checked to see the changes in effective permeability and effective conductivity due to mixed or segregated flows within the fractures. When non-linear relative permeability (with a Corey exponent of 2) and non-Darcy flow (with Geertsma's correlation) are modeled for mixed flow, effective permeability is found as 39% lower and pressure drop is 39 % higher than segregated flow case. When Darcy flow and linear relative permeability is modeled for mixed flow, the loss in effective permeability and pressure drop have been found negligible (1.2 %) by comparing with segregated flow. In case of mixed flow, non-linear relative permeability with Darcy flow reduces effective relative permeability (25 % loss) more than non-Darcy flow with linear relative permeability (13 % loss). In case of non-linear relative permeability with Darcy flow the pressure drop (43 %) is higher than linear relative permeability and non-Darcy flow (14 %). Effective dimensionless conductivity in mixed flow is lower than in segregated flow. In mixed flow case, Non-linear relative permeability with Darcy flow cause more loss in effective dimensionless conductivity (41 %) than in non-Darcy flow with linear permeability (21 %). But the loss in productivity due to Darcy flow and linear relative permeability in mixed flow is negligible (1.3 %) and the loss in effective conductivity is about 10 %. Multiphase and non-Darcy flow effects in hydraulically fractured gas wells reduce effective fracture conductivity. By ignoring gravity segregation, effective fracture conductivity can be underestimated by up to a factor of 2 when fracture relative permeability is non-linear and non-Darcy flow effect exists. Multiphase and non-Darcy flow effects in hydraulically fractured gas wells increase the pressure drop down the fracture and consequently reduce the effective fracture conductivity of the proppant. Effective permeability reduction caused by non-Darcy flow can be compensated by choosing a higher permeability proppant. Fredrick and Graves' 1st correlation (1994) underestimates non-Darcy flow effect, thus it should not be used in hydraulic fracture studies especially for high permeability proppant packs. The difference in effective fracture conductivity between two phase mixed flow and segregated flow models quantifies the amount of present segregation effects. The pressure gradient is inversely proportional to effective permeability, but also proportional to the flow rate. A relative increase in total pressure drop is related to a relative decrease in effective conductivity. Segregation increases by increasing conductivity in the fracture or by decreasing ratio of fracture length to fracture height. When the vertical over horizontal pressure gradient decreases the gravity segregation increases. The impact of segregation effects is largely caused by relative permeability and non-Darcy flow. Water/gas ratio does not significantly affect the difference in effective conductivity between mixed and segregated flow. Water/gas ratio does not affect the average pressure gradient in the fracture. Roughly one third of effective permeability in the fracture is lost due to mixed flow by comparing with segregated flow. As the water saturation decreases, the effective gas permeability decreases at greater than a linear rate with water saturation. Non-linearity due to relative permeability has greater effect on pressure drop and effective permeability than non-linearity due to non-Darcy flow. Effective conductivity and as a result productivity is more susceptible to non-Darcy flow and non-linear relative permeability than phase segregation effect due to gravity. By considering changes in phase saturation due to condensation, vaporization, the study can be extended. The chosen proppant and transporting fluid type is not defined. Quantitative results for each permutated scenario for certain type of proppant and transporting fluid will help in proppant and transporting fluid selection.

L. Jin and G.S. Penny [27] have investigated two phase non-Darcy gas flow through proppant Packs by experimental study under the assumptions of no gas condensation, constant gas and liquid densities under different pressures, and linear flow geometry. Under the mentioned assumptions, conductivity of proppant packs under two phase and non-Darcy flow, and coefficient of inertial resistance β have been predicted. By using the predicted values, mobile liquid saturation at certain gas-liquid flow rate, and the relative permeability of proppant pack by considering non-Darcy and two phase flow effects can be calculated. On the other hand, it provides some eye opener hints to understand fracturing fluid clean up process and proppant flow back mechanism under the effect of two phase flow. In case of dry gas flow Forchheimer's correlation works fine, but increasing liquid saturation in two phase flow starts deviation from the Forchheimer's correlation.

R.D. Evans and C.S. Hudson [28] have showed the effect of immobile liquid saturation on the non-Darcy flow coefficient in porous media under multiphase conditions by experimental approach with the assumptions of unidirectional linear flow, constant viscosity, density and gas deviation factor. Study submits a correlation to predict non-Darcy coefficient as a function of rock and fluid properties for multiphase flow. Viscosity and density are functions of pressure. Especially gases are more susceptible to pressure than liquids in terms of viscosity and density. β calculated at given density will be deviated by changing density due to changing pressure differential. In addition to density change, the effect of changing viscosity altogether will cause a deviation from Forchheimer's Equation results. The practical application of the solution is to find out the value of non-Darcy flow coefficient in *sand stones* under immobile liquid saturation multiphase flow by using the correlation developed in this experimental study. To estimate the value of β, Geertsma Equation is valid for certain range of permeability and porosity. β increases by increasing liquid saturation, and by decreasing permeability and porosity under the immobile multiphase flow. At a constant temperature, a unique relationship exists between β and the effective gas permeability, porosity, liquid saturation and effective overburden pressure. Using β values from published correlations (such as Janicek-Katz correlation) as function of porosity and permeability might give wrong estimations since these correlations does not consider the lithology changes. Therefore β should be developed for the particular rock in question. For different porosity and permeability values, the comparisons of Janicek-Katz correlation, the results of Geertsma Equation and the results of this study have been evaluated and submitted by graphs. Immobile liquid saturations reduces the value of β. Janicek-Katz correlation has been developed for carbonate formations. Geertsma Equation has been developed for sand stone with zero immobile saturation. Changing lithology and multiphase flow conditions require specific solution to estimate the value of β. Therefore, the comparison of the results of this experimental work with Janicek-Katz correlation and with Geertsma Equation is like comparing apples with oranges. If there is no any other choice to estimate the value of β, the results of Janicek-Katz correlation should be preferred to Geertsma Equation up to roughly 500 mD of permeability. At higher permeability values, lab experiments should be run to estimate the value of β. Similar experiments should be run for carbonate cores. Proposed experiments can be rerun by using a certain natural gas composition representing world average (instead of nitrogen) and crude oil samples at certain ranges of viscosities and API gravities (instead of glycerin) to obtain more general and more reliable correlations to find out the value of β. The concepts used in the solutions could be applied to find out mechanical skin effect on well productivity.

R.D. Barree and M.W. Conway (2007) [29] have investigated multiphase non-Darcy flow in proppant packs by laboratory experiments under the assumption of no phase change during the process. Multiphase flow conditions are implemented to the generalized equation for single phase non-Darcy flow. The solution can be used to predict non-Darcy multiphase flow coefficients in proppant packs under mentioned assumption. The value of the mean particle diameter T is constant for proppant packs and it is not affected by experimental conditions, unlike inertial flow coefficient β. The value of the mean particle diameter T can be determined by $T=1(k_d\beta)$ where k_d is constant Darcy permeability in Darcy, at flow ranges where the deviation from Forchheimer's equation is small. The transition constant can also be calculated by $T=\rho v/\mu$ from the Forchheimer plot when the linear Forchheimer curve is exactly twice the y-axis intercept value. The introduced transition constant T has been calculated as $1/(2D_m)$ where D_m is mean particle in cm. In reservoir scale, the mean particle diameter can be calculated closely only for proppants, but not for naturally occurred heterogeneous reservoir rocks. Applying the non-Darcy equation with transition constant instead of inertial flow coefficient β to high velocity multiphase flow in reservoirs might result erroneous. The transition constant determination from Forchheimer plot is applicable only in the laboratory but cannot represent the reservoir, and it cannot be determined at site. Proposed method can be applied to the porous and permeable media where particle size distributions are precisely predictable. If the wellhead multiphase rates can be translated to certain proppant pack saturations and flow capacities, then by analogy the submitted method can be applied to field cases to predict non-Darcy multiphase phase flow coefficients.

B. Ramirez, et all [20] have investigated non-Darcy flow in presence of retrograde condensation behavior and analyzed short term pressure transient tests in naturally fractured reservoirs by using single well compositional simulation. Reservoir pressure has been assumed above the dew point pressure, but below in near the wellbore to create non-Darcy flow. The practical use of this investigation is that, non-Darcy flow skin to be calculated under the presence of condensation in dual porosity and dual permeability reservoirs. Just by reducing the reservoir pressure more in near wellbore, non-Darcy effect in evaporation phase could also have been investigated.

F. Zeng and G. Zhao [35] have studied “gas well production analysis with non-Darcy flow and real-gas PVT behavior” by semi-analytical model integrated with pressure dependent gas properties and validated by finite difference method. Single gas production well located at the center of a closed circular reservoir and radial gas flow has been assumed. Study results allow to identify gas production rate behavior with non-Darcy flow, and to quantify normalized viscosity, Forchheimer number and the product of normalized gas viscosity and compressibility. Viscosity variation increases non-Darcy flow, lowers initial production rate and it has little effect on the production decline rate. In boundary dominated period, a large production decline rate identifies non-Darcy flow effect. The greater non-Darcy flow, relatively the longer steady production period. The greater the non-Darcy flow, the lower the initial production rate and the larger the decline rate. Fetkovich’s [36] type curves cannot be used where non-Darcy flow exists in the reservoir, because they underestimate reservoir permeability, overestimate well skin factor and misinterpret reservoir drainage area, thus the reservoir volume. In transient flow period, non-Darcy flow reduces the gas flow velocity in the reservoir, thus to deplete the reservoir takes longer time, and steady production period will be longer. In boundary dominated period, the reservoir pressure won't be enough to support additional pressure drop required by Forchheimer's inertial term, thus a larger decline rate occurs. During the boundary dominated period, at a certain skin with zero non-Darcy flow causes small production decline rate while at zero skin with a certain non-Darcy flow causes large decline rate. This phenomenon identifies the non-Darcy flow existence from the production data. At high Forchheimer's inertial term, traditional quadratic equation of Al Hussainy [37] derived from Ramey's [38] equation overestimates the production decline rate, while it gives good results under Darcy flow. During the boundary dominated period, dimensionless normalized viscosity and compressibility product gives smaller production decline rate than Carter's [39] model while in early time Carter's model gives small overestimation. In comparison of ideal gas and real gas behaviors of viscosity and compressibility product as a function of production time, in early time both gasses gives almost the same production rate decline, but in boundary dominated late time, ideal gas shows higher production decline rate than the real gas. Normalized viscosity variation by pressure has large effect on initial production rate but small effect in boundary dominated period. By decreasing pressure, increasing viscosity enhances non-Darcy flow. Non-Darcy flow in the reservoir is dominant if parameter b (reciprocal of decline curve exponent) in Arp's decline equation is less than its base value (b*) which can be observed as steeper production decline rate than exponential decline rate. Hence Forchheimer's number takes place in the equations. If b value is higher than b*, it is difficult to identify if non-Darcy flow exists or not. If they are almost identical and approaches to 0.5, then it can be said that the flow in the reservoir is Darcy type. The comparison of ideal gas and real gas in terms of viscosity and compressibility product, their resulted behavior is expected as a result of general laws of physics on gas compression and expansion. The solutions/results can be applied to condensate gas reservoirs, to naturally and/or artificially fractured reservoirs, and to multiphase flow reservoirs by adding the gravity effect.

3.3. Fracture effects:

J.A. Gil, et all [22] have investigated non-Darcy flow to design and evaluate fractured well tests incorporating wellbore storage by semi-analytical method, correlation and guide line, under the assumptions of laterally infinite reservoir, uniform thickness, vertical well intercepted by a fully penetrating hydraulic fracture, real gas flow, constant and uniform permeability, Darcy flow in reservoir and non-Darcy flow in fracture, and no mechanical skin. The practical use of this investigation under assumed conditions are to estimate non-Darcy coefficient, fracture half length and thus fracture conductivity, magnitude of the skin due to non-Darcy flow, without running two pressure tests at different production rates. Here, the critical value is the ratio of "reservoir permeability/fracture permeability". Actually, hydraulic fracturing operations are applied in tight reservoirs, that means mentioned ratio shall be quiet lower than '1' thus reducing the probability of non-Darcy flow. Mentioned method can be applied to the wells in reservoirs with naturally occurred low conductivity fractures. Especially in moderately permeable reservoirs with natural fractures the probability of non-Darcy flow is to be high. In high deliverability but low productivity wells are also a sign for non-Darcy effect.

T. Friedel and H.D. Voigt [23] have investigated non-Darcy flow in tight-gas reservoirs ($k<0.01$ mD) with fractured wells by in-house black oil numerical simulator containing pressure dependent transmissibility multiplier for permeability in the matrix and proppant packed fracture, under the assumptions of constant rate and constant pressure production, vertical well, stress dependent permeability, and single phase radial flow in addition to permeability less than 0.01 mD. The problem solved by this study is to identify the role of *reservoir and fracture non-Darcy flow effect* on well productivity in *fractured tight gas reservoirs* by considering *permeability (stress) dependency of inertial flow*. Practical application of this study is to take into account non-Darcy flow coefficient due to stress sensitivity of reservoir permeability in tight gas reservoirs and fracture closures. Tight gas reservoirs are stress-sensitive in terms of permeability of reservoir rock and proppant packed fracture. In both reservoir rock and proppant packed fracture, the permeability at a certain pressure decreases by decreasing reservoir pressure. Normally, a decrease in permeability increases the velocity which results an increase in non-Darcy flow effect. A decrease in permeability as a consequence of increasing the effective stress is accompanied by a reduction of flow velocities. There is almost a linear correlation between permeability, non-Darcy coefficients and effective stress. When the stress dependency, fracture closure and non-Darcy flow effects considered simultaneously, the reduction in productivity is lower than the summation of mentioned effects considered individually. Permeability dependency of non-Darcy flow coefficients is masked by stress dependency of permeability and fracture closure. Inertial flow affects the productivity despite the low gas rates. Depending on the proppant type, total gas production can reduce in the interval of 21-40% due to non-Darcy flow effects. New type curves have been presented for non-Darcy flow in fracture and reservoir to predict future well performance. The permeability sensitivity could have been investigated on the base of fluid's physical properties such as density. Mutual interaction effect of stress dependency of permeability, fracture closure and non-Darcy flow effect requires investigating the changes in fluid properties as functions of mentioned interacted parameters individually.

P. Handren, et al [24], have shown the impact of non-Darcy flow on production from hydraulically fractured wells by Stim-Lab's SLFrac production model based on Agarwal type curves and by inputting Lab measurements of incremental pressure drop due to multiphase and non-Darcy effects into SLFrac production model. The practical application of this study is to help proppant selection in designing stimulation for multiphase and non-Darcy flow reservoirs. When selecting a proppant for hydraulic fracturing, inertial forces in Forchheimer's term is more definitive than permeability. Unless non-Darcy and multiphase flow effects are considered, fracture conductivity predictions will be overestimated, effective producing fracture half length will be shorter, post stimulation production rates will be over estimated, proppant selection might be incorrect, production rate from fractured well will be reduced, total recoverable reserve will be reduced. To minimize the pressure drop due to non-Darcy effect domination within the fracture, it is necessary to reduce the inertial forces. The effects of multiphase flow through fracture are substantial and should not be ignored. Always non-Darcy flow considerations should be used for predictive purposes. Case studies show that non-Darcy effects is more significant than multiphase effects on fracture conductivity, thus in productivity. During fracturing operations in wells with low reservoir pressure, CO_2 should be preferred as transporting fluid instead of cross linked polymeric fluids not to reduce initial production rate. Lower mesh size of Light

Weight Ceramic (LWC) proppant has lower Forchheimer's coefficient than higher mesh size while it is vice versa in Sand proppant and Resin Coated Sand (RCS) proppant.

H. Mahdiyar et al [25] have developed a general method to estimate the effective fracture conductivity, thus effective wellbore radius, and flow skin factor by using in-house 2D mathematical simulator based on finite difference method, single well model, steady state flow of gas and gas condensate around hydraulically fractured well allowing for phase change in low interfacial tension (LIT) system, and by using 1D simulator for Open Hole systems. Instead of Hydraulically Fractured Well System approach, Equivalent Open Hole System has been used. This approach eliminates time consuming fine gridding applications. The assumptions of the study are steady state flow only from the fracture to the wellbore in a single layer and cylindrical reservoir, two separate uniform, isotropic porous media in fractured zone and remaining drainage zone, constant fracture width, vertical and symmetrical fracture against wellbore, negligible gravity and perforated casing effects, no pressure gradient internal and external radii of the fracture. Quite probable condensation process through the fracture might change the steady flow regiment which is not considered in the study. Inside the fracture the dominant velocity effect is inertial effect, but in the matrix the velocity effect is not significant. Instead of Hydraulically Fractured Well System, Equivalent Open Hole System approach in estimating flow skin factor is the base of the study. Pseudo steady and unsteady state flows. By pressure drop due to production, condensation stage will be followed by vaporization stage. The same formulation can be used for vaporization stage, too. Well productivity estimation could have been included.

M.L. Fraim and W.J. Lee [40] have determined the formation properties from long term gas well production affected by non-Darcy flow. The physical principles used in the solutions are Laplace space inverted by Stehfest's algorithm [41] for a vertically fractured well with finite conductivity, de-superpositioning in Laplace space, establishing non-Darcy flow correlation for vertically fractured wells and for homogenous reservoirs through deliverability equation, and algorithms for history matching and prediction of future well performance by developed type curves. The purpose of the study is determination of formation and well properties such as gas in place, drainage area, effective wellbore radius or half length of hydraulic fractures etc. by considering non-Darcy flow effect through developed type curves. Vertically fractured well located at the center of a unit square shaped homogenous and bonded reservoir, and finite conductivity for fractures have been assumed in the study. The practical applications of the solutions are the estimation of formation and well properties such as gas in place, drainage area, half length of hydraulic fractures etc. through developed type curves, modeling non-Darcy flow in the fracture of hydro fractured wells and in the formation of un-fractured wells, and modeling gas property changes as a function of pressure. By having the data of transient time and late time, and by reflecting them on developed type curves, following reservoir properties can be determined: Drainage area of the reservoir, fracture half length in fractured reservoirs, gas in place, reservoir permeability. As of today's literature, so many other variables have been added to this kind of early dated efforts. No doubt, it helped many reservoir engineers in approximately estimating some reservoir characteristics such as reserve estimation, fracture half length calculation, etc. in the last decade.

3.4. Well completion and skin effects:

J. Hagoort [30] has developed an improved model for estimating flow impairment by perforation damage. Method estimates perforation damage skin factor in two components as reduction in permeability and increase in non-Darcy flow. McLeod's inflow model [31] has been used in the study but instead of radial geometry, prolate spheroidal flow geometry has been applied in the numerical model. The assumptions of the solutions are prolate spheroidal flow geometry, steady state flow, straight, elongated, circular perforation holes are perpendicular to the wellbore and concentrically surrounded by a damaged zone of crushed and compacted rock due to perforation operation, and lower permeability and higher inertial resistance coefficient (non-Darcy flow coefficient) exist in perforation damage zone. Assumed flow geometry toward perforation hole is more realistic than cylindrical flow geometry. The practical applications of the solutions are to estimate the perforation effect on productivity of a perforated well and better understanding of the impact of crushed zone on the flow efficiency of individual perforations. Potential for non-Darcy flow in perforated wells is higher than in open-hole completions. Non-Darcy skin calculated in prolate spheroidal flow geometry is 1.4 times greater than found by radial flow geometry of McLeod's [31] flow model. For a single perforation, prolate spheroidal flow geometry can be more realistic than radial flow geometry. But mostly the perforation configurations are designed as spiral spacing through the pay zone, which cause helical flow paths around the perforation holes in the pay zone near wellbore. When the same well is in service for both injection and production in sequential time intervals such as underground gas storage wells, the crushed zone will act as a membrane against flow. Membranes have two sides with different contamination levels. The plot of flow rate versus pressure difference to maintain the fluid flow for injection period and for withdrawal period will create a hysteresis due to different contamination levels of membrane sides. By using the method introduced in this study, or by considering helical flow paths in quantification of mentioned hysteresis, flow impairment by perforation damage can be estimated.

J.P. Spivey, et all [21], have estimated non-Darcy flow coefficient from a single pressure build up test data following constant rate production in perforated cased completion with constant wellbore storage, infinite acting radial flow by using algorithm derived from diffusivity equation and by constructing type curves for build up tests with non-Darcy skin factor. Since the assumption implies non-Darcy flow occurrence through the perforation channels, the results are not reasonable for naturally or artificially fractured wells, in vugular or vertically layered anisotropic porous media, or in tight reservoir rocks. The results obtained by this method in wells satisfying the assumed conditions, can be used in identifying candidate wells for stimulation and in making more reliable decisions for proposing workover.

3.5. Flow rate effects:

M. Fourar, et al [32] have investigated inertia effects in high-rate flow through heterogeneous porous media by using numerical simulator. The assumptions of the investigation are that the flow is governed by Forchheimer's equation, the fluids are compressible, and the media are serial layered, parallel layered and correlated. Heterogeneous permeability effect on high rate velocity flows in porous media is the focusing point of the study. A theoretical relationship has been proposed for the inertial coefficient as a function of Reynolds' Number and the characteristics of the media. For the serial layers, the effective inertial coefficient is independent of Reynolds' Number and decreases by the increasing ratio of variance and the mean permeability. For the parallel layers (stratified porous media) and correlated media, the effective inertial coefficient is a function of Reynolds' Number and increases by the increasing ratio of variance and the mean permeability. Effective inertial coefficient is constant only for parallel type layers. Inertial effects reduce the permeability in high flow velocity zones more than in low flow velocity zones. In stratified porous media high Reynolds' Numbers have a tendency to establish a uniformly low effective permeability field. This study is a contribution to Forchheimer's equation by investigating the coefficient inertia effect as a function of Reynolds' Number, particularly velocity, in heterogeneous porous media. The solutions/results could be extended or improved by effective inertial coefficient to be investigated as functions of the mean permeability and the standard deviation. The same methodology should be applied to the cases of gas phase, multiphase, and condensation occurrence. It can also be applied to the corresponding problems in hydrology, geothermal energy and chemical engineering.

3.6. Thermal effects:

P.V.S.N. Murthy, P. Singh [43] have studied heat and mass transfer by natural convection in a non-Darcy porous medium by similarity solution and specified power function of mass flux. In the study, constant wall temperature which is higher than the ambient temperature, homogeneous fluid saturation in isotropic porous medium has been assumed. The problems solved by this study are to find out the effects of Grashof Number [44] as "Buoyancy Force / Viscose Force" representing the inertial effects in the porous medium, Buoyancy Ratio, Lewis Number [45] representing the diffusivity ratio ($Le=\alpha/D$) and Surface Mass Flux on non-dimensional heat and mass transfer coefficients, and to find out the effect of lateral mass flux on the free convection heat and mass transfer from a vertical wall in a fluid saturated porous medium with Forchheimer flow model. The practical applications of the solutions are generally geothermal reservoir engineering, thermal oil recovery methods. As the mass flux parameter moves from the injection domain to the suction domain the Nusselt [46] Number as "Total Heat Transfer / Conductive

Heat Transfer" and Sherwood Number [47] as "Mass Diffusivity / Molecular Diffusivity" increase while they decrease in the Forchheimer flow region. Increasing diffusivity ratio (Lewis number) increases mass transfer coefficient (Sherwood number) to a certain degree depending on the buoyancy ratio parameter and on intensity of injection parameter and then further increase in Lewis number cause a reduction in mass transfer coefficient in case of fluid injection. Increasing inertial effects reduces the flow intensity, and heat and mass transfer coefficients. Increasing diffusivity ratio (Lewis Number) decreases the heat transfer coefficient, increases the mass transfer coefficient. Fluid suction increases heat and mass transfer. At a constant inertia effect and Buoyancy Ratio, as the diffusivity ratio increases the heat transfer coefficient (Nusselt number) decreases but mass transfer coefficient (Sherwood number) increases for the suction period. All mentioned results are reasonable for the first suction/injection cycle. The fluid flow through the wall will clean the outer wall from contamination. Thus in the second cycle, fluid will flow through cleaned wall. The solutions/results could be extended or improved by repeating the process for several cycles. The concepts used in the solutions could be applied to underground gas storage operations.

P.V.S.N. Murthy, P. Singh [48] have also studied thermal dispersion effects on non-Darcy convection with lateral mass flux by method of similarity, numerical integration by fourth order of Runge-Kutta [49] and Newton-Raphson [50] methods for proper initial guess value. The assumptions of the study are the medium governing by Forchheimer extension, thermal diffusivity constant as the sum of molecular diffusivity and the dispersion thermal diffusivity due to mechanical thermal dispersion, velocity distribution of suction or injection as a power law function of distance, isothermal hot wall permeable for lateral mass flux, and higher wall temperature than ambient. The problems solved by this study are the impact of thermal dispersion with lateral mass flux on non-Darcy in fluid saturated porous media, and the combined effect of thermal dispersion and fluid suction/injection on the heat transfer rate. The results can be applied in geothermal applications and thermal oil recovery applications. Similarity solution is possible only for uniformly heated hot wall with injection/suction velocity as a function of $Ax^{1/2}$. Increasing thermal dispersion coefficient increases heat transfer. The heat transfer rate increases as the mass flux parameter passes from injection domain to suction domain. Reservoir rocks are expandable by heat as well as liquids. Therefore the porosity and permeability of the porous media are also temperature dependent. Porosity and permeability should be taken as temperature dependent.

3.7. Model studies of non-Darcy effects:

F. Zeng and G. Zhao [42] have developed a semi-analytical model for reservoirs with Forchheimer's non-Darcy flow on transient pressure behavior. Vertical well, infinite acting homogeneous reservoir, steady state radial flow, constant wellbore storage and constant skin factor have been assumed. The problems solved by this study are to predict non-Darcy flow effect not only at the completions but also in the reservoir region of several hundred times of wellbore radius, to supply type curves for pressure build up and drawdown tests, and to estimate the skin factor for non-Darcy flow across completions and the dimensionless Forchheimer number for non-Darcy flow in the reservoir by common drawdown, buildup and variable rate tests. The practical applications of the solutions are to identify the existence of non-Darcy flow in the reservoir, and to estimate non-Darcy flow parameters both in the reservoir and across the completion by using conventional well pressure tests. The pressure drawdown test curves reflect larger transition periods with lesser slope when non-Darcy flow is considered in the reservoir and at the completions, and on the other hand, pressure build up test curves reflect less transition period and steeper slopes. Permeability is dominant factor in defining inertial factor. The difference in permeabilities of reservoir and completion area can be quite different due to perforation, damage or stimulation, so can the inertial factor. Thus, the flow equation for completion area should have different parameters than that for the reservoir. The model and algorithm used in this study can be applied to gas condensate and multiphase flow cases. For drawdown and buildup tests with non-Darcy flow in the reservoir, the pressure derivative curves have tendency to approach to the constant of 0.5, in radial flow and compared to the cases with only non-Darcy flow across the completion region. The tendency of pressure derivative curves to approach to a constant is a diagnostic character of non-Darcy flow existence in the reservoir. In estimating Forchheimer's Number for non-Darcy flow in the reservoir and the skin factor for non-Darcy flow across the completion, the pressure build up tests are more reliable than drawdown tests. This is a very productive and practical method in identifying and estimating Forchheimer's number for non-Darcy flow in the reservoir, non-Darcy flow skin across the completion, permeability changes at the completion region due to mechanical skins, perforation and stimulation. The model can be applied for multiphase flows. Withdrawal and injection periods of gas storage wells can be analyzed by the same method. Method can be modified for different flow geometries.

S.A. Mathias, et al [51] have developed an approximate solution for Forchheimer flow to a well by numerical modeling through finite difference, matched asymptotic expansions, Laplace transformation, and similarity solution for large turbulent flow dimensionless coefficient. Existence of significant wellbore storage, high turbulence and infinitesimally small well radius has been assumed. The comparison of finite difference solution with Sen's solution [52] gives good match in post linear flow (turbulent flow), but under estimation in short time (non-Darcy flow) and over estimation in medium time. The comparison Matched Asymptotic Expansion with Sen's solution gives the same match in late time flow but under estimation in short time and medium time. The comparison of Laplace solution with Sen's solution gives almost similar results as in Matched Asymptotic Expansion. The comparison of Similarity solution with Sen's solution again submits similar results as above. Finally, since all solutions are approximations, it is not possible to say which one is better. Mentioned approximate solutions can be used for post linear flow (late time) but not for pre linear flow (early time). The best fit curve combining all mentioned approaches can be more reliable for post linear flow (late time).

3.6. Correlations of non-Darcy flow effects:

F.E. Londono, et al [53] have studied the behavior of gas viscosity and gas density for hydrocarbon (HC) gases to develop simplified correlations. HC gas viscosity is a function of pressure, temperature, density and molecular weight, and on the other hand HC gas density is a function of pressure, temperature and molecular weight as clearly defined in Equation of State (EOS). On the other hand, since HC gases are real gases, gas deviation factor (Z) [54, 55] is also a function of pressure, temperature and density. In investigating HC gas viscosity, authors have considered

Jossi, Stiel and Thodos Correlation [56] and Lee, Gonzales and Eakin Correlation [57].

K.G. Brown and W.K. Sawyer [58] have investigated two surveillance methods for operators to track the damage including non-Darcy effects in addition to mechanical skin and total skin. One of them is called Sawyer Brown Method (SB Method), and the other one is called Minute Rise De-convolution Method (MRD Method). SB Method has been developed on the base of pseudo steady state radial gas flow. The main motivation of this study was to find out the path of damage development over time which might provide considerable insight to the source of the damage. MRD Method has been developed on the base of real gas law to estimate the flow rate. The advantages of these two methods are no requirement of service companies or down-hole equipment, and the wells can be tested at more frequent intervals than conventional testing methods.

J.P. Spivey, et al [59] have studied how to identify the timing and sources of damage for underground gas storage wells commonly using wellhead Electronic Flow Measurement (EFM) systems. Authors have developed new analysis modules to process extremely large data of EFM systems.

CHAPTER 4

STATEMENT OF THE PROBLEM

As a practical method in literature to track the occurrence of damage including non-Darcy effect, Kenneth G. Brown and Walter K. Sawyer in 2002 [58] have developed a method called “Sawyer-Brown Method” (SB Method). The theoretical base of SB Method is pseudo steady state radial gas flow.

As explained in Chapter 5 in detail, in solving pseudo steady state radial gas flow by SB Method, gas viscosity dependent constants have been used although they are functions of gas viscosity and gas compressibility which are dependent variables of pressure, temperature, density and molecular weight. In the last decade, following SB Method which has been introduced in 2002, no new contribution has been done to the mentioned method. The major objective and new contribution of this dissertation is to investigate non-Darcy effect by considering gas viscosity, gas deviation factor and gas density as dependent variable of pressure and temperature. As explained in Chapter 8, fluid flow in the reservoir has been assumed as isothermal. Therefore, viscosity, deviation factor and density of gas have been assumed as dependent variable of pressure. To achieve the objective of this dissertation, Jossi, Stiel and Thodos Correlation (JST Correlation) [56], implicit model of Londono-Archer-Blasingame [53] approach, Lee-Gonzalez-Eakin (LGE Correlation) [57] approach and P.M. Dranchuk and J.H. Abou-Kasem known as DOK-EOS Method [62] have been introduced to Sawyer-Brown Method [58] in addition to “gas viscosity versus pressure” (as given in Fig.7.5.) and “gas compressibility versus pressure” (as given in Fig. 7.6.) correlations developed on the basis of field data.

CHAPTER 5

THEORY IN MODELING OF THE PROBLEM

5.1. Assumptions

Isothermal and radial pseudo steady state gas flow has been assumed. Reasons of these assumptions have been explained in Chapter 6.

5.2. Sawyer-Brown Method

As mentioned in Chapter 4, Sawyer-Brown Method (SB Method) has been developed by Kenneth G. Brown and Walter K. Sawyer in 2002 [58] as a practical method to track the occurrence of damage including non-Darcy effect. The theoretical base of SB Method is pseudo steady state radial gas flow as:

$$P_r^2 - P_{wf}^2 = Aq(b_o + s_m + Dq) \qquad \text{(Eq.5.1)}$$

where P_r is reservoir pressure (psi), P_{wf} is flowing well bottom hole pressure (psi), q is flow rate (MMscf/D), s_m is mechanical skin (dimensionless), D is turbulence coefficient (1/MMscf). In Eq.4.1. “A” and “b_o” are constants and given by following equations:

$$A = (1.422 \text{ x } 10^6 \mu_g zT) / (k_g h) \qquad \text{(Eq.5.2)}$$

where μ_g is gas viscosity(cP), z is gas compressibility factor, T is reservoir temperature (^{0}R), k_g is gas permeability (mD), h is average reservoir thickness (ft), and:

$$b_o = \ln(r_e/r_w) - 3/4 \qquad \text{(Eq.5.3)}$$

where r_e is drainage radius (ft) and r_w is well radius (ft).

By the authors of SB method, Eq.5.1 has been expressed in quadratic form as the Jones Equation [60]:

$$P_r^2 - P_{wf}^2 = aq^2 + bq \qquad \text{(Eq.5.4)}$$

where “a” and “b” are coefficients of Jones Equation as:

$a = AD$ (Eq.5.5)

and

$b = A(b_o+s_m)$ (Eq.5.6)

By implementing Eq.5.5 into Eq.5.1 and solving it for s_m:

$s_m = (1/A)\ (\Delta P^2/q) - Dq - b_o$ (Eq.5.7)

Thus, total skin (s_T) will be as:

$s_T = s_m + Dq$ (Eq.5.8)

or through Eq.5.7:

$s_T = [\Delta P^2/(Aq)] - b_o$ (Eq.5.9)

In SB Method, “A” value in Eq.5.2 has been taken as constant although it is a function of gas viscosity (μ_g) and gas compressibility (z) which are pressure (P_r and P_{wf}), temperature (T), density (ρ) and molecular weight (Mw) dependent variables.

5.3. Al Hussainy-Ramey Approach by Pseudo Pressure:

On flow of real gases through porous media, Al Hussainy and Ramey [37] have proposed a linearization approach by using pseudo pressure.

$m(p) = 2 \int_{pm}^{p} (p/\mu z)dp$ (Eq.5.10)

Here, m(p) is real gas pseudo pressure, μ (real gas viscosity) and z (real gas compressibility factor) are function of pressure at boundary conditions of pm and p. In solving Eq.5.10, authors have applied Eilerts et al [61] and reached at following equation:

$[m(p_r) - m(p_{bh})] = [(q_{sc}p_{sc}T) / \pi khT_{sc}][\ln(r/r_w) + s + Dq_{sc}]$ (Eq.5.11)

Here $m(p_r)$ and $m(p_{bh})$ are real gas pseudo pressure at reservoir and bottom hole consequently.

5.4. Viscosity Correlations:

Regarding hydrocarbon gas mixtures viscosity and density behavior as pressure dependent variables, Londono F.E. and et al. [53] had reported simplified correlations to optimize existing models by using extensive number of measured gas mixture viscosities and densities, to create large scale database of mentioned properties including their pseudo reduced properties over a wide range of composition, pressure and temperature. They have refitted Jossi, Stiel and Thodos Correlation (JST Correlation) [56]. In original JST Correlation, proposed for gas viscosity is as:

$$[(\mu_g-\mu^*)\xi + 10^{-4}]^{1/4} = f(\rho_r) \qquad \text{(Eq.5.10)}$$

where μ_g is gas viscosity (cP), μ^* is gas viscosity at low pressure(cP), and reduced density function $f(\rho_r)$ is:

$$f(\rho_r) = 0.1023+0.023364\,\rho_r + 0.058533\,\rho_r^2 - 0.040758\,\rho_r^3 + 0.0093324\,\rho_r^4 \qquad \text{(Eq.5.11)}$$

Reduced density ρ_r (dimensionless) is:

$$\rho_r = \rho/\rho_c \qquad \text{(Eq.5.12)}$$

ρ is hydrocarbon gas mixture density (g/cc) and ρ_c is density at critical point (g/cc).

In Eq.5.10 ξ is:

$$\xi = T_c^{1/6} / (M_w^{1/2} P_c^{2/3}) \qquad \text{(Eq.5.13)}$$

where T_c is critical temperature (K), M_w is molecular weight (lb/lb-mol) and P_c is critical pressure (atm).

JST Correlation coefficients in Eq.5.11 and Eq.5.13 have been refitted with optimized coefficient by Londono F.E. and et al. [53] as:

$$f(\rho_r) = 0.10367+0.131243\rho_r+0.0171893\rho_r^2-0.0312987\rho_r^3+ 0.00884909\,\rho_r^4 \qquad \text{(Eq.5.14)}$$

$$\xi = T_c^{-0.121699} / (M_w^{0.391956} P_c^{-0.150857}) \qquad \text{(Eq.5.15)}$$

The data base used in obtaining coefficients of Eq.5.11 and Eq.5.13 had an upper limit of 2 for reduced density. But data base used in obtaining optimized coefficients of Eq.5.14 and Eq.5.15 had reduced densities greater than 2.

Another considered correlation in estimating hydrocarbon gas viscosity is Lee, Gonzales, and Eakin Correlation (LGE Correlation) [57]:

$$\mu_g = 10^{-4} K \exp(X \rho^{Y}) \qquad \text{(Eq.5.16)}$$

where:

$$K = [(9.379 + 0.01607 M_w) T^{1.5}] / (209.2 + 19.26 M_w + T) \qquad \text{(Eq.5.17)}$$

$$X = 3.448 + (986.4 / T) + 0.01009 M_w \qquad \text{(Eq.5.18)}$$

$$Y = 2.447 – 0.2224 X \qquad \text{(Eq.5.19)}$$

Here μ_g is hydrocarbon gas mixture viscosity, ρ is density (g/cc), M_w is molecular weight of (lb/lb-mole) and T is temperature (^{0}R).

Londono F.E. and et al. (2002) [53] had optimized LGE Correlation coefficients given in Eq.5.17, Eq.5.18, and Eq.5.19 as:

$$K = [(16.7175 + 0.0419188 M_w) T^{1.40256}] / (212.209 + 18.1349 M_w + T) \qquad \text{(Eq.5.20)}$$

$$X = 2.12574 + (2063.71 / T) + 0.0119260 M_w \qquad \text{(Eq.5.21)}$$

$$Y = 1.09809 – 0.0392851 X \qquad \text{(Eq.5.22)}$$

Following Implicit Model had also developed by Londono F.E. and et al. [53] to estimate hydrocarbon gas mixture viscosity as function of gas viscosity at 1 atm, gas density and temperature:

$$\mu_g = \mu_{1\,atm} + f(\rho) \qquad \text{(Eq.5.23)}$$

where

$$\mu_{1\,atm} = [-6.39821 – 0.6045922 \ln(\gamma_g) + 0.749768 \ln(T) + 0.1261051 \ln(\gamma_g)\ln(T)] / [1 + 0.0697180 \ln(\gamma_g) – 0.1013889 \ln(T) – 0.021594 \ln(\gamma_g)\ln(T)] \qquad \text{(Eq.5.24)}$$

here γ_g is gas specific gravity and T is temperature (^{0}R).

$f(\rho) = (a + b\rho + c\rho^2 + d\rho^3) / (e + f\rho + g\rho^2 + h\rho^3)$ (Eq.5.25)

where ρ is gas density (g/cc), and:

$a = 0.953363 – 1.07384T + 0.00131729T^2$ (Eq.5.26)

$b = -0.971028 + 11.2077T + 0.0901300T^2$ (Eq.5.27)

$c = 1.01803 + 4.98986T + 0.302737T^2$ (Eq.5.28)

$d = -0.990531 + 4.17585T – 0.636620T^2$ (Eq.5.29)

$e = 1.00000 – 3.19646T + 3.90961T^2$ (Eq.5.30)

$f = -1.00364 –0.181633T – 7.79089T^2$ (Eq.5.31)

$g = 9.98080 – 1.62108T + 0.000634836T^2$ (Eq.5.32)

$h = -1.00103 + 0.676875T + 4.62481T^2$ (Eq.5.33)

Average absolute error for above described Implicit Model to estimate viscosity is 3.05 percent.

5.5. Density Correlations:

Equation of State (EOS) for real gases is:

$\rho = (1 / 62.37)(P / z)(M_w / RT)$ (Eq.5.34)

where 62.37 is conversion factor (1 g/cc = 62.37 lb/ft^3), ρ is gas density (g/cc), P is pressure (psia), M_w is molecular weight (lb/lb-mole) z is gas compressibility factor (dimensionless), T is temperature (^0R) and R is universal gas constant 10.732 (psia ft^3 / lb-mole ^0R).

M.B. Standing and D.L. Katz [54] had presented gas compressibility factor estimation by explicit function of pseudo-reduced pressure and temperature. P.M. Dranchuk and J.H. Abou-Kasem [62] had presented following equation known as DAK-EOS to calculate z-factor:

$z = 1 + [0.3265 + (-1.0700/T_r) + (-0.5339/T_r^3) + (0.01569/T_r^4) + (-0.05165/T_r^5)]\rho_r$

$+ [0.5475 + (-0.7361/ T_r) + (0.1844/ T_r)]\rho_r^2 - 0.1056[(-0.7361/ T_r) + (0.1844/ T_r^2)]\rho_r^5$

$+ 0.6134(1 + 0.7210\rho_r^2)(\rho_r^2/T_r^3)\exp(-0.7210\ \rho_r^2)$ (Eq.5.35)

where z is gas compressibility factor (dimensionless), T_r is reduced temperature (dimensionless), ρ_r is reduced density (ρ/ρ_c dimensionless), ρ is density (g/cc), and ρ_c is:

$\rho_c = z_c(P_r / zT_r)$ here $z_c = 0.27$ (Eq.5.36)

Londono F.E. and et al. [53] had resolved DAK-EOS by using H.F. Poettmann and P.G. Carpenter [55], and modified Eq.5.35 with new coefficients as:

$z = 1 + [0.3024696 + (-1.046964/T_r) + (-0.1078916/T_r^3) + (-0.7694186/T_r^4) + (0.1965439/T_r^5)]\rho_r + [0.6527819 + (-1.118884/ T_r) + (0.3951957/ T_r)]\rho_r^2 - 0.09313593[(-1.118884/ T_r) + (0.3951957/ T_r^2)]\rho_r^5 + 0.8483081(1 + 0.7880011\rho_r^2)(\rho_r^2/T_r^3)\exp(-0.7880011\rho_r^2)$ (Eq.5.37)

Then, they had optimized DAK-EOS for z-factor coupled with:

$P_{pc} = 725.89 - 70.27\gamma_g - 9.05\gamma_g^2$ (Eq.5.38)

$T_{pc} = 40.39 + 549.47\gamma_g - 94.01\gamma_g^2$ (Eq.5.39)

where P_{pc} is pseudo-critical pressure (psia), T_{pc} is pseudo-critical temperature (^{0}R), and γ_g is gas specific gravity (air=1.0).

This optimized model provides average absolute error is 3.06 percent for estimating z-factor by DAK-EOS method.

5.6. Al-Marhoun Correlation

Although the reservoir studied in this dissertation is a gas reservoir with no oil, in case of gas condensation, Rs factor (solution gas oil ratio) values are calculated by Al-Marhoun Correlation [63]. According to Al-Marhoun correlation:

$Rs = \{x / [(\gamma_g^{-1.87909})(\gamma_c^{3.04659})(T^{1.302347})]\}^{(1/0.722569)}$ (Eq.5.40) where

$X = [-b + \text{Sqrt}(b^2 - 4ac)] / 2a$ (Eq.5.41)

and

$a = -2.278475 \times 10^{-9}$ (Eq. 5.42)

$b = 7.02362 \times 10^{-3}$ (Eq. 5.43)

$c = -64.13891 - P$ (Eq.5.44)

here γ_g is gas specific gravity, γ_c condensate specific gravity, and T is temperature (^{0}R).

CHAPTER 6

METHOD OF SOLUTION

Throughout this dissertation, factors causing deviations from Darcy flow behavior have been investigated in pseudo steady state radial gas flow model. The effect of turbulence and viscous forces have been focused on and modeled by CMG IMEX Simulator, their individual, mutual and collective effects on hydrocarbon flow behavior in porous media quantitatively have been studied and finally predicted by using the field data of North Marmara Underground Gas Storage. Production history and reservoir parameters of KM-1A well among the wells in North Marmara Underground Gas Storage have been chosen since this well is vertical which satisfies radial pseudo steady state gas flow assumption. Besides, isothermal gas flow through porous media also has been assumed by considering three supporting factors:

a. Gas deviation factor calculated from the field data is below and close to the value of 1 as seen in Figure 7.6.

b. Permeability values calculated by using the porosities from Density Log for perforated producing layers doesn’t show a tight reservoir as seen in Table.B.1.

c. Pressure drop at the bottom of well is not high as to cause Joule-Thompson effect [84] which is mainly result of changes in gas deviation factor as a function of pressure, and results in temperature drop in the bottom of the well due to high pressure drop. Pressure drop graphs and tables for the investigated gas well (from Fig.7.24 to Fig.7.27 and from Table C.1 to C.4) also shows the amount of pressure drops as a result of production history. There, it can clearly be seen that the pressure drops at the bottom hole is not considerable for Joule-Thompson effect.

For radial fluid flow through porous medium, a single and vertical well has been modeled in CMG IMEX numerical simulator. Reservoir zone has been divided to 30 parallel layers as seen in Figure 6.1. and Figure 6.2. These 30 layers have been calibrated depending on permeability values calculated from density log as given in Table B.1.

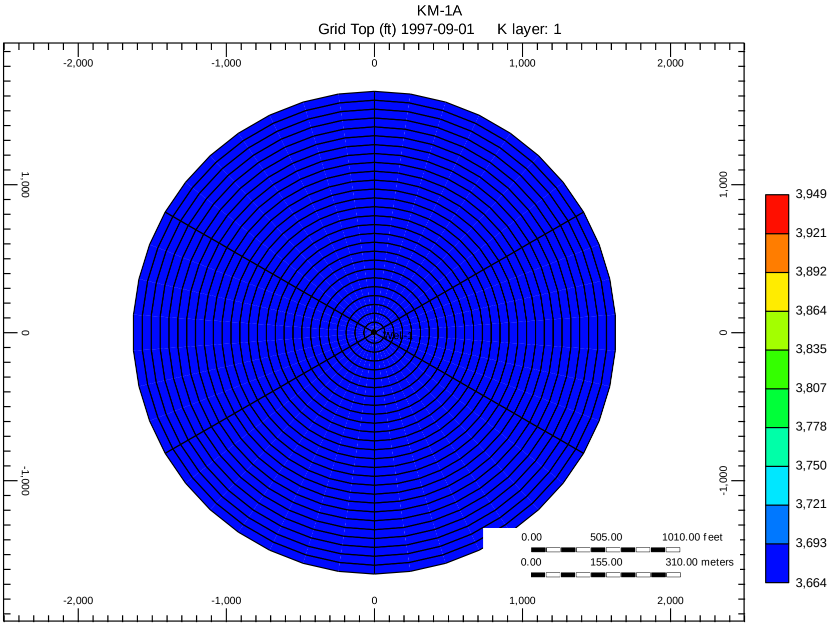

Figure 6.1: Grid top view for single and vertical well through porous medium (in the legend at right bottom, the red color shows the deepest layer's depth while blue shows the toppest layer's depth.).

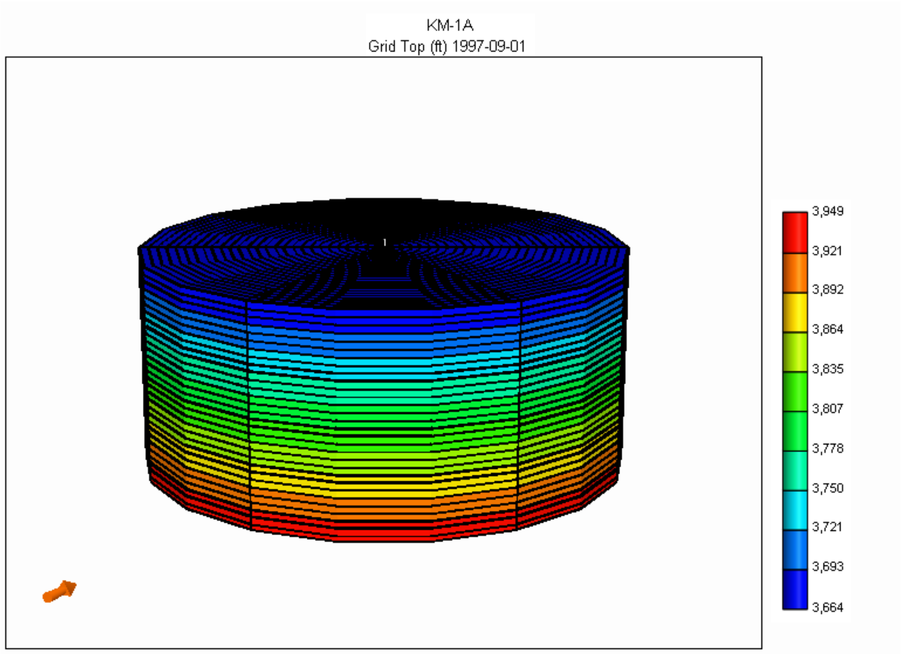

Figure 6.2: Three dimensional view of grid for a single and vertical well through porous medium (in the legend at right bottom, the red color shows the deepest layer's depth while blue shows the toppest layer's depth.)..

As explained in Chapter 5, Sawyer Brown Method (SB Method) [58] has been based on pseudo steady state radial gas flow. In solving pseudo steady state radial gas flow equation (Eq.5.1), gas viscosity, density and gas deviation factor have been taken as pressure dependent variables.

To achieve the solution, North Marmara gas production and pressure history data have been entered to CMG IMEX simulator as input in addition to other calibration data such as porosity and permeability. The simulator has been run for different scenarios such as Darcy flow, non-Darcy flow with Geertsma correlation [72], Frederick and Graves First and Second Correlations [71].

In applying Geertsma Correlation [72], following constants have been implemented to the simulator:

$\alpha = 48511.34$ $N1g = 0.5$ $N2g = 5.5$

In applying Frederick and Graves First Correlation [71], following constants have been input to the simulator:

$\alpha = 7.89E10$ N1g = 1.6 N2g = 0.404

In applying Frederick and Graves Second Correlation [71], following constants have been input to the simulator:

$\alpha = 2.11E10$ N1g = 1.55 N2g = 1.0

The results have been extracted as excel table after each run of the simulator. Then, Jossi, Stiel and Thodos Correlation (JST Correlation) [56], Lee, Gonzales, and Eakin Correlation (LGE Correlation) [57], implicit model of Londono F.E. and et al. [53], P.M. Dranchuk and J.H. Abou-Kasem[62] (DOK-EOS Method) have been used in combined on the basis of "Sawyer Brown Method" [58] by using the extracted data.

Instead of having a constant viscosity and gas deviation factor of Sawyer Brown Method, gas viscosity, gas deviation factor and gas density values have been taken as function of pressure. Thus, by above mentioned combinations and correlations, a contribution has been done to Sawyer Brown Method.

To calibrate the bottom hole pressures obtained from simulation runs with KM-1A well bottom hole pressures, following well test data has been taken [68]:

Table 6.1: Well test results for KM-1A

Q, MMSCF/day	**P_{bh}, psi**
8.2	2016
9.6	2006
11.3	1995
13.9	1971

Resulting graph from Table 6.1. is given in Figure 6.3.

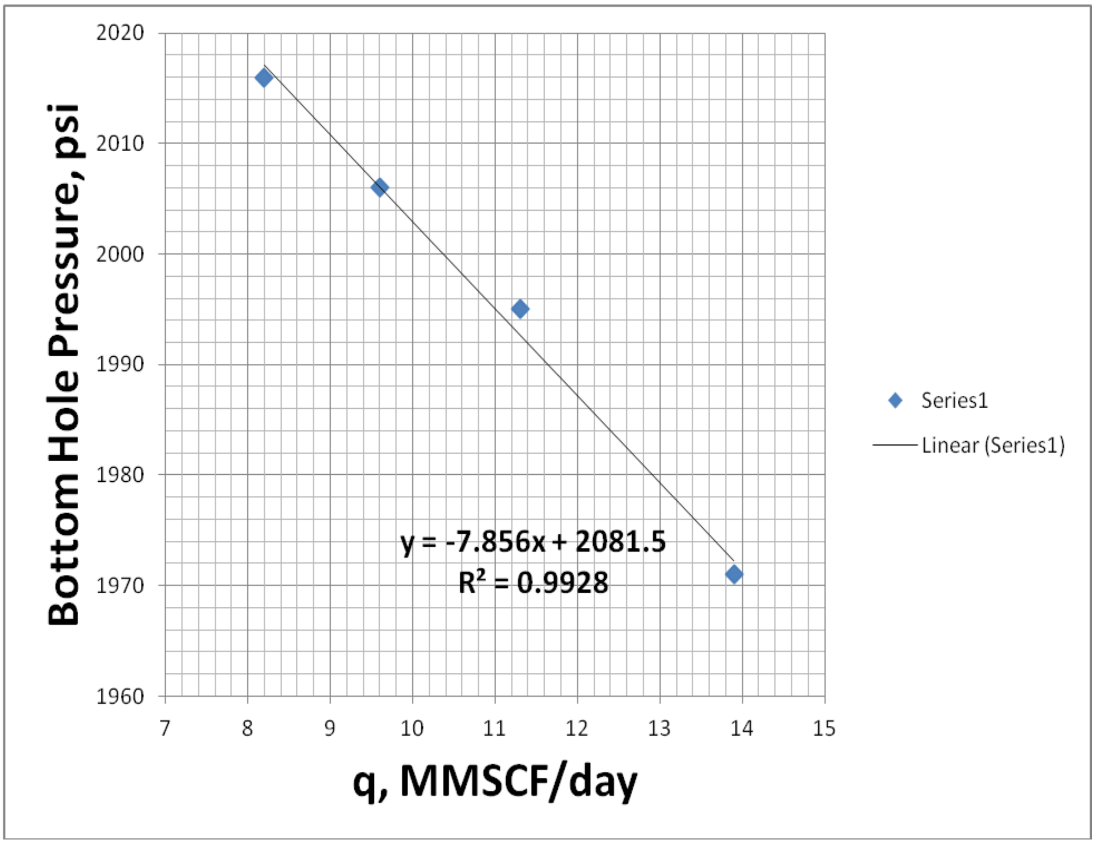

Figure 6.3: Bottom-hole pressure versus flow rate (Table 6.1).

By using the correlation in Figure 6.2 which is produced with well test data of KM-1A well, calibrated pressures against production rates have been tabulated in Table 6.2.

The error analysis of this calibration is also given in Figure 6.3. As it is seen in the error analysis, for all production rates of North Marmara well KM-1A, the calibration error has been found below 3.5 percent.

Table 6.2: Comparison of simulated reservoir pressures with calculated pressures by calibration for KM-1A well.

Date	Gas Production Rate, q, MMSCF/D	Simulated Reservoir Pressure, Pr, psi	Calculated Pressure by Calibration, Pc, psi
1997/10	5.06	2003	2042
1997/11	5.86	1999	2035
1997/12	6.21	1995	2033
1998/01	6.14	1990	2033
1998/02	6.09	1987	2034
1998/03	5.65	1983	2037
1998/04	7.32	1978	2024
1998/05	7.11	1973	2026
1998/06	9.38	1967	2008
1998/07	9.91	1960	2004
1998/08	7.97	1955	2019
1998/09	10.80	1948	1997
1998/10	10.83	1946	1996
1998/11	11.35	1933	1992
1998/12	11.82	1926	1989

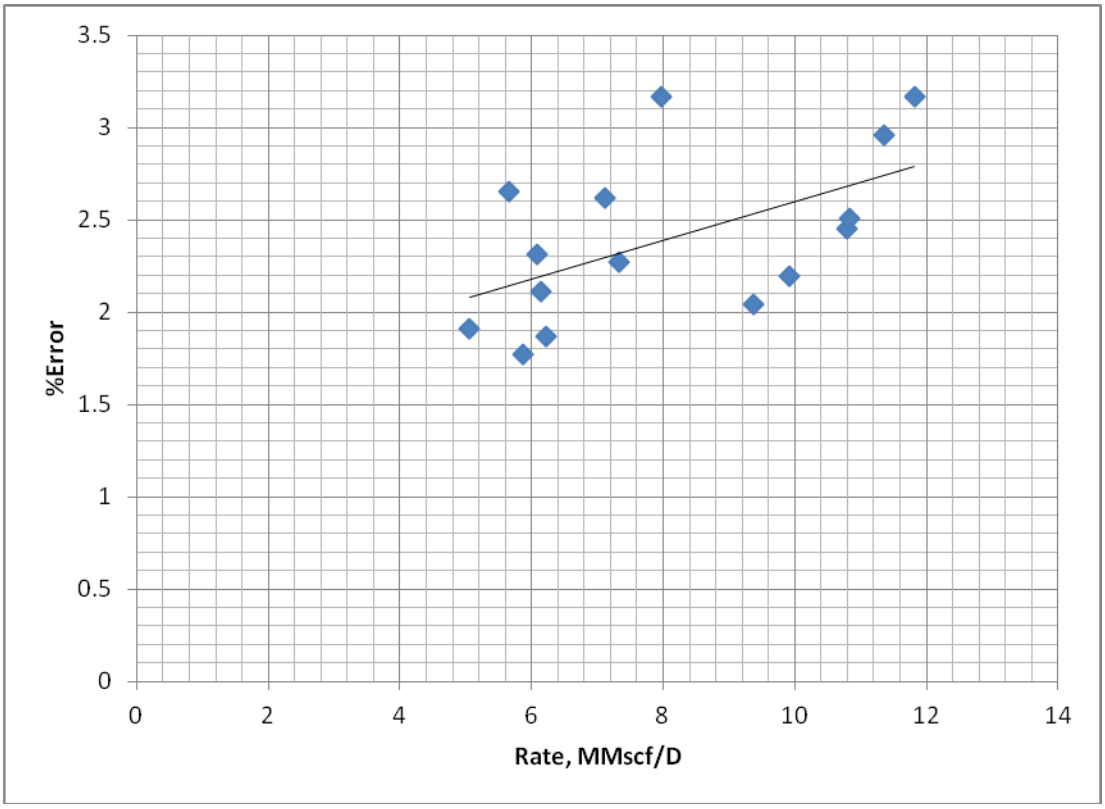

Figure 6.4: Calibration error obtained from well test for KM-1A well (Table 6.2).

CHAPTER 7

RESULTS AND DISCUSSIONS

Case field of this dissertation is North Marmara Gas Field which is an offshore field, and case well is KM-1A.

North Marmara gas filed is located at about 7 km southwest of Silivri and 2.5 km off the coast. The map showing the locations of offshore wells is given in Appendix A.1 [64].

The well KM-1A has been chosen as case well for this dissertation since it is a vertical well and radial flow assumption applies. This well has been drilled up to the base formation to test the whole stack.

In KM-1A Sogucak Formation which is the producing formation, starts at 1140 m and ends in 1220 m.

The lithology of Sogucak Formation is limestone. North Marmara Gas Field Sogucak Formation Structure Contour Map is given in Appendix A.2. and North Marmara Gas Field Sogucak Formation “Porosity X Thickness” (Øh) Map is given in Apendix A.3. [65].

After depletion of North Marmara Gas Field, in addition to 5 numbers of offshore wells, 6 number of directional wells have been drilled from on shore to convert the field to underground gas reservoir [66].

Appendix A.4 shows well completion figures of well KM-1A [67]. North Marmara Gas Field, Well KM-1A Density & Neutron logs are given in Appendix A.5. Here, Density Log is in pink color while Neutron Log is in blue. Regarding porosity and permeability readings, density log is chosen due to its more sensitivity to porosity. Density log readings for porosity and permeability are tabulated and given in Appendix B as B.Table.1. In this table, values of porosity and permeability against perforated intervals are shown in yellow filled columns and lines. By using data in mentioned table, permeability and porosity correlation is obtained for KM-1A and given in Figure 7.1.

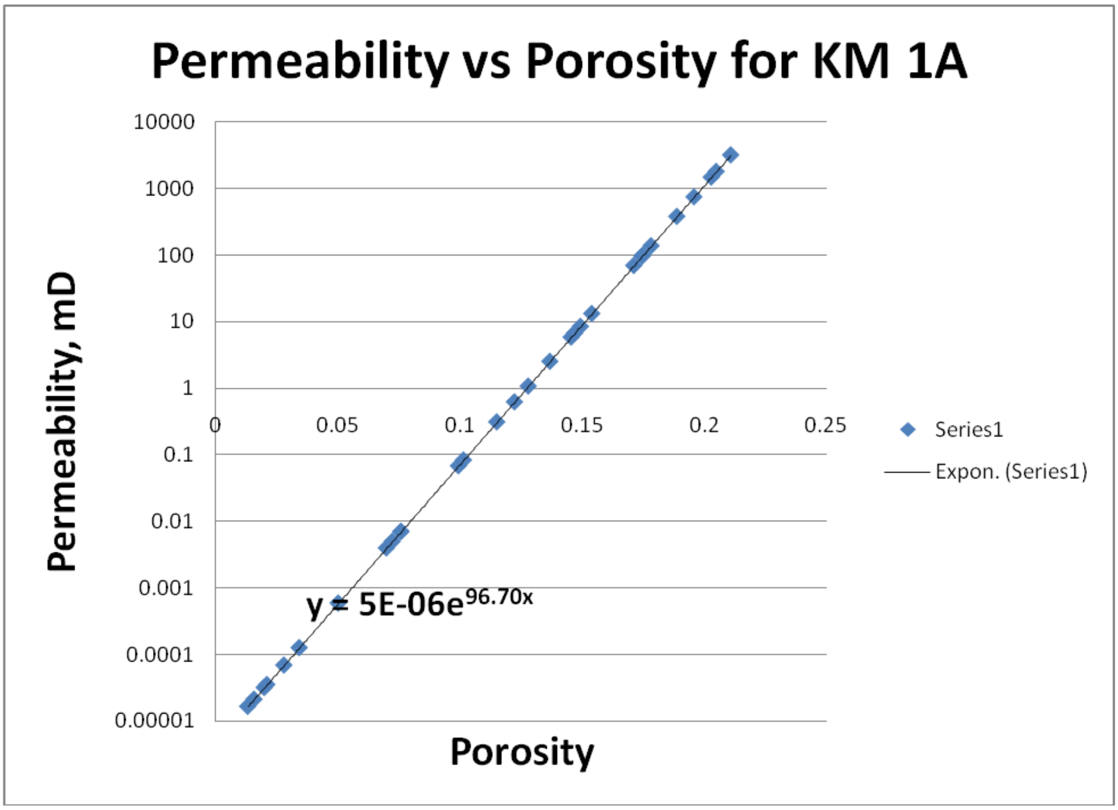

Figure 7.1: Permeability and Porosity relation for KM-1A (Table B.1).

Porosity and permeability values (Table B.1) obtained from Density Log (Figure A.5) are implemented to simulation model for KM-1A in CMG IMEX.

Production history for KM-1A is given in Appendix B as Table B.2. By using Table B.2 values, daily production rates, cumulative production, and wellhead pressure history by time are graphed and consequently shown in Figure 7.2, 7.3, and 7.4.

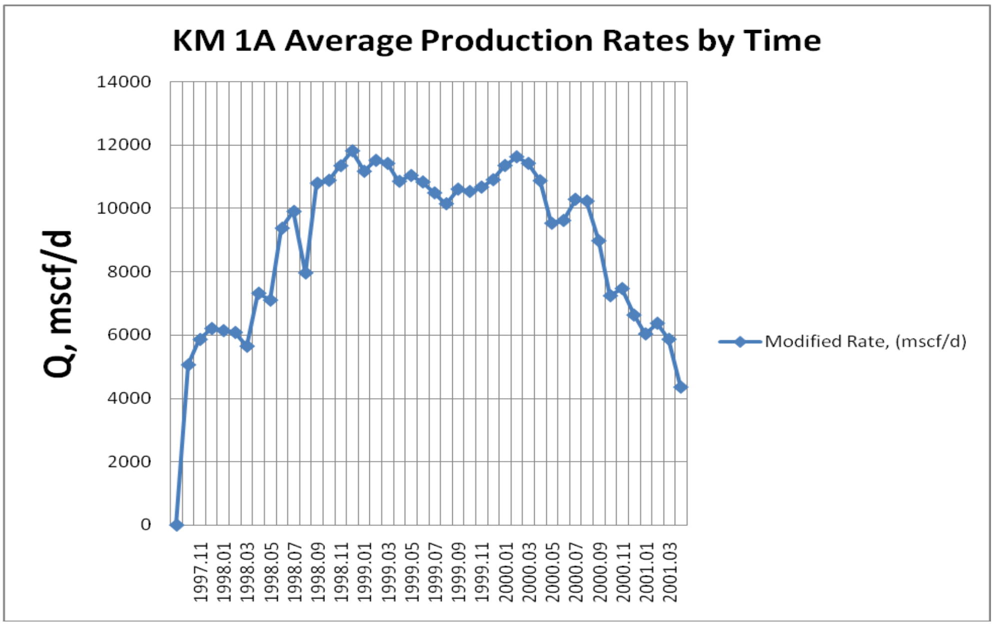

Figure 7.2: Average production rates of KM-1A (Table B.2).

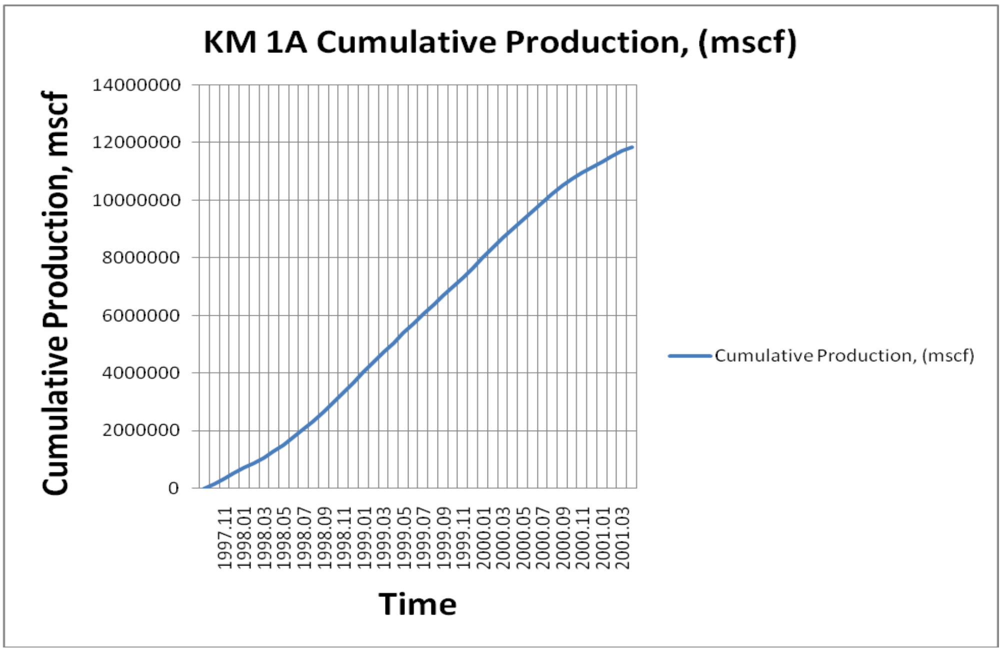

Figure 7.3: Cumulative production of KM-1A (Table B.2).

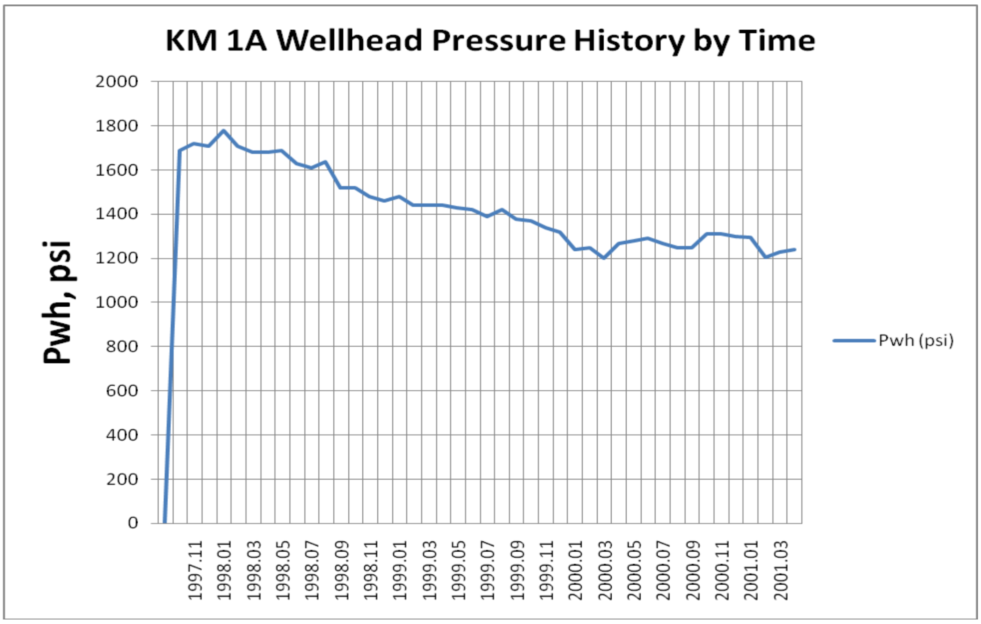

Figure 7.4: Wellhead Pressure behavior of KM-1A (Table B.2).

Average petro-physical characteristics and initial conditions for KM-1A are given in Appendix B, Table B.3 and Table B.4 [64, 68, 69].

Indigenous reservoir gas composition and Russian gas composition are consequently given in Appendix B, Table B.5 and B.6 [69, 70]. In these tables, critical values have been taken from R.C. Weast [44, 45, 46, 47].

Table B.7 shows PVT data of Reservoir Gas Volume Factor (Bg), Gas Expansion Coefficient (Eg=1/Bg), Gas Viscosity (μ_g) and Gas Deviation factor (z). Through this table values, Gas Viscosity (μ_g) and Deviation factor (z) behavior against Pressure are graphed and shown in Figure 7.5 and 7.6.

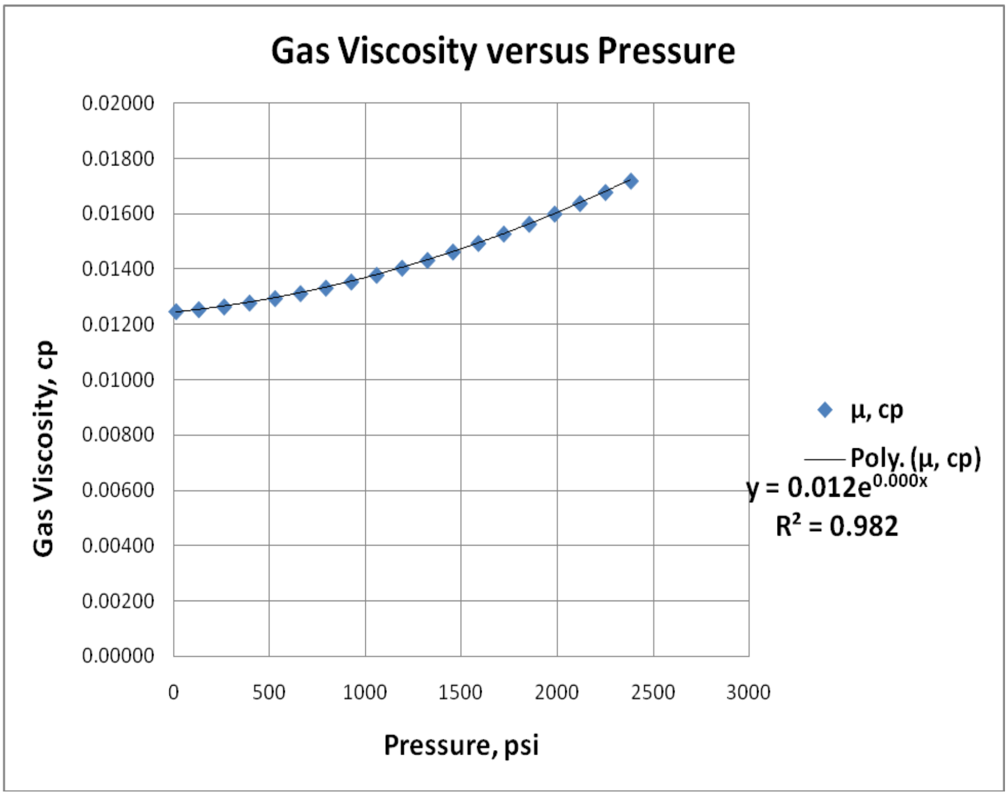

Figure 7.5: Gas Viscosity (μ_g) versus Pressure (Table B.7).

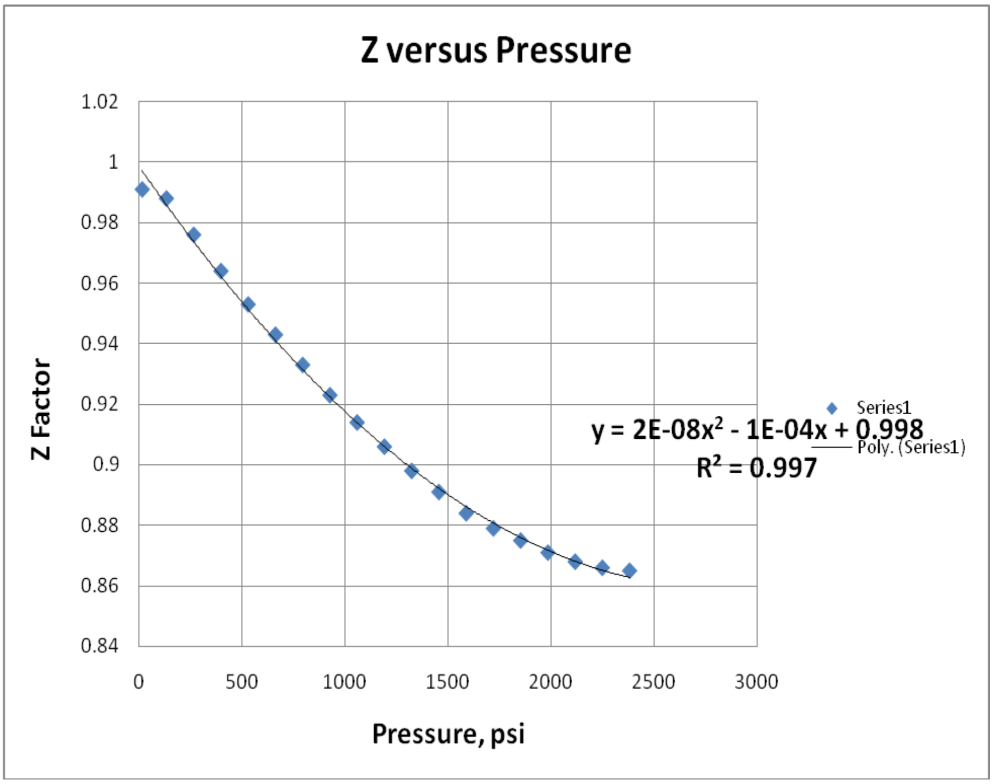

Figure 7.6: Gas Deviation Factor (z) versus Pressure (Table B.7).

Rs (solution gas oil ratio) values are calculated by Al-Marhoun Correlation [63] by Eq.5.40 as explained method in Chapter 5. The resulting table is given in Table B.8 and its graphical result is given in Figure 7.7.

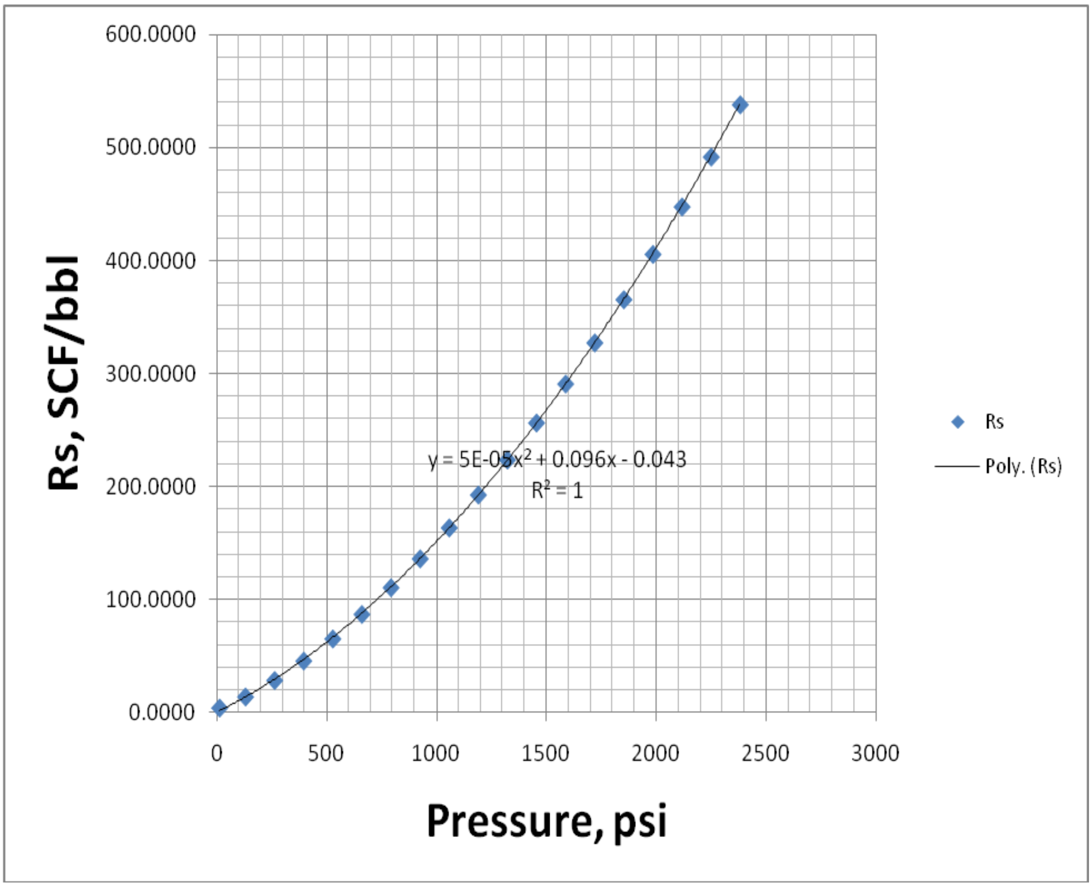

Figure 7.7: Calculated solution gas oil ratio (Rs) versus pressure (Table B.8).

Rock and fluid properties, and production history data of North Marmara Gas Reservoir have been implemented to the model done in CMG IMEX. It has been run for separate scenarios by considering skin assumptions, Darcy flow case, and non-Darcy flow case. Regarding non-Darcy flow case, “Frederick and Grave First Correlation (FG1)” [71], “Frederick and Grave Second Correlation (FG2)” and “Geertsma Correlation” [72] have been applied.

Results of these CMG IMEX simulator runs are given in Appendix C as Table C.1 for Assumed Skin 0, Table C.2 for Assumed Skin 5, Table C.3 for Assumed Skin 10 and Table C.4 for Assumed Skin 33.3.

Bottom-hole pressure behaviors as rate dependent by time for each assumed skin value (Skin 0, 5, 10 and 33.3) and for each flow case (Darcy flow, non-Darcy flow FG1, non-Darcy flow FG2 and non-Darcy flow Geertsma) are graphed and given from Figure 7.8 to Figure 7.23. Table references of these graphs are given at the bottom of each graph. In these graphs, green dash lines represent reservoir pressures, blue dash lines represent gas production rates and red solid lines represent bottom-hole pressures. The reason of the ossilations of red solid lines is the change of gas production rates which cause a sudden change of bottom-hole pressure. Following the rate stabilization, red colored bottom-hole pressure lines stop ossilation. Besides, it is clearly seen from the same graphs that increasing gas production rates reduce bottom-hole pressures while reducing rates increase bottom-hole pressures. During the depletion of the resevoir, bottom-hole pressure has reducing tendency as expected. On the other hand, the increasing bottom-hole pressure tendency almost after mid 2000 shown in these graphs can be explained as the result of pressure build up due to reduced production rates. Similar bottom-hole pressure behavior can be seen from Fig 7.24 to Fig.7.27 as pressure drops.

In case of Darcy flow, when simulation resulting graphs are compared (Figures 7.8, 7.12, 7.16 and 7.20), it is obviously seen that increasing skin factors reduce the bottom hole pressures. Similar effect can be seen for non-Darcy flow cases when FG1 correlation applied to the simulation (Figure 7.9, 7.13, 7.17 and 7.21), when FG2 correlation applied to the simulation (Figure 7.10, 7.14, 7.18 and 7.22), and when Geertsma correlation applied to the simulation (Figure 7.11, 7.15, 7.19 and 7.23).

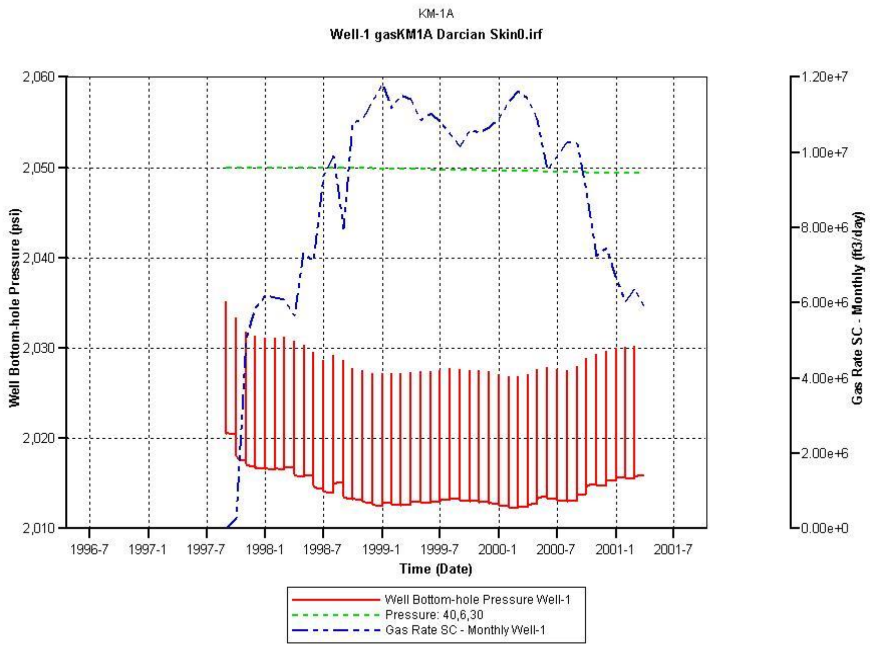

Figure 7.8: Wellbore bottom-hole pressure behavior for Darcy flow at Skin 0 (Table C.1).

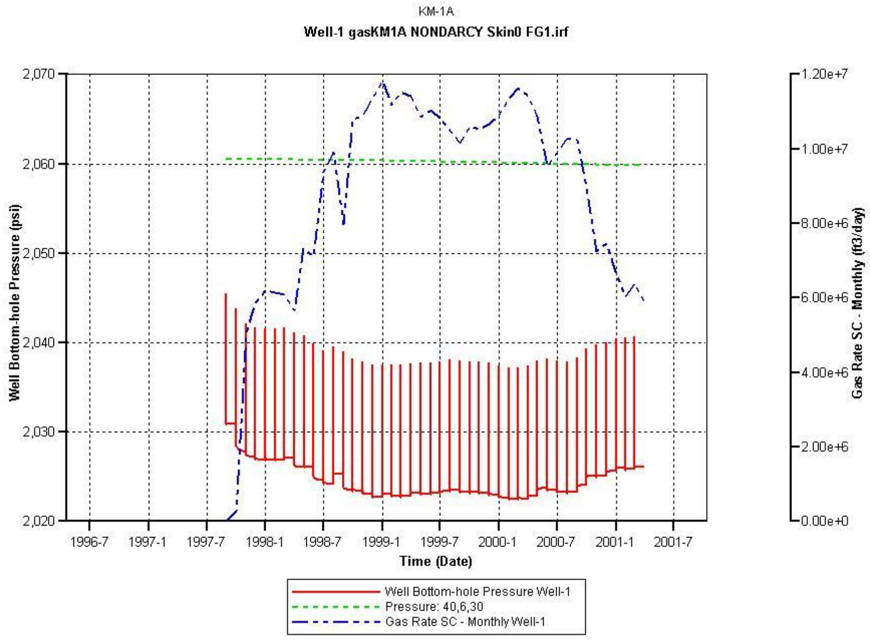

Figure 7.9: Wellbore bottom-hole pressure behavior for non-Darcy flow by FG1 Correlation at Skin 0 (Table C.1).

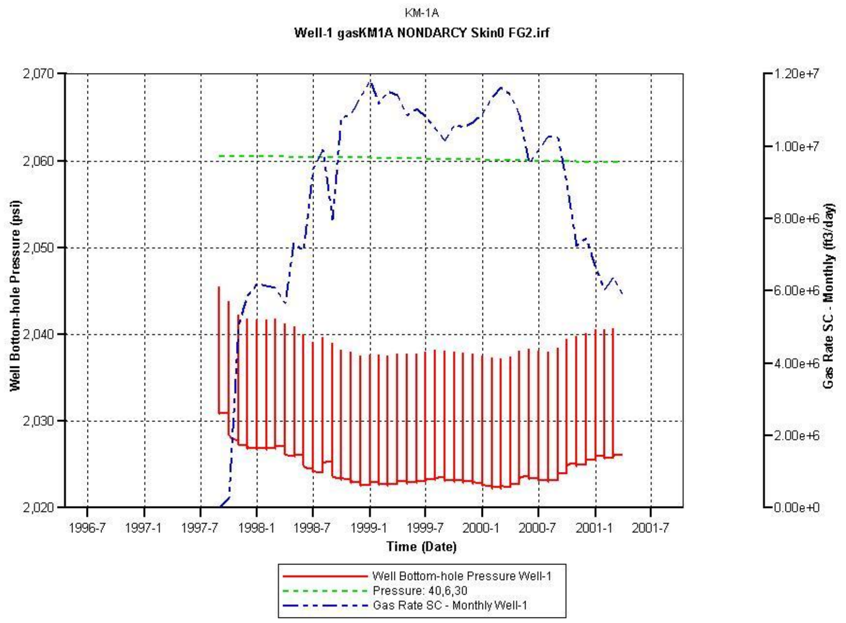

Figure 7.10: Wellbore bottom-hole pressure behavior for non-Darcy flow by FG2 Correlation at Skin 0 (Table C.1).

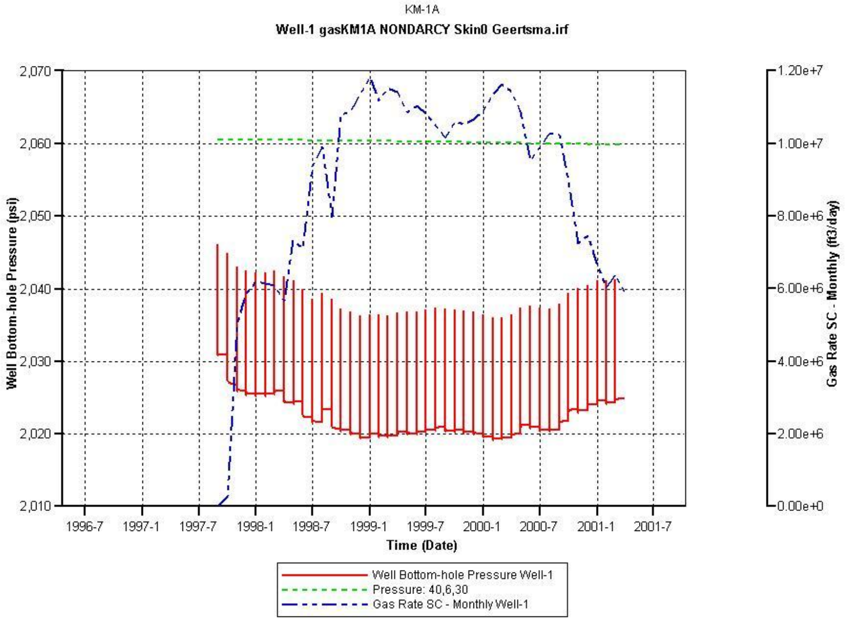

Figure 7.11: Wellbore bottom-hole pressure behavior for non-Darcy flow by Geertsma Correlation at Skin 0 (Table C.1).

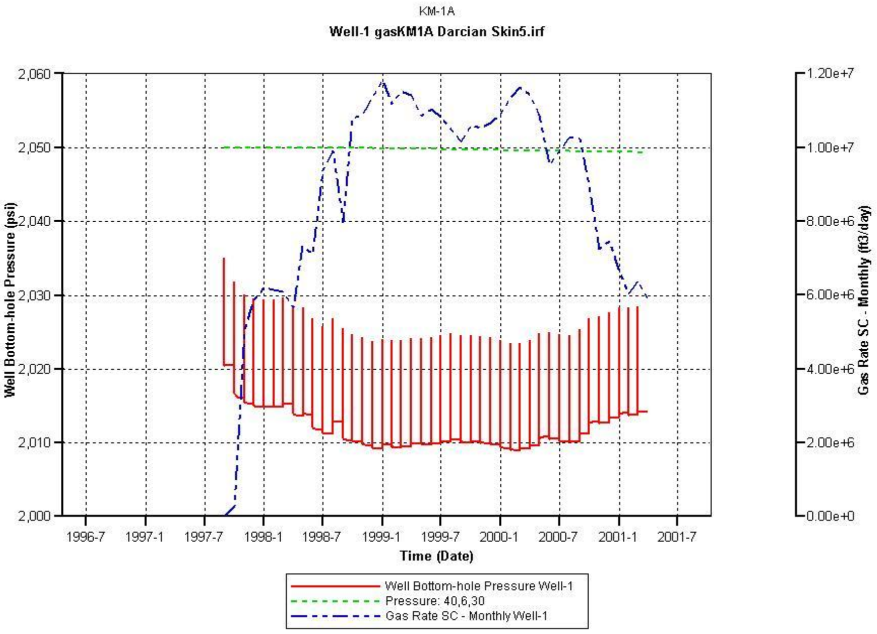

Figure 7.12: Wellbore bottom-hole pressure behavior for Darcy flow at Skin 5 (Table C.2).

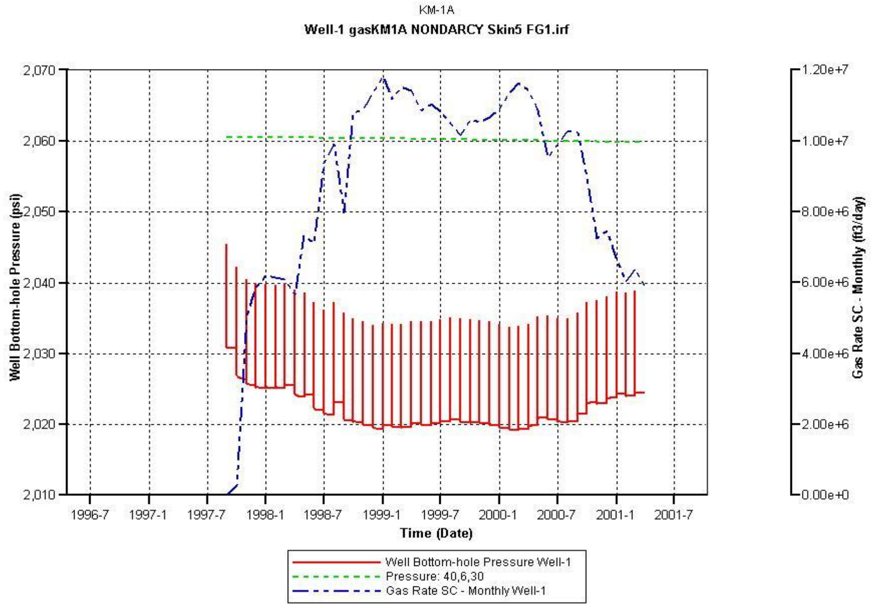

Figure 7.13: Wellbore bottom-hole pressure behavior for non-Darcy flow by FG1 Correlation at Skin 5 (Table C.2).

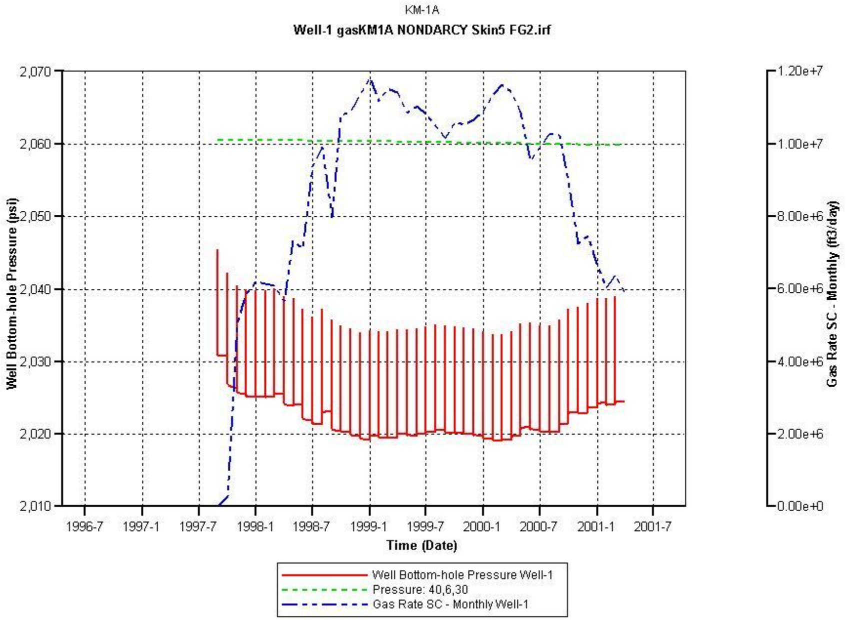

Figure 7.14: Wellbore bottom-hole pressure behavior for non-Darcy flow by FG2 Correlation at Skin 5 (Table C.2).

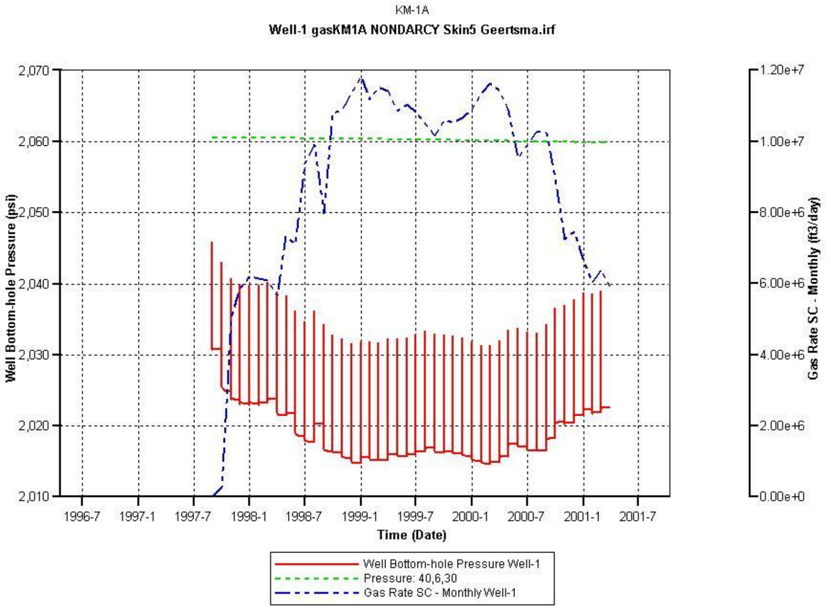

Figure 7.15: Wellbore bottom-hole pressure behavior for non-Darcy flow by Geertsma Correlation at Skin 5 (Table C.2).

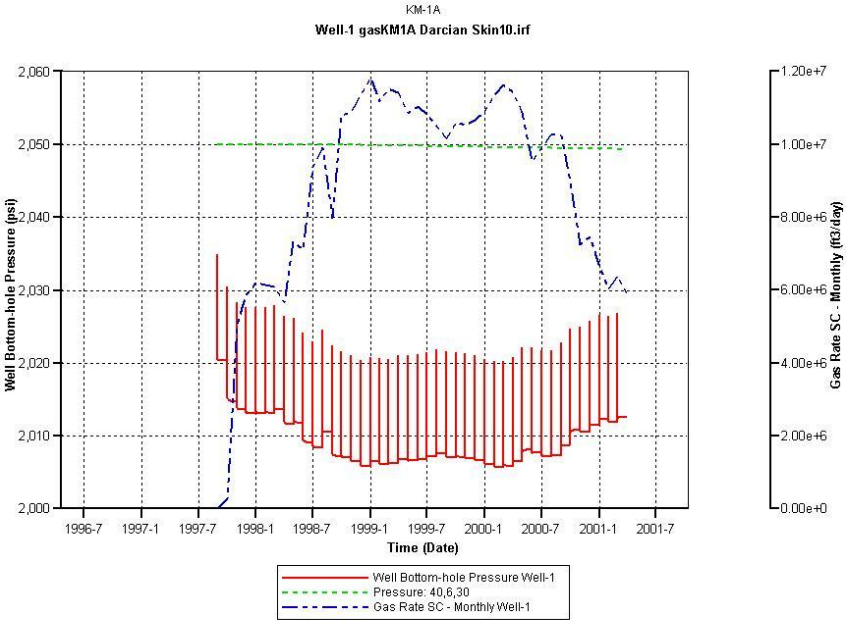

Figure 7.16: Wellbore bottom-hole pressure behavior for Darcy flow at Skin 10 (Table C.3).

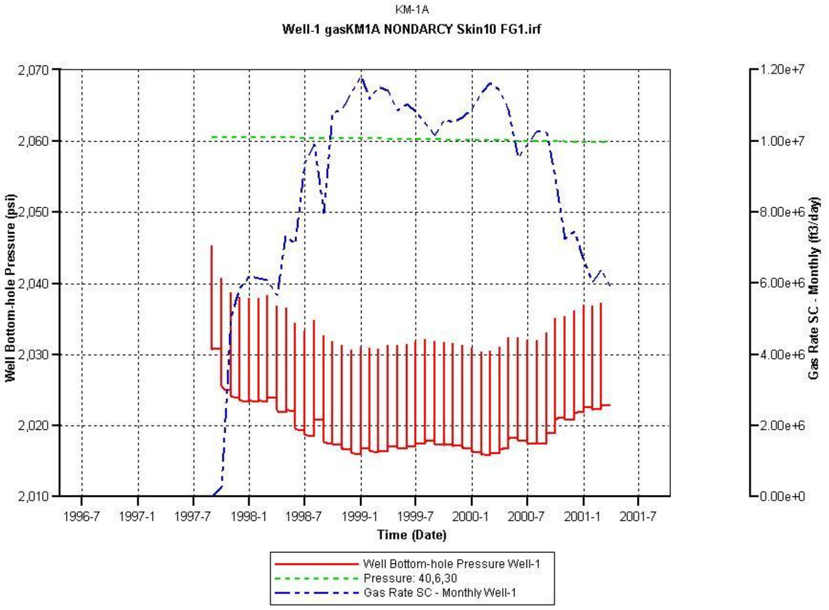

Figure 7.17: Wellbore bottom-hole pressure behavior for non-Darcy flow by FG1 Correlation at Skin 10 (Table C.3).

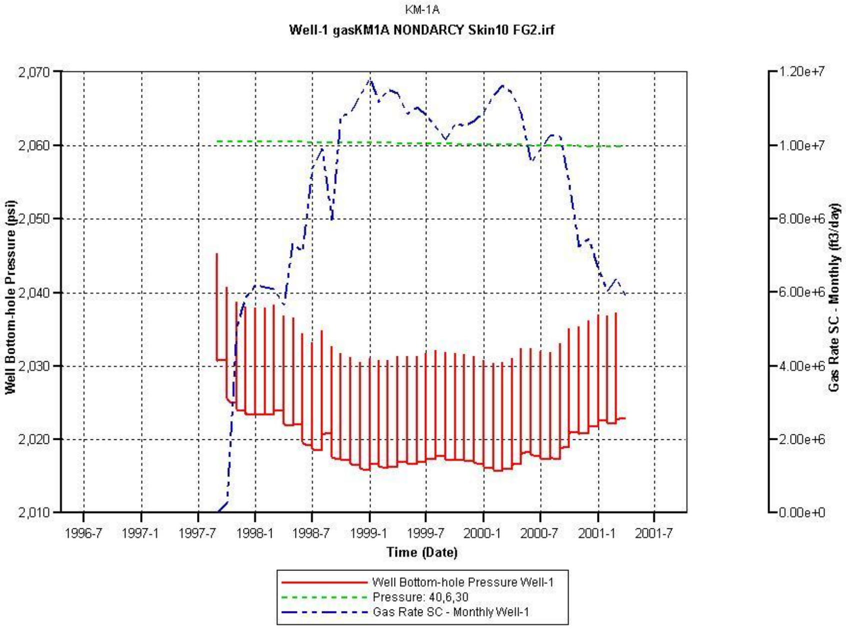

Figure 7.18: Wellbore bottom-hole pressure behavior for non-Darcy flow by FG2 Correlation at Skin 10 (Table C.3).

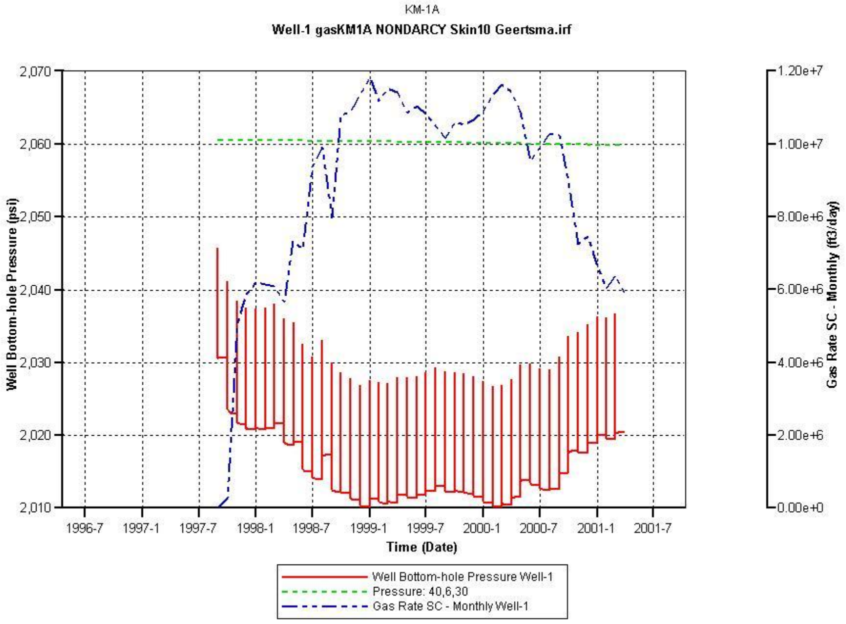

Figure 7.19: Wellbore bottom-hole pressure behavior for non-Darcy flow by Geertsma Correlation at Skin 10 (Table C.3).

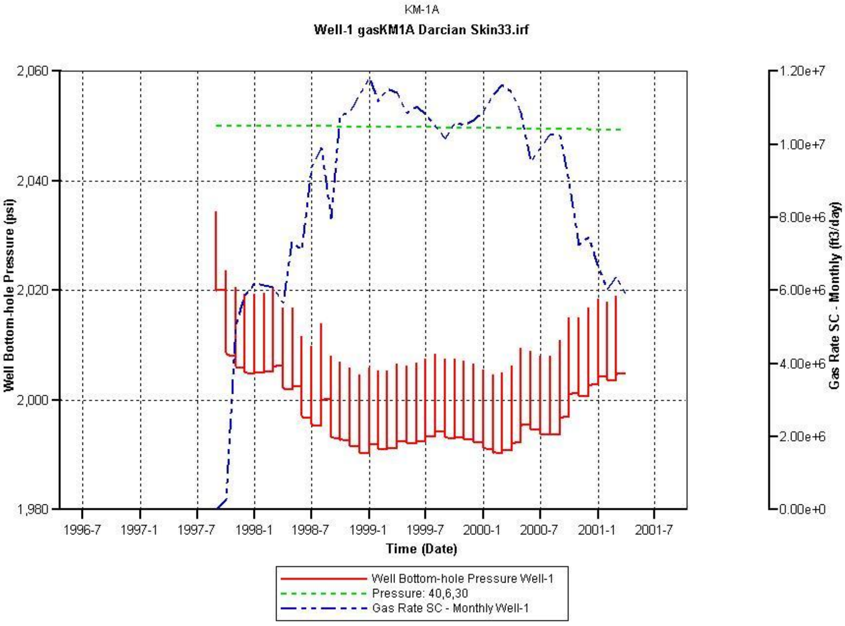

Figure 7.20: Wellbore bottom-hole pressure behavior for Darcy flow at Skin 33.3 (Table C.4).

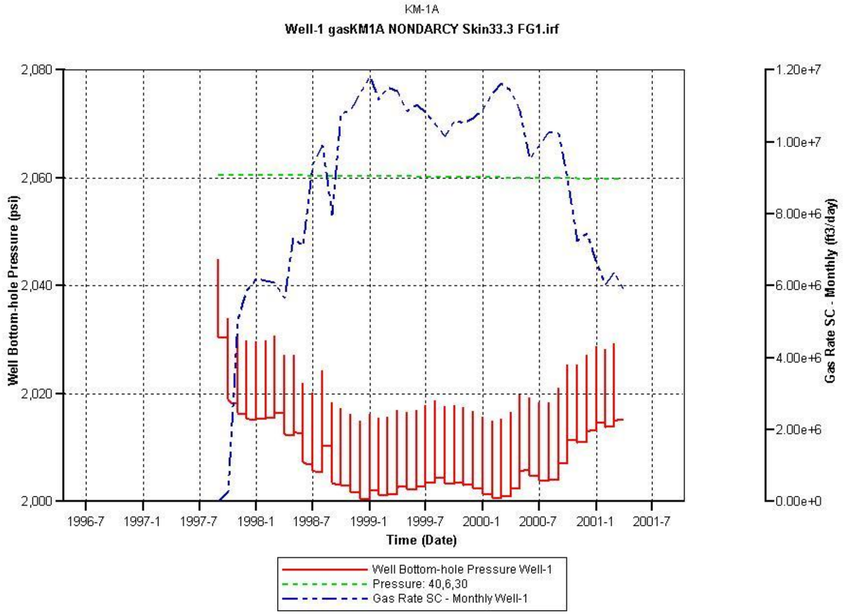

Figure 7.21: Wellbore bottom-hole pressure behavior for non-Darcy flow by FG1 Correlation at Skin 33.3 (Table C.4).

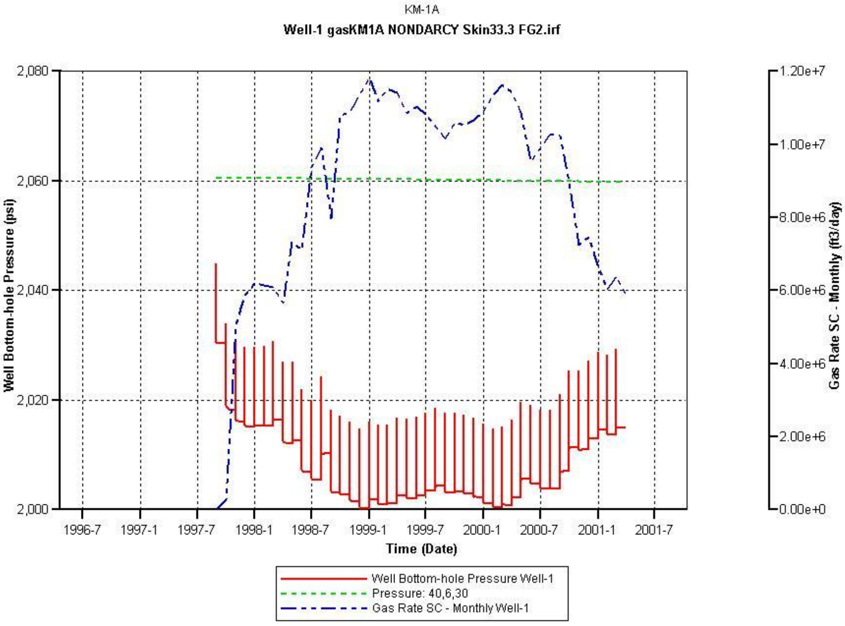

Figure 7.22: Wellbore bottom-hole pressure behavior for non-Darcy flow by FG2 Correlation at Skin 33.3 (Table C.4).

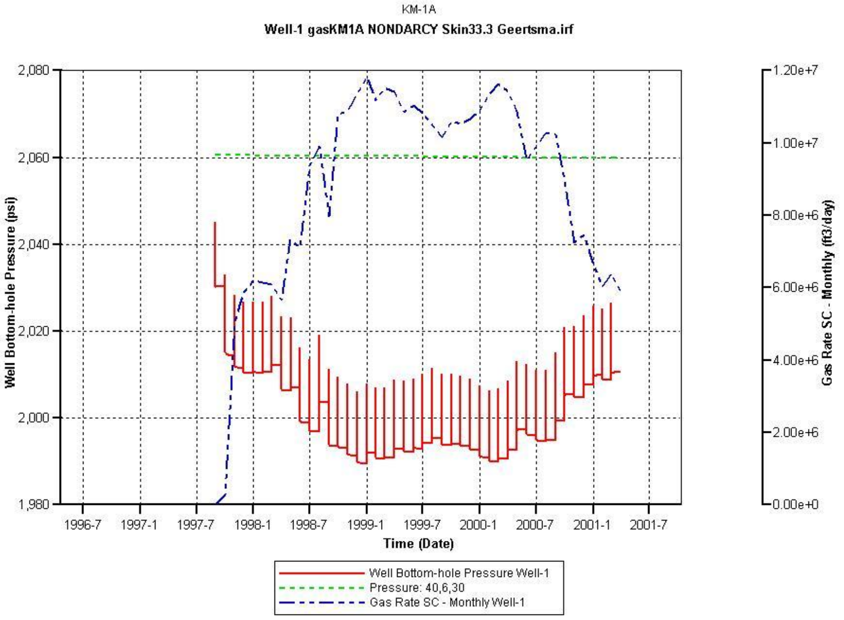

Figure 7.23: Wellbore bottom-hole pressure behavior for non-Darcy flow by Geertsma Correlation at Skin 33.3 (Table C.4).

Table C.1, C.2, C.3 and C.4 are also the results of Sawyer-Brown analysis and re-evaluated in terms of pressure drops (Pr-Pbh) for each assumed skin value (Skin 0, 5, 10 and 33.3) and results are graphed as below:

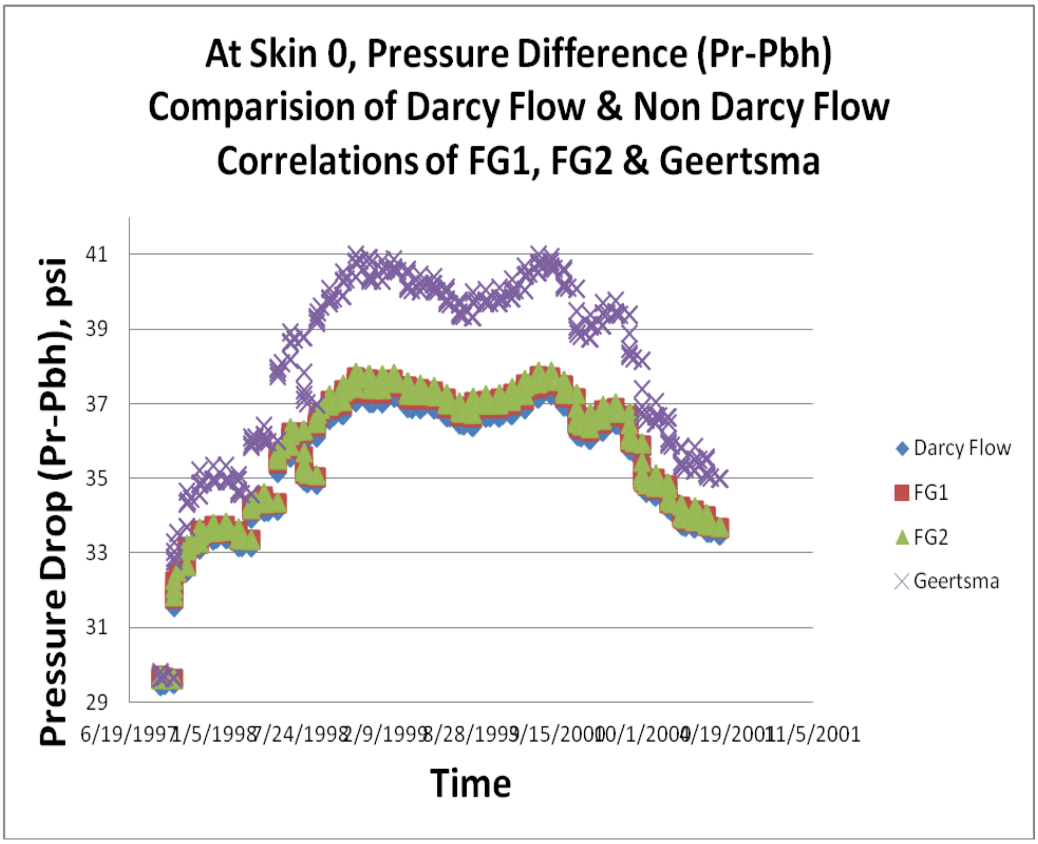

Figure 7.24: Pressure drop (Pr-Pbh) behavior at Skin 0 (Table C.1.).

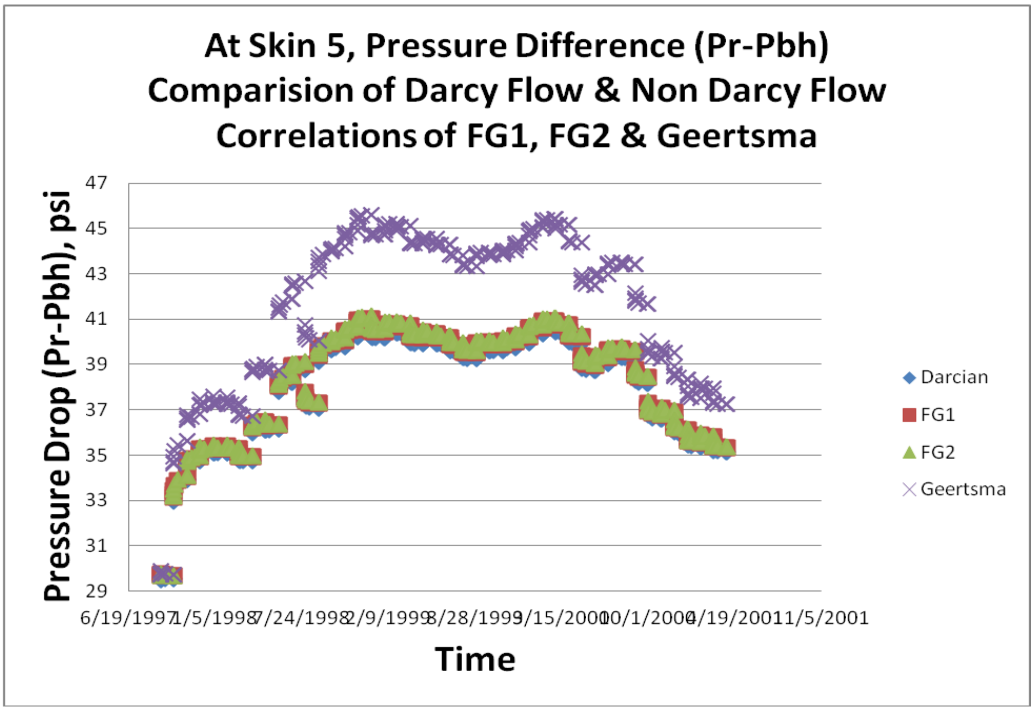

Figure 7.25: Pressure drop (Pr-Pbh) behavior at Skin 5 (Table C.2).

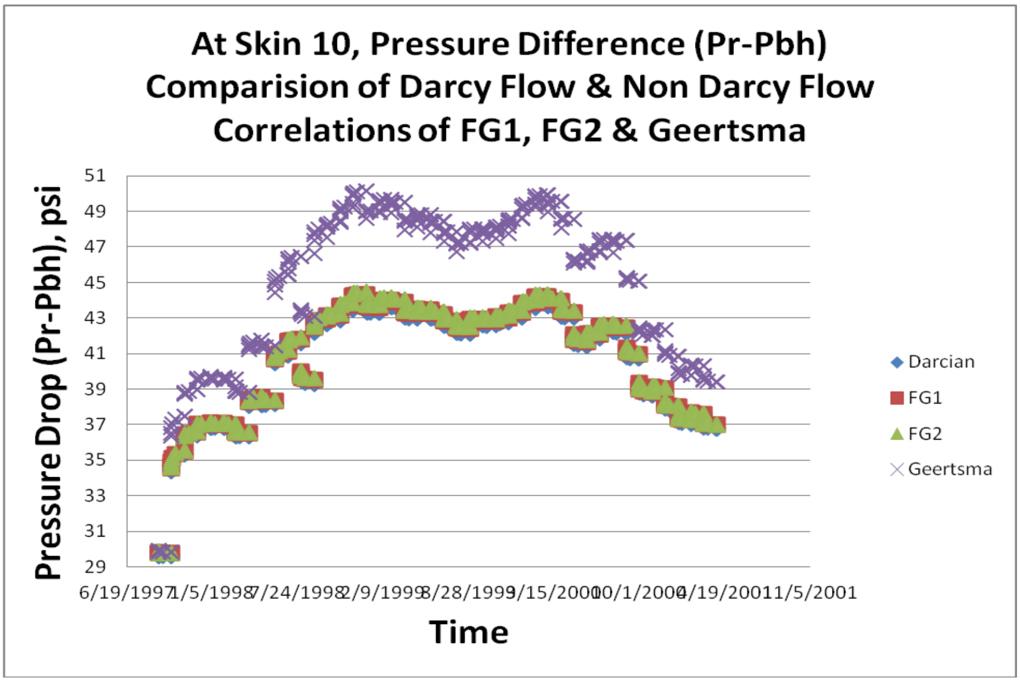

Figure 7.26: Pressure drop (Pr-Pbh) behavior at Skin 10 (Table C.3).

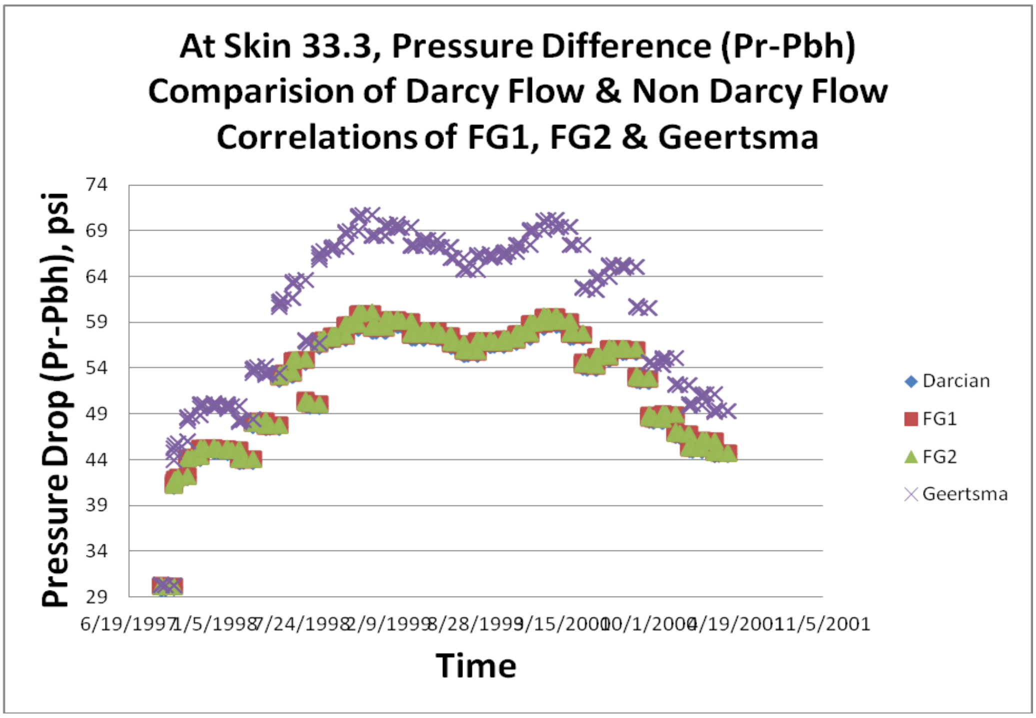

Figure 7.27: Pressure drop (Pr-Pbh) behavior at Skin 33.3 (Table C.4).

In Figure 7.24, 25, 26 & 27, colored legends are given at the right side of ech graph and it is clearly seen that Geertsma Correlation for non-Darcy fluid flow through porous media estimates higher pressure drop (Reservoir pressure – Bottomhole pressure) than Frederic and Grave's First & Second Correlations. Increasing skin effect also results higher pressure drop in both Darcy flow and non-Darcy flow.

By using reservoir pressure and bottomhole pressure data obtained from numerical simulation results, pseudo stedy state radial gas flow equation in the form of SB Method can be written as Eq.7.1:

$$P_r^2 - P_{wf}^2 = Aq(b_o + s_m + Dq) \qquad \text{(Eq.7.1)}$$

This equation has been solved for North Marmara well KM-1A parameters. Table C.5 of Appendix C gives the results for pseudo steady state radial gas flow at reservoir, and bottom-hole by Sawyer-Brown Method (SB Method).

Eq.7.1 has been expressed in quadratic form as the Jones Equation [60]:

$$P_r^2 - P_{wf}^2 = aq2 + bq \qquad \text{(Eq.7.2)}$$

thus

$$(P_r^2 - P_{wf}^2)/q = aq+b \qquad \text{(Eq.7.3)}$$

Here Jones constants "a" and "b" have been calculated by using Table C.5 data and resulting linear graph is given in Figure 7.28.

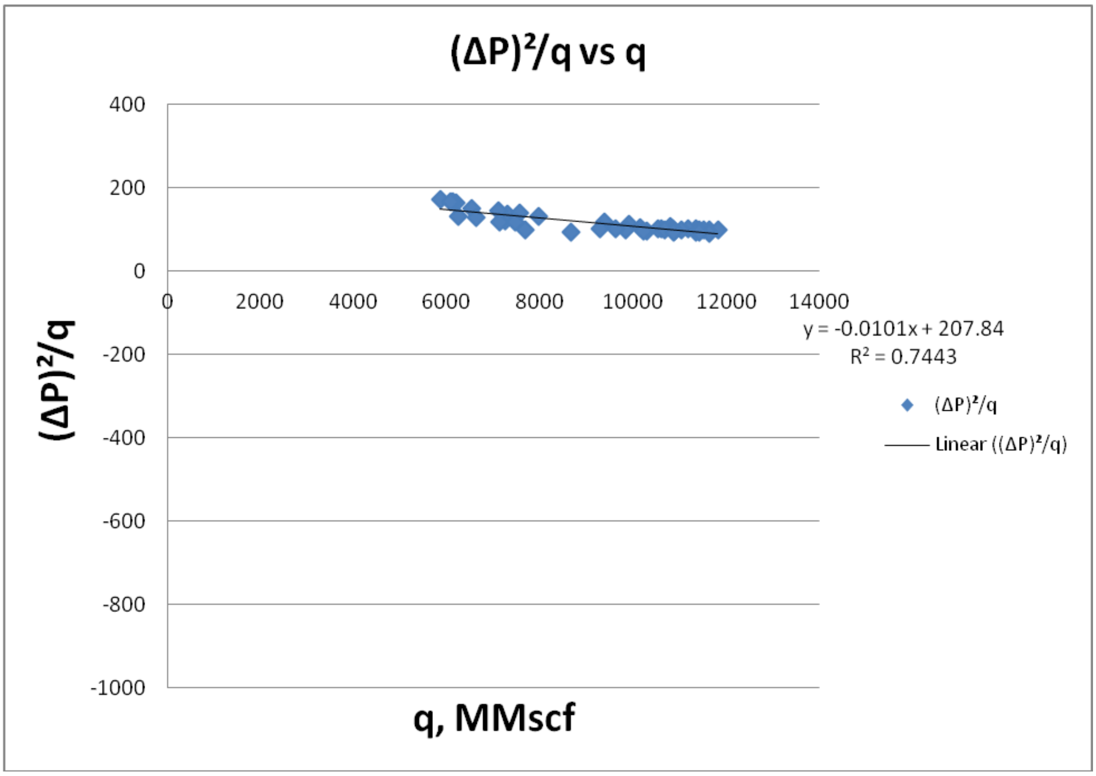

Figure 7.28: (ΔP2)/q versus q graph to find out Jones constants (Table C.5).

As it is seen in Figure 7.28, Jones constant [60] are:

a = -0.0101 and b = 207.84

In solving Eq.5.1, A value has been calculated through:

$A = (1.422 \times 10^6 \mu_g zT) / (k_g h)$ (Eq.7.4)

Results for the coefficient “A” in Eq.5.2 are given in Table C.5 as function of pressure. Thus, from Eq.5.5 non-Darcy factor:

D = a/A have been calculated.

Mechanical skin (s_m) is calculated through:

$b = A(b_o+s_m)$ (Eq.7.5)

Finally, total skin (s_T) is calculated by:

$s_T = s_m + Dq$ (Eq.7.6)

In order to test the validity of SB Method a numerical test has been conducted by using the calibrated simulation model. Input skin was 33 obtained from well test analysis [68]. Total skin behavior in reservoir as function of production rate is given in Figure 7.29. As can be easily seen in the graph, at flow rates higher than 8 MMscf/day, total skin effect obtained from Sawyer-Brown analysis is around 33 which is in good agreement with the total skin effect obtained from well tests that has been implemented in the input data file. Below a flow rate of 8 MMscf/day, total skin value deviates from this value and increases as the rate decreases. Note that, SB Method has been developed for non-Darcy flow. Since for low flow rates the flow approaches to obey Darcy flow conditions, SB Method does not apply. It can be concluded that the SB Method correctly identified skin as 33 for high rates but overestimated the input value for low flow rates. It could be argued that at lower flow rates non-Darcy flow does not exist and that's why the method introduces unusually high skin factors.

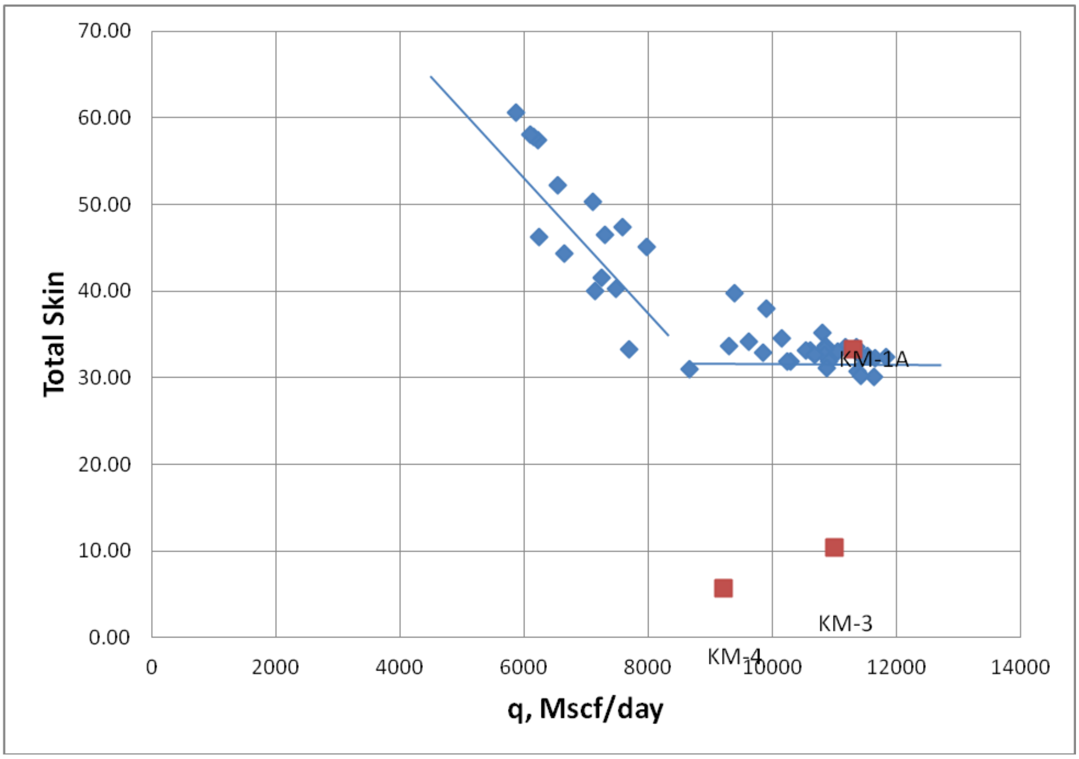

Figure 7.29: Total skin at reservoir versus rate (Table C.5).

From the Table C.5 and C.6 data, turbulence in flow has been checked through reservoir and wellhead against production rates of Well KM-1A. Resulting graph has been given in Figure 7.30. As it is seen, in the reservoir, Reynolds Number [85] values are below 0.2 even at the highest flow rates of production history of KM-1A. Therefore, it can confidently be considered that there is no turbulence in producing reservoir of KM-1A well of North Marmara gas field. This result can be checked using Reynolds number calculations conducted by using the following equation:

$$Re = \{\rho*Q*SQRT[K/(A*Ø)]\}/(\mu) \qquad \text{(Eq.7.7)}$$

The results of Figure 7.30 show that the Reynolds number is less than 0.2 in the reservoir but higher than 2.5 near the wellbore. Darcy's law is only valid for slow, viscous flow; fortunately, most porous media flow cases fall in this category. Typically any flow with a Reynolds' number less than one is clearly laminar, and it would be valid to apply Darcy's law. Experimental tests have shown that flow regimes with Reynolds' numbers up to 10 may still be Darcy flow, as in the case of groundwater flow.

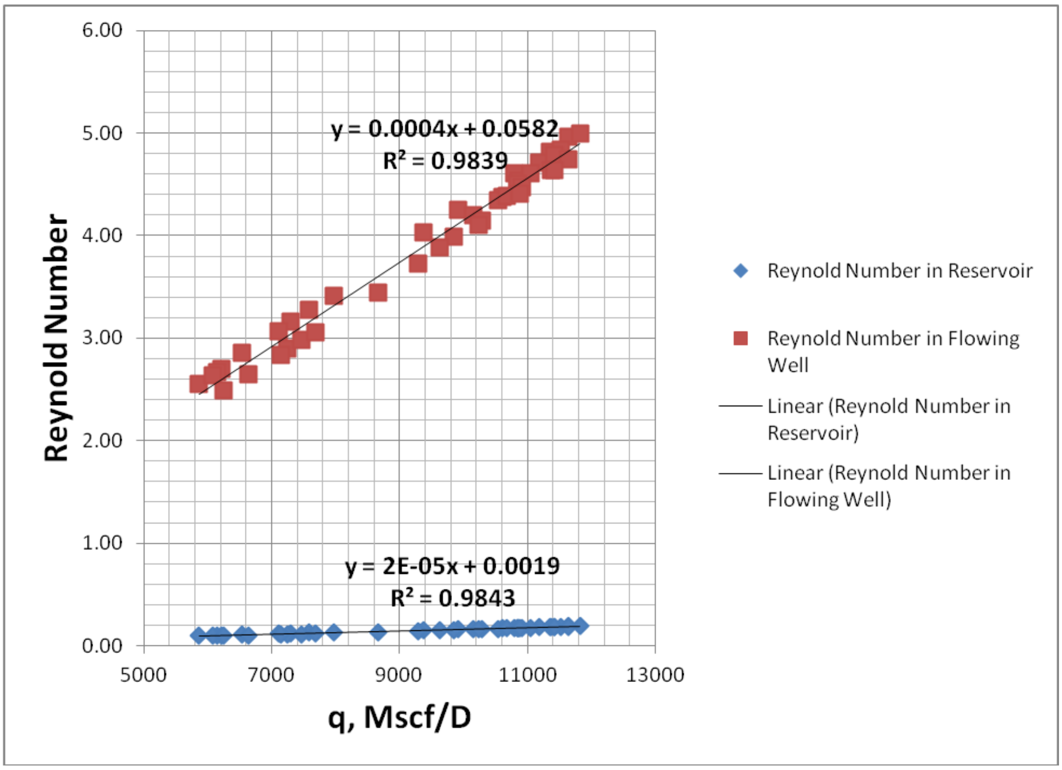

Figure 7.30: Comparison of Reynolds' Numbers of gas flow through reservoir and flowing well for KM-1A well of North Marmara gas field (Table C.5 and C.6).

CHAPTER 8

CONCLUSIONS

1. Sawyer-Brown Method developed to investigate non-Darcy flow effects is improved by incorporating pressure dependent gas viscosity, gas compressibility gas deviation factor.

2. At low flow rates close to Darcy flow conditions SB Method gives over estimated skin values.

3. Geertsma Correlation for non-Darcy fluid flow through porous media gives higher pressure drop (Pr-Pbh) than Frederick and Grave's first and second correlations. Thus, higher non-Darcy factor results higher pressure drops.

4. As the skin factor increases the pressure drop increases.

5. Joule-Thompson effect does not apply to North Marmara KM-1A.

6. Obtained Reynold Numbers in flow through reservoir section of KM-1A well of North Marmara gas field is below 0.2 even at the highest production rates of this well's production history. Thus, there is no turbulence effect in reservoir flow of this well.

CHAPTER 9

RECOMMENDATIONS

1. Empirically, single phase and multi phase non-Darcy flow has been studied and reported by several scientists and researchers in the literature [73, 74, 75, and 76]. On the other hand, theoretically single phase non-Darcy flow through porous media has also been studied [77, 78, 79, 80, 81, 82, 83 and 84]. By reasonably combining empirical and theoretical studies mentioned by these references on non-Darcy fluid flow, new correlations for better fits can be obtained.

2. R. Al-Hussainy, H.J. Ramey and P.B. Crawford [37] approach can be combined to Sawyer Brown Method for linearization of non-linear flow equations by using pseudo pressure.

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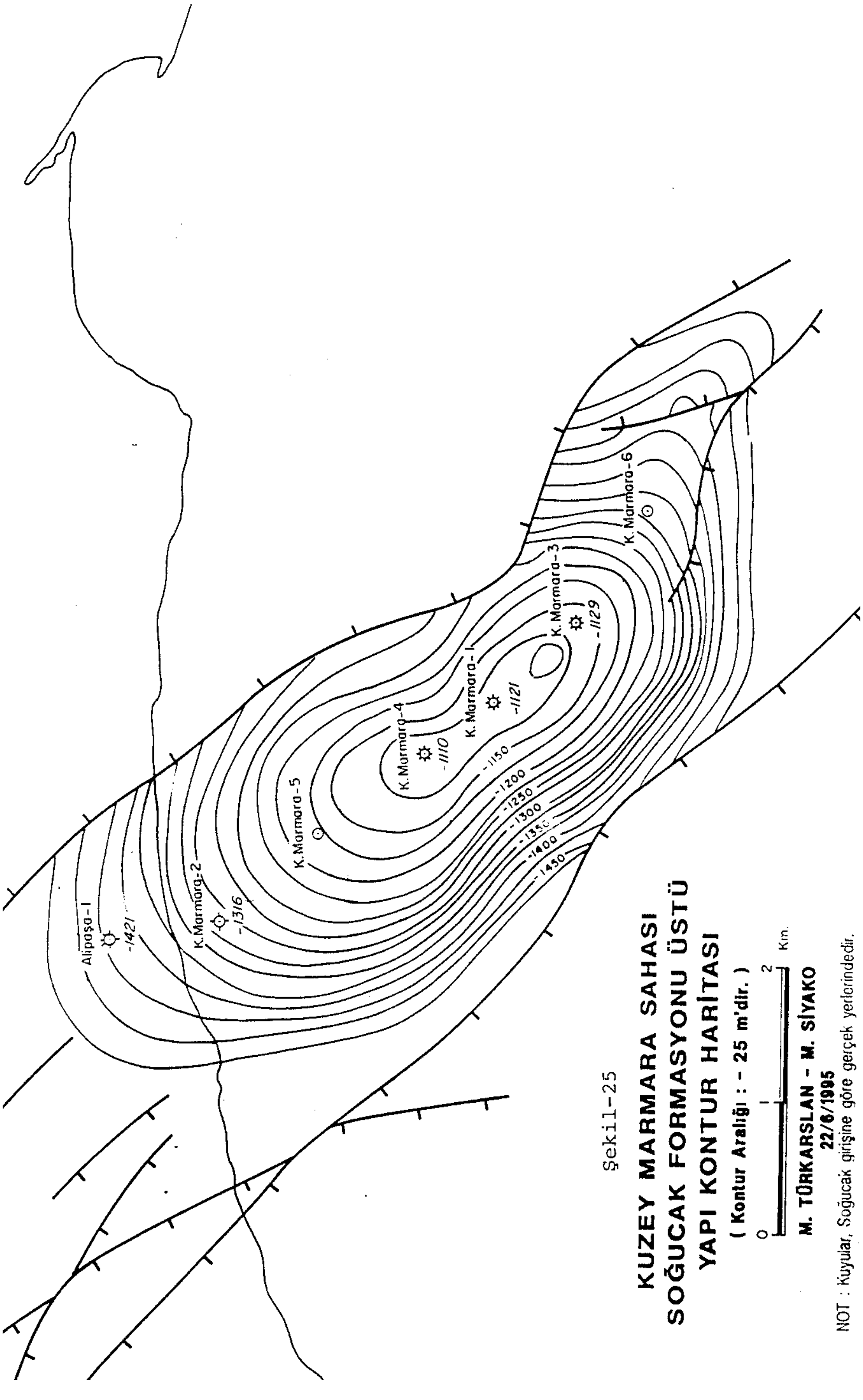
APPENDIX A

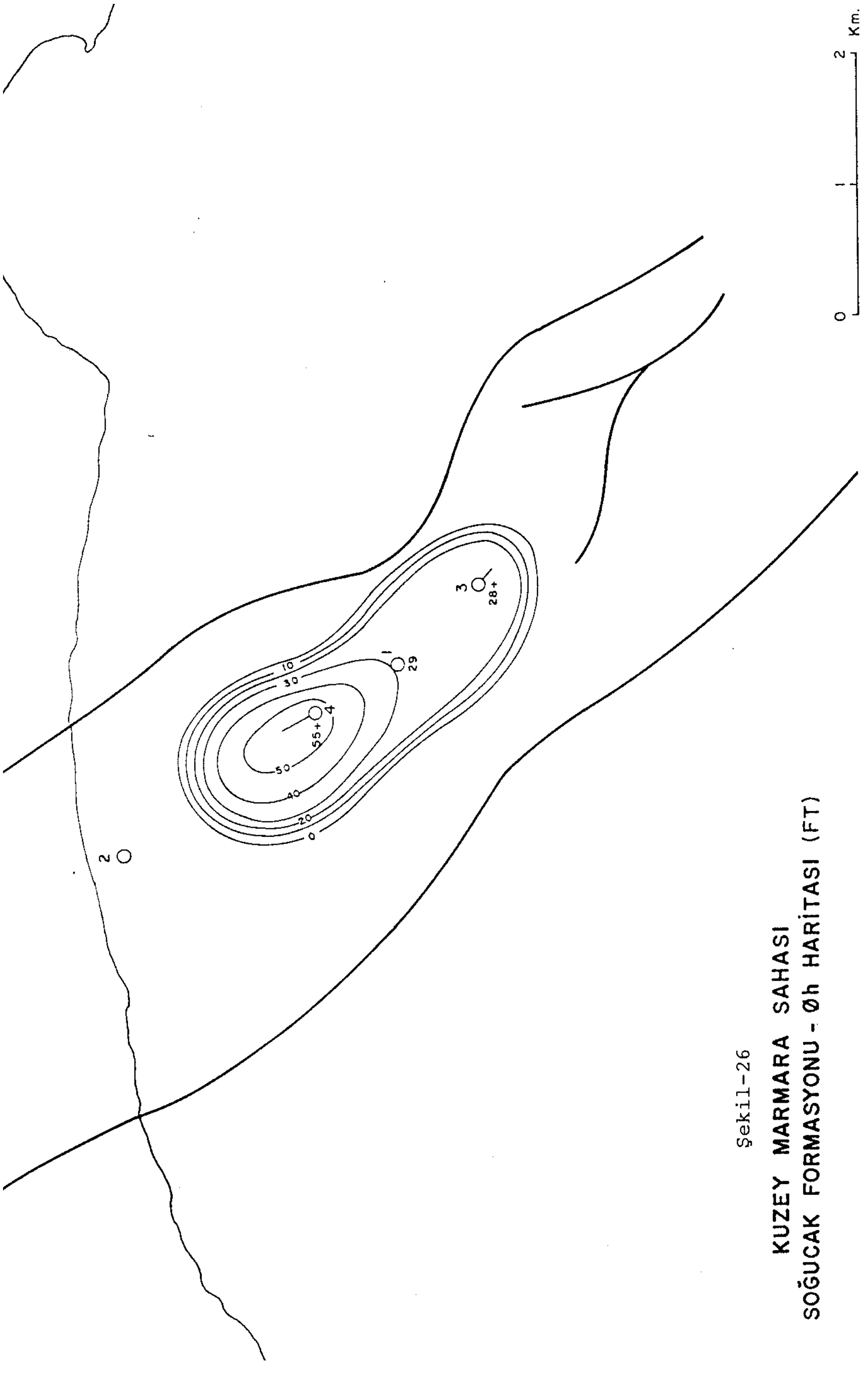
NORTH MARMARA GAS FIELD

A.1: North Marmara Gas Field, Offshore Well Locations Map.

A.2: North Marmara Gas Field, Sogucak Formation Structure Contour Map.



A.3: North Marmara Gas Field, Sogucak Formation "Porosity X Thickness" (Øh) Map.

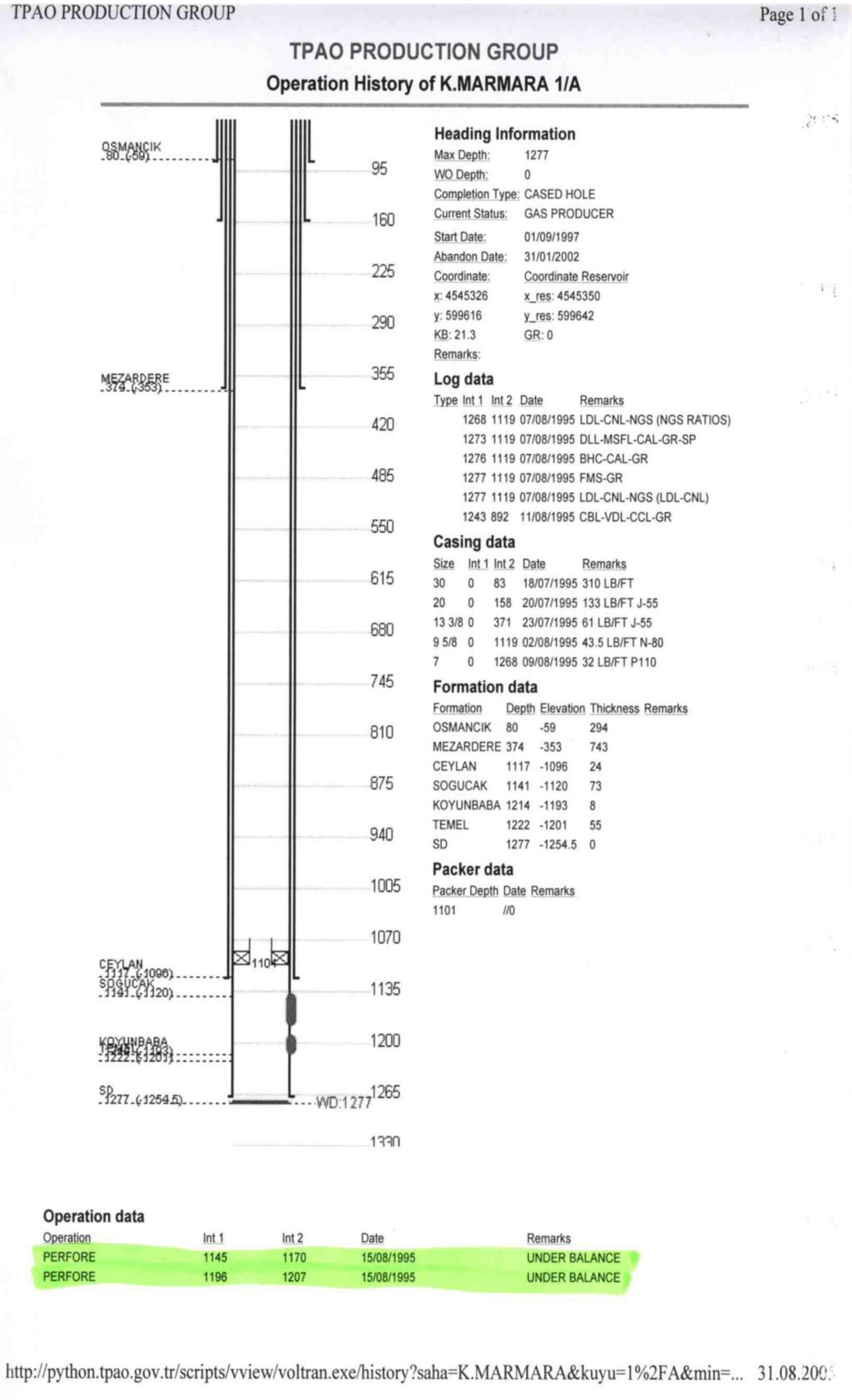


Şekil-26

KUZEY MARMARA SAHASI

SOĞUCAK FORMASYONU - Øh HARİTASI (FT)

A.4: North Marmara Gas Field, Well KM-1A well completion figures.



TPAO PRODUCTION GROUP Page 1 of 1

TPAO PRODUCTION GROUP

Operation History of K.MARMARA 1/A

Heading Information

Max Depth:	1277
WO Depth:	0
Completion Type:	CASED HOLE
Current Status:	GAS PRODUCER
Start Date:	01/09/1997
Abandon Date:	31/01/2002
Coordinate:	Coordinate Reservoir
x: 4545326	x_res: 4545350
y: 599616	y_res: 599642
KB: 21.3	GR: 0
Remarks:	

Log data

Type	Int 1	Int 2	Date	Remarks
	1268	1119	07/08/1995	LDL-CNL-NGS (NGS RATIOS)
	1273	1119	07/08/1995	DLL-MSFL-CAL-GR-SP
	1276	1119	07/08/1995	BHC-CAL-GR
	1277	1119	07/08/1995	FMS-GR
	1277	1119	07/08/1995	LDL-CNL-NGS (LDL-CNL)
	1243	892	11/08/1995	CBL-VDL-CCL-GR

Casing data

Size	Int 1	Int 2	Date	Remarks
30	0	83	18/07/1995	310 LB/FT
20	0	158	20/07/1995	133 LB/FT J-55
13 3/8	0	371	23/07/1995	61 LB/FT J-55
9 5/8	0	1119	02/08/1995	43.5 LB/FT N-80
7	0	1268	09/08/1995	32 LB/FT P110

Formation data

Formation	Depth	Elevation	Thickness	Remarks
OSMANCIK	80	-59	294	
MEZARDERE	374	-353	743	
CEYLAN	1117	-1096	24	
SOGUCAK	1141	-1120	73	
KOYUNBABA	1214	-1193	8	
TEMEL	1222	-1201	55	
SD	1277	-1254.5	0	

Packer data

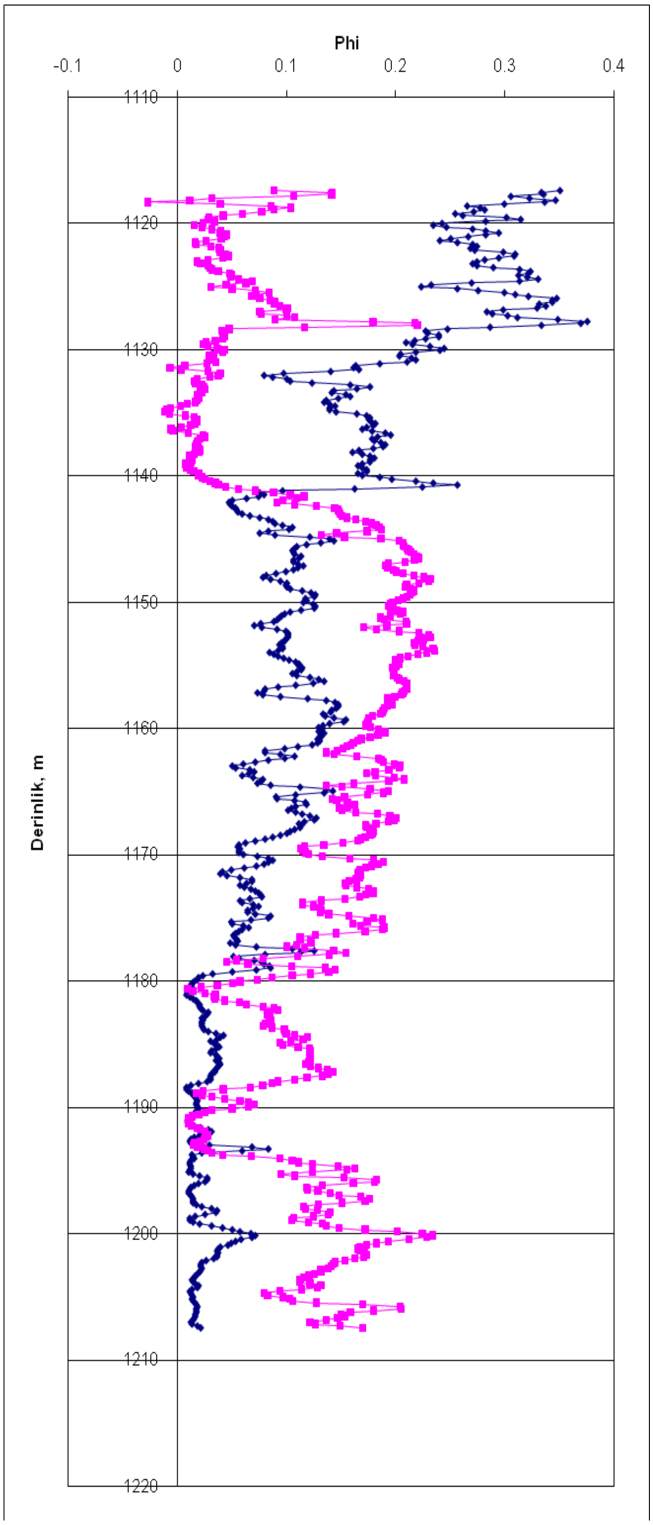
Packer Depth	Date	Remarks
1101	//0	

Operation data

Operation	Int 1	Int 2	Date	Remarks
PERFORE	1145	1170	15/08/1995	UNDER BALANCE
PERFORE	1196	1207	15/08/1995	UNDER BALANCE

http://python.tpao.gov.tr/scripts/vview/voltran.exe/history?saha=K.MARMARA&kuyu=1%2FA&min=... 31.08.200

A.5: North Marmara Gas Field, Well KM-1A Density & Neutron logs.



APPENDIX B

TABLES

Table B.1: KM-1A Porosity & Permeability readings from Density Log.

DEPTH ft	DEPTH m	AVERAGE DPHI	LAYER #	DENSITY POROSITY	k md
3664	1117	0.120	1	0.0698653	0.003948
3667	1118	0.048			
3670	1119	0.042			
3674	1120	0.032	2	0.0341981	0.000125
3677	1121	0.030			
3680	1122	0.040			
3683	1123	0.031	3	0.0501319	0.000586
3687	1124	0.055			
3690	1125	0.065			
3693	1126	0.090	4	0.099255	0.067719
3697	1127	0.128			
3700	1128	0.079			
3703	1129	0.032	5	0.0279419	6.85E-05
3706	1130	0.035			
3710	1131	0.016			
3713	1132	0.024	6	0.0157059	2.1E-05
3716	1133	0.021			
3720	1134	0.003			
3723	1135	0.011	7	0.0131657	1.64E-05
3726	1136	0.009			
3729	1137	0.019			
3733	1138	0.014	8	0.0199203	3.15E-05
3736	1139	0.013			
3739	1140	0.032			
3742	1141	0.092	9	0.1277802	1.068486
3746	1142	0.127			
3749	1143	0.164			
3752	1144	0.166	10	0.1954988	746.3619
3756	1145	0.208			
3759	1146	0.213			
3762	1147	0.201	11	0.2105028	3185.062
3765	1148	0.220			
3769	1149	0.211			
3772	1150	0.199	12	0.2025815	1480.549

3775	1151	0.193			
3779	1152	0.216			
3782	1153	0.207	13	0.2045899	1797.947
3785	1154	0.199			
3788	1155	0.208			
3792	1156	0.200	14	0.1885194	380.0277
3795	1157	0.190			
3798	1158	0.175			
3802	1159	0.180	15	0.1709327	69.37021
3805	1160	0.152			
3808	1161	0.181			
3811	1162	0.189	16	0.174272	95.81272
3815	1163	0.174			
3818	1164	0.160			
3821	1165	0.165	17	0.174667	99.54359
3824	1166	0.185			
3828	1167	0.173			
3831	1168	0.124	18	0.1537501	13.16752
3834	1169	0.170			
3838	1170	0.167			
3841	1171	0.164	19	0.1491255	8.419224
3844	1172	0.148			
3847	1173	0.136			
3851	1174	0.178	20	0.1453031	5.817428
3854	1175	0.131			
3857	1176	0.127			
3861	1177	0.085	21	0.075728	0.006959
3864	1178	0.112			
3867	1179	0.031			
3870	1180	0.044	22	0.072252	0.004973
3874	1181	0.085			
3877	1182	0.087			
3880	1183	0.107	23	0.1149548	0.309101
3884	1184	0.116			
3887	1185	0.122			
3890	1186	0.124	24	0.075804	0.007011
3893	1187	0.052			
3897	1188	0.051			
3900	1189	0.025	25	0.0210172	3.51E-05
3903	1190	0.016			
3906	1191	0.022			
3910	1192	0.035	26	0.1013181	0.082672
3913	1193	0.128			
3916	1194	0.140			

3920	1195	0.135	27	0.1366313	2.514864
3923	1196	0.152			
3926	1197	0.123			
3929	1198	0.162	28	0.1779941	137.3261
3933	1199	0.204			
3936	1200	0.168			
3939	1201	0.142	29	0.1221499	0.619864
3943	1202	0.120			
3946	1203	0.105			
3949	1204	0.144	30	0.1467494	6.690773
3952	1205	0.154			
3956	1206	0.142			

Table B.2: KM-1A Production Data.

KM-1A PRODUCTION DATA

Year and Month	Number of days	Pwh (psi)	Rate (Mscf/D)	Number of Producing days	Modified Rate, (Mscf/D)	Cumulative Production, (Mscf)
1997.10	31	1690	6538	24	5062	156912
1997.11	30	1720	5865	30	5865	332862
1997.12	31	1710	6210	31	6210	525372
1998.01	31	1780	6143	31	6143	715805
1998.02	28	1710	6085	28	6085	886185
1998.03	31	1680	7298	24	5650	1061337
1998.04	30	1680	7577	29	7324	1281070
1998.05	31	1690	7106	31	7106	1501356
1998.06	30	1630	9379	30	9379	1782726
1998.07	31	1610	9907	31	9907	2089843
1998.08	31	1640	7965	31	7965	2336758
1998.09	30	1520	10801	30	10801	2660788
1998.10	31	1520	11644	29	10893	2998464
1998.11	30	1480	11353	30	11353	3339054
1998.12	31	1460	11822	31	11822	3705536
1999.01	31	1480	11175	31	11175	4051961
1999.02	28	1440	11521	28	11521	4374549
1999.03	31	1440	11425	31	11425	4728724
1999.04	30	1440	10859	30	10859	5054494
1999.05	31	1430	11044	31	11044	5396858
1999.06	30	1420	10839	30	10839	5722028
1999.07	31	1390	10845	30	10495	6047378
1999.08	31	1420	10151	31	10151	6362059
1999.09	30	1380	10612	30	10612	6680419
1999.10	31	1370	10538	31	10538	7007097
1999.11	30	1340	10677	30	10677	7327407
1999.12	31	1320	10909	31	10909	7665586
2000.01	31	1240	11360	31	11360	8017746
2000.02	29	1250	11633	29	11633	8355103
2000.03	31	1200	11427	31	11427	8709340
2000.04	30	1270	10880	30	10880	9035740
2000.05	31	1280	9852	30	9534	9331300
2000.06	30	1290	9623	30	9623	9619990
2000.07	31	1270	10291	31	10291	9939011
2000.08	31	1250	10234	31	10234	10256265
2000.09	30	1250	9291	29	8981	10525704
2000.10	31	1310	7246	31	7246	10750330

2000.11	30	1310	7471	30	7471	10974460
2000.12	31	1300	6636	31	6636	11180176
2001.01	31	1295	6239	30	6038	11367346
2001.02	28	1205	7140	25	6375	11545846
2001.03	31	1230	8664	21	5869	11727790
2001.04	30	1240	7690	17	4358	11858520

Table B.3: KM-1A Average Petro-physical Characteristics.

KM-1A AVERAGE PETROPHYSICAL PROPERTIES

Well #	Depth				Øe	Sw	k	Pi	S
	Level	m	ft	Interval	%	%	md	psia	Factor
KM-1A	Top	1141	3742	R1	18.3	5.9	200	2054	33.1
	Bottom	1180.5	3872						
	Top	1181.5	3875	R2	9.9	16.4			
	Bottom	1190	3903						
	Top	1193.5	3915	R3	12.65	10	200	2054	33.1
	Bottom	1215	3985						

Table B.4: KM-1A Initial Conditions.

Pressure, psi	2054
Temperature, ^{0}C (^{0}R)	68.3 (615)
Gas Deviation Factor (z)	0.872
Gas Expansion Factor (Bg)	0.00733
Average kh (md.ft)	23670
Average k (mD)	200
Average Porosity	0.166
Total Skin	33.1

Table B.5: Indigenous reservoir gas composition.

KM RESERVOIR GAS COMPOSITION

COMPONENT	% mol	Tc (^{0}R)	WEIGHTED Tc (^{0}R)	Pc (psi)	WEIGHTED Pc (psi)	Mw (g/mol)	WEIGHTED MW (g/mol)	Mw (lb/mol)	WEIGHTED MW (lb/mol)
N2	2.32	272.2	6.32	493	11.44	28.01	0.65	61.62	1.43
CO2	1.22	548	6.69	1071	13.07	44.01	0.54	96.82	1.18
C1	92.42	344.2	318.11	673	622.19	16.043	14.83	35.29	32.62
C2	2.22	550.0	12.23	709	15.75	30.069	0.67	66.15	1.47
C3	0.86	666.2	5.73	617	5.31	44.096	0.38	97.01	0.83
IC4	0.20	735.0	1.47	529	1.06	58.123	0.12	127.87	0.26
NC4	0.26	765.6	1.99	551	1.43	58.123	0.15	127.87	0.33
IC5	0.10	830.0	0.83	484	0.48	72.15	0.07	158.73	0.16
NC5	0.07	845.9	0.59	490	0.34	72.15	0.05	158.73	0.11
C6	0.09	913.6	0.81	440	0.39	86.18	0.08	189.60	0.17
C7	0.07	972.8	0.69	397	0.28	100.21	0.07	220.46	0.16
C8	0.05	1024.8	0.53	365	0.19	114.23	0.06	251.31	0.13
C9	0.04	1069.8	0.46	331	0.14	128.20	0.06	282.04	0.12
C10+	0.08	1111.9	0.87	306	0.24	142.29	0.11	313.04	0.24
Total	100		354.76		671.46		17.82		38.56

Table B.6: Russian Gas Composition.

RUSSIAN GAS COMPOSITION

COMPONENT	% mol	Tc (^{0}R)	WEIGHTED Tc (^{0}R)	Pc (psi)	WEIGHTED Pc (psi)	Mw (g/mol)	WEIGHTED Mw (g/mol)	Mw (lb/mol)	WEIGHTED Mw (lb/mol)
C1	98.55	344	339.23	673	663.50	16.043	15.81	35.2946	34.78
C2	0.43	550	2.36	709	3.05	30.069	0.13	66.1518	0.28
C3	0.13	666	0.87	617	0.80	44.08	0.06	96.976	0.13
C4	0.05	766	0.38	551	0.28	58.123	0.03	127.871	0.06
C5+	0.01	846	0.08	489	0.05	72.15	0.01	158.73	0.02
N2	0.79	272	2.15	493	3.89	28.01	0.22	61.622	0.49
CO2	0.04	548	0.22	1071	0.43	44.01	0.02	96.822	0.04
Total	100		345		672		16.3		35.8

Table B.7: PVT Properties.

PVT PROPERTIES

P, bar	P, psi	Bg, m3/sm3	Eg, sm3/m3	µ, cp	z
1	14.7	1.18162	0.8462958	0.01248	0.991
9	132.3	0.13157	7.6005168	0.01255	0.988
18	264.6	0.06499	15.3869826	0.01265	0.976
27	396.9	0.04282	23.3535731	0.01279	0.964
36	529.2	0.03175	31.4960630	0.01295	0.953
45	661.5	0.02511	39.8247710	0.01313	0.943
54	793.8	0.02070	48.3091787	0.01333	0.933
63	926.1	0.01756	56.9476082	0.01355	0.923
72	1058.4	0.01522	65.7030223	0.01379	0.914
81	1190.7	0.01340	74.6268657	0.01405	0.906
90	1323	0.01196	83.6120401	0.01433	0.898
99	1455.3	0.01079	92.6784059	0.01463	0.891
108	1587.6	0.00982	101.8329939	0.01494	0.884
117	1719.9	0.00901	110.9877913	0.01528	0.879
126	1852.2	0.00832	120.1923077	0.01563	0.875
135	1984.5	0.00774	129.1989664	0.01600	0.871
144	2116.8	0.00723	138.3125864	0.01638	0.868
153	2249.1	0.00679	147.2754050	0.01678	0.866
162	2381.4	0.00640	156.2500000	0.01719	0.865

Table B.8: Solution gas oil ratio, Rs.

CALCULATED Rs VALUES

P, bar	**P, psi**	Rs
1	14.7	3.8469
9	132.3	13.7138
18	264.6	28.2133
27	396.9	45.4595
36	529.2	65.0463
45	661.5	86.7464
54	793.8	110.4196
63	926.1	135.9771
72	1058.4	163.3630
81	1190.7	192.5455
90	1323	223.5110
99	1455.3	256.2607
108	1587.6	290.8085
117	1719.9	327.1800
126	1852.2	365.4116
135	1984.5	405.5506
144	2116.8	447.6552
153	2249.1	491.7949
162	2381.4	538.0517

APPENDIX C

CMG IMEX OUTPUT DATA

Table C.1: CMG IMEX Numerical simulation results for assumed Skin 0.

		Skin 0							
		Darcy Flow		Non-Darcy Flow FG1		Non-Darcy Flow FG2		Non-Darcy Flow Geertsma	
DATE	Gas Rate SC - Monthly	Pbh	Pr	Pbh	Pr	Pbh	Pr	Pbh	Pr
	(ft3/day)	(psi)	(psi)	(psi)	(psi)	(psi)	(psi)	(psi)	(psi)
8/31/1997	0	0	0	0	0	0	0	0	0
9/1/1997	90.2957	0	2050.01	0	2060.53	0	2060.53	0	2060.53
9/1/1997	112.87	2035.14	2050.01	2045.54	2060.53	2045.54	2060.53	2046.09	2060.53
9/1/1997	225.739	2020.48	2050.01	2030.82	2060.53	2030.81	2060.53	2030.73	2060.53
9/1/1997	790.087	2020.57	2050.01	2030.92	2060.53	2030.92	2060.53	2030.88	2060.53
9/1/1997	3611.83	2020.56	2050.01	2030.91	2060.53	2030.9	2060.53	2030.88	2060.53
9/2/1997	17720.5	2020.55	2050.01	2030.89	2060.53	2030.89	2060.53	2030.87	2060.53
9/10/1997	88264.1	2020.54	2050.01	2030.88	2060.52	2030.88	2060.52	2030.85	2060.52
9/30/1997	270887	2020.53	2050.01	2030.87	2060.48	2030.87	2060.48	2030.84	2060.48
10/1/1997	272432	2020.53	2050.01	2030.87	2060.48	2030.87	2060.48	2030.84	2060.48
10/1/1997	272819	2033.38	2050.01	2043.78	2060.48	2043.79	2060.48	2044.92	2060.48
10/1/1997	274750	2018.48	2050.01	2028.72	2060.48	2028.66	2060.48	2027.62	2060.48
10/1/1997	284406	2018.36	2050.01	2028.66	2060.48	2028.63	2060.48	2027.69	2060.48
10/1/1997	332688	2018.14	2050.01	2028.45	2060.48	2028.42	2060.48	2027.45	2060.48
10/2/1997	574098	2017.92	2050.01	2028.23	2060.48	2028.2	2060.48	2027.2	2060.48
10/10/1997	1.78E+06	2017.7	2050.01	2028.01	2060.48	2027.98	2060.48	2026.96	2060.48
10/31/1997	5.06E+06	2017.53	2050.01	2027.84	2060.48	2027.82	2060.48	2026.78	2060.48
11/1/1997	5.06E+06	2017.53	2050.01	2027.84	2060.48	2027.82	2060.48	2026.78	2060.48
11/1/1997	5.06E+06	2031.77	2050.01	2042.18	2060.48	2042.25	2060.48	2043.06	2060.48
11/1/1997	5.06E+06	2017.1	2050.01	2027.33	2060.48	2027.25	2060.48	2025.85	2060.48
11/1/1997	5.06E+06	2017.17	2050.01	2027.46	2060.48	2027.42	2060.48	2026.17	2060.48
11/1/1997	5.07E+06	2017.13	2050.01	2027.43	2060.48	2027.39	2060.48	2026.15	2060.48
11/2/1997	5.11E+06	2017.08	2050.01	2027.38	2060.48	2027.35	2060.48	2026.1	2060.48
11/10/1997	5.32E+06	2017.01	2050.01	2027.31	2060.48	2027.27	2060.48	2026.02	2060.48
11/30/1997	5.86E+06	2016.92	2050.01	2027.22	2060.48	2027.19	2060.48	2025.92	2060.48
12/1/1997	5.86E+06	2016.92	2050.01	2027.22	2060.48	2027.19	2060.48	2025.92	2060.48
12/1/1997	5.86E+06	2031.31	2050.01	2041.72	2060.48	2041.8	2060.48	2042.44	2060.48
12/1/1997	5.87E+06	2016.68	2050.01	2026.89	2060.48	2026.81	2060.48	2025.28	2060.48
12/1/1997	5.87E+06	2016.76	2050.01	2027.05	2060.48	2027.01	2060.48	2025.63	2060.48
12/1/1997	5.87E+06	2016.74	2050.01	2027.04	2060.48	2027	2060.48	2025.65	2060.48
12/2/1997	5.89E+06	2016.72	2050.01	2027.02	2060.48	2026.98	2060.48	2025.63	2060.48
12/10/1997	5.97E+06	2016.68	2050.01	2026.98	2060.48	2026.94	2060.48	2025.58	2060.48
12/31/1997	6.21E+06	2016.62	2050.01	2026.92	2060.48	2026.88	2060.48	2025.52	2060.48
1/1/1998	6.21E+06	2016.62	2050.01	2026.92	2060.48	2026.88	2060.48	2025.52	2060.48
1/1/1998	6.21E+06	2031.16	2050.01	2041.57	2060.48	2041.65	2060.48	2042.25	2060.48
1/1/1998	6.21E+06	2016.54	2050.01	2026.76	2060.48	2026.68	2060.48	2025.15	2060.48
1/1/1998	6.21E+06	2016.65	2050.01	2026.94	2060.48	2026.9	2060.48	2025.52	2060.48
1/1/1998	6.21E+06	2016.65	2050.01	2026.95	2060.48	2026.91	2060.48	2025.56	2060.48

1/2/1998	6.21E+06	2016.65	2050.01	2026.95	2060.48	2026.91	2060.48	2025.56	2060.48
1/10/1998	6.19E+06	2016.64	2050.01	2026.93	2060.48	2026.9	2060.48	2025.55	2060.48
1/31/1998	6.14E+06	2016.6	2050.01	2026.9	2060.48	2026.86	2060.48	2025.51	2060.48
2/1/1998	6.14E+06	2016.6	2050.01	2026.9	2060.48	2026.86	2060.48	2025.51	2060.48
2/1/1998	6.14E+06	2031.14	2050.01	2041.55	2060.48	2041.63	2060.48	2042.24	2060.48
2/1/1998	6.14E+06	2016.52	2050.01	2026.74	2060.48	2026.66	2060.48	2025.13	2060.48
2/1/1998	6.14E+06	2016.62	2050.01	2026.92	2060.48	2026.88	2060.48	2025.51	2060.48
2/1/1998	6.14E+06	2016.63	2050.01	2026.93	2060.48	2026.89	2060.48	2025.55	2060.48
2/2/1998	6.14E+06	2016.63	2050.01	2026.93	2060.48	2026.89	2060.48	2025.55	2060.48
2/10/1998	6.12E+06	2016.62	2050	2026.92	2060.48	2026.88	2060.48	2025.54	2060.48
2/28/1998	6.09E+06	2016.6	2050	2026.89	2060.47	2026.86	2060.47	2025.52	2060.47
3/1/1998	6.08E+06	2016.6	2050	2026.89	2060.47	2026.86	2060.47	2025.52	2060.47
3/1/1998	6.08E+06	2031.26	2050	2041.68	2060.47	2041.77	2060.47	2042.46	2060.47
3/1/1998	6.08E+06	2016.67	2050	2026.9	2060.47	2026.82	2060.47	2025.39	2060.47
3/1/1998	6.08E+06	2016.79	2050	2027.09	2060.47	2027.05	2060.47	2025.79	2060.47
3/1/1998	6.08E+06	2016.81	2050	2027.12	2060.47	2027.08	2060.47	2025.85	2060.47
3/2/1998	6.06E+06	2016.83	2050	2027.13	2060.47	2027.1	2060.47	2025.88	2060.47
3/10/1998	5.95E+06	2016.84	2050	2027.14	2060.47	2027.11	2060.47	2025.89	2060.47
3/31/1998	5.65E+06	2016.83	2050	2027.14	2060.47	2027.11	2060.47	2025.88	2060.47
4/1/1998	5.65E+06	2016.83	2050	2027.14	2060.47	2027.11	2060.47	2025.88	2060.47
4/1/1998	5.65E+06	2030.76	2050	2041.16	2060.47	2041.23	2060.47	2041.7	2060.47
4/1/1998	5.65E+06	2016.05	2050	2026.25	2060.47	2026.15	2060.47	2024.37	2060.47
4/1/1998	5.66E+06	2016.07	2050	2026.35	2060.47	2026.29	2060.47	2024.63	2060.47
4/1/1998	5.67E+06	2016	2050	2026.28	2060.47	2026.22	2060.47	2024.57	2060.47
4/2/1998	5.76E+06	2015.92	2050	2026.2	2060.47	2026.15	2060.47	2024.48	2060.47
4/10/1998	6.20E+06	2015.84	2049.99	2026.12	2060.46	2026.07	2060.46	2024.39	2060.47
4/30/1998	7.32E+06	2015.77	2049.99	2026.05	2060.46	2026	2060.46	2024.31	2060.46
5/1/1998	7.32E+06	2015.77	2049.99	2026.05	2060.46	2026	2060.46	2024.31	2060.46
5/1/1998	7.32E+06	2030.36	2049.99	2040.76	2060.46	2040.85	2060.46	2041.12	2060.46
5/1/1998	7.32E+06	2015.76	2049.99	2025.96	2060.46	2025.86	2060.46	2024.05	2060.46
5/1/1998	7.32E+06	2015.87	2049.99	2026.15	2060.46	2026.09	2060.46	2024.43	2060.46
5/1/1998	7.32E+06	2015.88	2049.99	2026.16	2060.46	2026.11	2060.46	2024.48	2060.46
5/2/1998	7.31E+06	2015.88	2049.99	2026.17	2060.46	2026.12	2060.46	2024.49	2060.46
5/10/1998	7.25E+06	2015.88	2049.99	2026.16	2060.46	2026.11	2060.46	2024.48	2060.46
5/31/1998	7.11E+06	2015.85	2049.98	2026.13	2060.45	2026.08	2060.45	2024.46	2060.45
6/1/1998	7.11E+06	2015.85	2049.98	2026.13	2060.45	2026.08	2060.45	2024.46	2060.45
6/1/1998	7.11E+06	2029.56	2049.98	2039.94	2060.45	2040	2060.45	2039.9	2060.45
6/1/1998	7.11E+06	2014.82	2049.98	2024.98	2060.45	2024.85	2060.45	2022.53	2060.45
6/1/1998	7.11E+06	2014.82	2049.98	2025.05	2060.45	2024.96	2060.45	2022.71	2060.45
6/1/1998	7.14E+06	2014.71	2049.98	2024.96	2060.45	2024.87	2060.45	2022.61	2060.45
6/2/1998	7.25E+06	2014.61	2049.98	2024.85	2060.45	2024.77	2060.45	2022.49	2060.45
6/10/1998	7.85E+06	2014.49	2049.98	2024.74	2060.45	2024.66	2060.45	2022.37	2060.45
6/30/1998	9.38E+06	2014.4	2049.97	2024.64	2060.44	2024.56	2060.44	2022.26	2060.45
7/1/1998	9.38E+06	2014.4	2049.97	2024.64	2060.44	2024.56	2060.44	2022.26	2060.45
7/1/1998	9.38E+06	2028.71	2049.97	2039.08	2060.44	2039.15	2060.44	2038.6	2060.45
7/1/1998	9.38E+06	2014.08	2049.97	2024.22	2060.44	2024.09	2060.44	2021.53	2060.45
7/1/1998	9.38E+06	2014.16	2049.97	2024.38	2060.44	2024.28	2060.44	2021.81	2060.45
7/1/1998	9.39E+06	2014.13	2049.97	2024.36	2060.44	2024.27	2060.44	2021.81	2060.45
7/2/1998	9.41E+06	2014.1	2049.97	2024.33	2060.44	2024.24	2060.44	2021.78	2060.44
7/10/1998	9.54E+06	2014.05	2049.97	2024.28	2060.44	2024.19	2060.44	2021.73	2060.44
7/31/1998	9.91E+06	2013.98	2049.96	2024.22	2060.43	2024.13	2060.43	2021.65	2060.44
8/1/1998	9.91E+06	2013.98	2049.96	2024.22	2060.43	2024.13	2060.43	2021.65	2060.44
8/1/1998	9.91E+06	2029.17	2049.96	2039.56	2060.43	2039.65	2060.43	2039.39	2060.44
8/1/1998	9.91E+06	2014.67	2049.96	2024.85	2060.43	2024.74	2060.43	2022.59	2060.44
8/1/1998	9.90E+06	2014.86	2049.96	2025.13	2060.43	2025.06	2060.43	2023.07	2060.44
8/1/1998	9.88E+06	2014.95	2049.96	2025.22	2060.43	2025.16	2060.43	2023.22	2060.44
8/2/1998	9.78E+06	2015.04	2049.96	2025.31	2060.43	2025.25	2060.43	2023.33	2060.43
8/10/1998	9.29E+06	2015.11	2049.96	2025.38	2060.43	2025.32	2060.43	2023.42	2060.43

8/31/1998	7.97E+06	2015.13	2049.95	2025.4	2060.42	2025.34	2060.42	2023.45	2060.42
9/1/1998	7.97E+06	2015.13	2049.95	2025.4	2060.42	2025.34	2060.42	2023.45	2060.42
9/1/1998	7.97E+06	2028.63	2049.95	2039	2060.42	2039.05	2060.42	2038.55	2060.42
9/1/1998	7.97E+06	2013.87	2049.95	2024	2060.42	2023.86	2060.42	2021.15	2060.42
9/1/1998	7.97E+06	2013.84	2049.95	2024.05	2060.42	2023.94	2060.42	2021.25	2060.42
9/1/1998	8.00E+06	2013.72	2049.95	2023.93	2060.42	2023.82	2060.42	2021.11	2060.42
9/2/1998	8.15E+06	2013.59	2049.95	2023.8	2060.42	2023.69	2060.42	2020.97	2060.42
9/10/1998	8.89E+06	2013.46	2049.95	2023.67	2060.42	2023.57	2060.42	2020.82	2060.42
9/30/1998	1.08E+07	2013.36	2049.94	2023.57	2060.41	2023.46	2060.41	2020.7	2060.41
10/1/1998	1.08E+07	2013.36	2049.94	2023.57	2060.41	2023.46	2060.41	2020.7	2060.41
10/1/1998	1.08E+07	2027.82	2049.94	2038.17	2060.41	2038.23	2060.41	2037.26	2060.41
10/1/1998	1.08E+07	2013.22	2049.94	2023.34	2060.41	2023.19	2060.41	2020.32	2060.41
10/1/1998	1.08E+07	2013.32	2049.94	2023.52	2060.41	2023.4	2060.41	2020.59	2060.41
10/1/1998	1.08E+07	2013.31	2049.94	2023.52	2060.41	2023.41	2060.41	2020.62	2060.41
10/2/1998	1.08E+07	2013.3	2049.94	2023.51	2060.41	2023.4	2060.41	2020.61	2060.41
10/10/1998	1.08E+07	2013.27	2049.94	2023.48	2060.41	2023.37	2060.41	2020.58	2060.41
10/31/1998	1.09E+07	2013.22	2049.93	2023.43	2060.4	2023.32	2060.4	2020.52	2060.4
11/1/1998	1.09E+07	2013.22	2049.93	2023.43	2060.4	2023.32	2060.4	2020.52	2060.4
11/1/1998	1.09E+07	2027.55	2049.93	2037.89	2060.4	2037.94	2060.4	2036.86	2060.4
11/1/1998	1.09E+07	2012.93	2049.93	2023.04	2060.4	2022.89	2060.4	2019.89	2060.4
11/1/1998	1.09E+07	2013.01	2049.93	2023.2	2060.4	2023.08	2060.4	2020.13	2060.4
11/1/1998	1.09E+07	2012.99	2049.93	2023.19	2060.4	2023.07	2060.4	2020.13	2060.4
11/2/1998	1.09E+07	2012.96	2049.93	2023.16	2060.4	2023.05	2060.4	2020.1	2060.4
11/10/1998	1.10E+07	2012.93	2049.92	2023.12	2060.39	2023.01	2060.39	2020.06	2060.39
11/30/1998	1.14E+07	2012.88	2049.91	2023.07	2060.38	2022.96	2060.38	2020.01	2060.39
12/1/1998	1.14E+07	2012.88	2049.91	2023.07	2060.38	2022.96	2060.38	2020.01	2060.39
12/1/1998	1.14E+07	2027.2	2049.91	2037.53	2060.38	2037.58	2060.38	2036.33	2060.39
12/1/1998	1.14E+07	2012.58	2049.91	2022.68	2060.38	2022.53	2060.38	2019.39	2060.39
12/1/1998	1.14E+07	2012.66	2049.91	2022.84	2060.38	2022.71	2060.38	2019.61	2060.39
12/1/1998	1.14E+07	2012.64	2049.91	2022.83	2060.38	2022.7	2060.38	2019.6	2060.39
12/2/1998	1.14E+07	2012.62	2049.91	2022.8	2060.38	2022.68	2060.38	2019.58	2060.38
12/10/1998	1.15E+07	2012.58	2049.91	2022.77	2060.38	2022.64	2060.38	2019.54	2060.38
12/31/1998	1.18E+07	2012.53	2049.9	2022.71	2060.37	2022.59	2060.37	2019.48	2060.37
1/1/1999	1.18E+07	2012.53	2049.9	2022.71	2060.37	2022.59	2060.37	2019.48	2060.37
1/1/1999	1.18E+07	2027.25	2049.9	2037.58	2060.37	2037.64	2060.37	2036.44	2060.37
1/1/1999	1.18E+07	2012.69	2049.9	2022.8	2060.37	2022.65	2060.37	2019.64	2060.37
1/1/1999	1.18E+07	2012.82	2049.9	2023.02	2060.37	2022.9	2060.37	2019.95	2060.37
1/1/1999	1.18E+07	2012.85	2049.9	2023.05	2060.37	2022.94	2060.37	2020.02	2060.37
1/2/1999	1.18E+07	2012.88	2049.89	2023.08	2060.37	2022.97	2060.37	2020.06	2060.37
1/10/1999	1.16E+07	2012.89	2049.89	2023.09	2060.36	2022.98	2060.36	2020.07	2060.36
1/31/1999	1.12E+07	2012.88	2049.88	2023.08	2060.35	2022.97	2060.35	2020.06	2060.35
2/1/1999	1.12E+07	2012.88	2049.88	2023.08	2060.35	2022.97	2060.35	2020.06	2060.35
2/1/1999	1.12E+07	2027.25	2049.88	2037.58	2060.35	2037.63	2060.35	2036.46	2060.35
2/1/1999	1.12E+07	2012.63	2049.88	2022.74	2060.35	2022.59	2060.35	2019.52	2060.35
2/1/1999	1.12E+07	2012.72	2049.88	2022.91	2060.35	2022.78	2060.35	2019.76	2060.35
2/1/1999	1.12E+07	2012.7	2049.88	2022.9	2060.35	2022.78	2060.35	2019.76	2060.35
2/2/1999	1.12E+07	2012.69	2049.88	2022.88	2060.35	2022.76	2060.35	2019.75	2060.35
2/10/1999	1.13E+07	2012.66	2049.87	2022.86	2060.34	2022.74	2060.34	2019.72	2060.35
2/28/1999	1.15E+07	2012.64	2049.86	2022.83	2060.33	2022.71	2060.33	2019.69	2060.34
3/1/1999	1.15E+07	2012.64	2049.86	2022.83	2060.33	2022.71	2060.33	2019.69	2060.34
3/1/1999	1.15E+07	2027.16	2049.86	2037.49	2060.33	2037.55	2060.33	2036.34	2060.34
3/1/1999	1.15E+07	2012.57	2049.86	2022.68	2060.33	2022.53	2060.33	2019.47	2060.34
3/1/1999	1.15E+07	2012.68	2049.86	2022.87	2060.33	2022.74	2060.33	2019.74	2060.34
3/1/1999	1.15E+07	2012.68	2049.86	2022.88	2060.33	2022.76	2060.33	2019.77	2060.34
3/2/1999	1.15E+07	2012.69	2049.86	2022.88	2060.33	2022.77	2060.33	2019.78	2060.34
3/10/1999	1.15E+07	2012.68	2049.86	2022.88	2060.33	2022.76	2060.33	2019.77	2060.33
3/31/1999	1.14E+07	2012.66	2049.84	2022.85	2060.31	2022.74	2060.31	2019.75	2060.32
4/1/1999	1.14E+07	2012.66	2049.84	2022.85	2060.31	2022.74	2060.31	2019.75	2060.32

4/1/1999	1.14E+07	2027.35	2049.84	2037.69	2060.31	2037.75	2060.31	2036.67	2060.32
4/1/1999	1.14E+07	2012.79	2049.84	2022.9	2060.31	2022.76	2060.31	2019.83	2060.32
4/1/1999	1.14E+07	2012.91	2049.84	2023.12	2060.31	2023	2060.31	2020.15	2060.32
4/1/1999	1.14E+07	2012.94	2049.84	2023.15	2060.31	2023.04	2060.31	2020.22	2060.32
4/2/1999	1.14E+07	2012.96	2049.84	2023.17	2060.31	2023.07	2060.31	2020.25	2060.32
4/10/1999	1.12E+07	2012.98	2049.84	2023.19	2060.31	2023.09	2060.31	2020.27	2060.31
4/30/1999	1.09E+07	2012.98	2049.82	2023.19	2060.3	2023.08	2060.3	2020.28	2060.3
5/1/1999	1.09E+07	2012.98	2049.82	2023.19	2060.3	2023.08	2060.3	2020.28	2060.3
5/1/1999	1.09E+07	2027.41	2049.82	2037.75	2060.3	2037.81	2060.3	2036.77	2060.3
5/1/1999	1.09E+07	2012.8	2049.82	2022.92	2060.3	2022.77	2060.3	2019.83	2060.3
5/1/1999	1.09E+07	2012.89	2049.82	2023.09	2060.3	2022.98	2060.3	2020.1	2060.3
5/1/1999	1.09E+07	2012.89	2049.82	2023.09	2060.3	2022.98	2060.3	2020.11	2060.3
5/2/1999	1.09E+07	2012.88	2049.82	2023.08	2060.29	2022.97	2060.29	2020.11	2060.3
5/10/1999	1.09E+07	2012.87	2049.82	2023.07	2060.29	2022.96	2060.29	2020.1	2060.29
5/31/1999	1.10E+07	2012.85	2049.8	2023.05	2060.27	2022.94	2060.27	2020.08	2060.28
6/1/1999	1.10E+07	2012.85	2049.8	2023.05	2060.27	2022.94	2060.27	2020.08	2060.28
6/1/1999	1.10E+07	2027.41	2049.8	2037.76	2060.27	2037.82	2060.27	2036.8	2060.28
6/1/1999	1.10E+07	2012.83	2049.8	2022.95	2060.27	2022.81	2060.27	2019.9	2060.28
6/1/1999	1.10E+07	2012.94	2049.8	2023.14	2060.27	2023.03	2060.27	2020.2	2060.28
6/1/1999	1.10E+07	2012.95	2049.8	2023.16	2060.27	2023.05	2060.27	2020.24	2060.28
6/2/1999	1.10E+07	2012.96	2049.8	2023.17	2060.27	2023.06	2060.27	2020.26	2060.28
6/10/1999	1.10E+07	2012.96	2049.8	2023.17	2060.27	2023.07	2060.27	2020.26	2060.27
6/30/1999	1.08E+07	2012.95	2049.78	2023.16	2060.25	2023.06	2060.25	2020.25	2060.26
7/1/1999	1.08E+07	2012.95	2049.78	2023.16	2060.25	2023.06	2060.25	2020.25	2060.26
7/1/1999	1.08E+07	2027.56	2049.78	2037.91	2060.25	2037.98	2060.25	2037.06	2060.26
7/1/1999	1.08E+07	2012.99	2049.78	2023.12	2060.25	2022.98	2060.25	2020.16	2060.26
7/1/1999	1.08E+07	2013.11	2049.78	2023.32	2060.25	2023.21	2060.25	2020.48	2060.26
7/1/1999	1.08E+07	2013.12	2049.78	2023.34	2060.25	2023.24	2060.25	2020.53	2060.26
7/2/1999	1.08E+07	2013.14	2049.78	2023.36	2060.25	2023.26	2060.25	2020.56	2060.26
7/10/1999	1.07E+07	2013.15	2049.78	2023.37	2060.25	2023.27	2060.25	2020.57	2060.25
7/31/1999	1.05E+07	2013.15	2049.76	2023.36	2060.23	2023.27	2060.23	2020.57	2060.24
8/1/1999	1.05E+07	2013.15	2049.76	2023.36	2060.23	2023.27	2060.23	2020.57	2060.24
8/1/1999	1.05E+07	2027.76	2049.76	2038.12	2060.23	2038.19	2060.23	2037.38	2060.24
8/1/1999	1.05E+07	2013.18	2049.76	2023.32	2060.23	2023.18	2060.23	2020.47	2060.24
8/1/1999	1.05E+07	2013.3	2049.76	2023.52	2060.23	2023.42	2060.23	2020.8	2060.24
8/1/1999	1.05E+07	2013.32	2049.76	2023.54	2060.23	2023.45	2060.23	2020.85	2060.24
8/2/1999	1.05E+07	2013.33	2049.76	2023.56	2060.23	2023.47	2060.23	2020.88	2060.24
8/10/1999	1.04E+07	2013.35	2049.76	2023.57	2060.23	2023.48	2060.23	2020.89	2060.23
8/31/1999	1.02E+07	2013.35	2049.74	2023.57	2060.21	2023.48	2060.21	2020.9	2060.22
9/1/1999	1.02E+07	2013.35	2049.74	2023.57	2060.21	2023.48	2060.21	2020.9	2060.22
9/1/1999	1.02E+07	2027.68	2049.74	2038.03	2060.21	2038.1	2060.21	2037.26	2060.22
9/1/1999	1.02E+07	2013.06	2049.74	2023.18	2060.21	2023.04	2060.21	2020.24	2060.22
9/1/1999	1.02E+07	2013.14	2049.74	2023.35	2060.21	2023.24	2060.21	2020.5	2060.22
9/1/1999	1.02E+07	2013.12	2049.74	2023.33	2060.21	2023.23	2060.21	2020.51	2060.22
9/2/1999	1.02E+07	2013.1	2049.74	2023.31	2060.21	2023.21	2060.21	2020.49	2060.22
9/10/1999	1.03E+07	2013.07	2049.73	2023.29	2060.21	2023.19	2060.21	2020.46	2060.21
9/30/1999	1.06E+07	2013.05	2049.72	2023.27	2060.19	2023.17	2060.19	2020.44	2060.2
10/1/1999	1.06E+07	2013.05	2049.72	2023.27	2060.19	2023.17	2060.19	2020.44	2060.2
10/1/1999	1.06E+07	2027.57	2049.72	2037.92	2060.19	2037.99	2060.19	2037.09	2060.2
10/1/1999	1.06E+07	2012.98	2049.72	2023.11	2060.19	2022.97	2060.19	2020.16	2060.2
10/1/1999	1.06E+07	2013.08	2049.72	2023.29	2060.19	2023.19	2060.19	2020.46	2060.2
10/1/1999	1.06E+07	2013.09	2049.72	2023.3	2060.19	2023.2	2060.19	2020.49	2060.2
10/2/1999	1.06E+07	2013.09	2049.72	2023.31	2060.19	2023.21	2060.19	2020.5	2060.2
10/10/1999	1.06E+07	2013.09	2049.71	2023.3	2060.19	2023.2	2060.19	2020.5	2060.19
10/31/1999	1.05E+07	2013.07	2049.7	2023.29	2060.17	2023.19	2060.17	2020.49	2060.18
11/1/1999	1.05E+07	2013.07	2049.7	2023.29	2060.17	2023.19	2060.17	2020.49	2060.18
11/1/1999	1.05E+07	2027.52	2049.7	2037.87	2060.17	2037.93	2060.17	2037.02	2060.18
11/1/1999	1.05E+07	2012.91	2049.7	2023.04	2060.17	2022.9	2060.17	2020.06	2060.18

11/1/1999	1.05E+07	2013.01	2049.7	2023.22	2060.17	2023.11	2060.17	2020.34	2060.18
11/1/1999	1.05E+07	2013	2049.7	2023.22	2060.17	2023.11	2060.17	2020.36	2060.18
11/2/1999	1.05E+07	2013	2049.7	2023.21	2060.17	2023.11	2060.17	2020.36	2060.18
11/10/1999	1.06E+07	2012.98	2049.69	2023.2	2060.16	2023.1	2060.16	2020.35	2060.17
11/30/1999	1.07E+07	2012.97	2049.68	2023.18	2060.15	2023.08	2060.15	2020.33	2060.16
12/1/1999	1.07E+07	2012.97	2049.68	2023.18	2060.15	2023.08	2060.15	2020.33	2060.16
12/1/1999	1.07E+07	2027.38	2049.68	2037.72	2060.15	2037.78	2060.15	2036.8	2060.16
12/1/1999	1.07E+07	2012.77	2049.68	2022.89	2060.15	2022.74	2060.15	2019.84	2060.16
12/1/1999	1.07E+07	2012.86	2049.68	2023.06	2060.15	2022.95	2060.15	2020.11	2060.16
12/1/1999	1.07E+07	2012.85	2049.68	2023.06	2060.15	2022.95	2060.15	2020.13	2060.16
12/2/1999	1.07E+07	2012.84	2049.68	2023.05	2060.15	2022.94	2060.15	2020.12	2060.15
12/10/1999	1.08E+07	2012.82	2049.67	2023.03	2060.14	2022.92	2060.14	2020.1	2060.15
12/31/1999	1.09E+07	2012.8	2049.66	2023.01	2060.13	2022.9	2060.13	2020.08	2060.13
1/1/2000	1.09E+07	2012.8	2049.66	2023.01	2060.13	2022.9	2060.13	2020.08	2060.13
1/1/2000	1.09E+07	2027.13	2049.66	2037.47	2060.13	2037.52	2060.13	2036.42	2060.13
1/1/2000	1.09E+07	2012.51	2049.66	2022.62	2060.13	2022.47	2060.13	2019.45	2060.13
1/1/2000	1.09E+07	2012.59	2049.66	2022.78	2060.13	2022.66	2060.13	2019.69	2060.13
1/1/2000	1.09E+07	2012.57	2049.66	2022.77	2060.13	2022.65	2060.13	2019.69	2060.13
1/2/2000	1.09E+07	2012.55	2049.66	2022.75	2060.13	2022.63	2060.13	2019.67	2060.13
1/10/2000	1.11E+07	2012.52	2049.65	2022.72	2060.12	2022.6	2060.12	2019.64	2060.13
1/31/2000	1.14E+07	2012.49	2049.64	2022.69	2060.11	2022.57	2060.11	2019.6	2060.11
2/1/2000	1.14E+07	2012.49	2049.64	2022.69	2060.11	2022.57	2060.11	2019.6	2060.11
2/1/2000	1.14E+07	2026.88	2049.64	2037.21	2060.11	2037.26	2060.11	2036.03	2060.11
2/1/2000	1.14E+07	2012.27	2049.64	2022.38	2060.11	2022.23	2060.11	2019.12	2060.11
2/1/2000	1.14E+07	2012.36	2049.64	2022.55	2060.11	2022.42	2060.11	2019.35	2060.11
2/1/2000	1.14E+07	2012.35	2049.64	2022.54	2060.11	2022.42	2060.11	2019.36	2060.11
2/2/2000	1.14E+07	2012.34	2049.64	2022.53	2060.11	2022.41	2060.11	2019.35	2060.11
2/10/2000	1.15E+07	2012.31	2049.63	2022.51	2060.1	2022.39	2060.1	2019.33	2060.11
2/29/2000	1.16E+07	2012.28	2049.62	2022.48	2060.09	2022.36	2060.09	2019.29	2060.09
3/1/2000	1.16E+07	2012.28	2049.62	2022.48	2060.09	2022.36	2060.09	2019.29	2060.09
3/1/2000	1.16E+07	2026.85	2049.62	2037.18	2060.09	2037.23	2060.09	2036	2060.09
3/1/2000	1.16E+07	2012.27	2049.62	2022.37	2060.09	2022.22	2060.09	2019.15	2060.09
3/1/2000	1.16E+07	2012.38	2049.62	2022.57	2060.09	2022.44	2060.09	2019.42	2060.09
3/1/2000	1.16E+07	2012.39	2049.62	2022.58	2060.09	2022.46	2060.09	2019.46	2060.09
3/2/2000	1.16E+07	2012.39	2049.61	2022.59	2060.09	2022.47	2060.09	2019.47	2060.09
3/10/2000	1.16E+07	2012.39	2049.61	2022.59	2060.08	2022.47	2060.08	2019.48	2060.09
3/31/2000	1.14E+07	2012.38	2049.59	2022.57	2060.07	2022.46	2060.07	2019.46	2060.07
4/1/2000	1.14E+07	2012.38	2049.59	2022.57	2060.07	2022.46	2060.07	2019.46	2060.07
4/1/2000	1.14E+07	2027.06	2049.59	2037.4	2060.07	2037.46	2060.07	2036.37	2060.07
4/1/2000	1.14E+07	2012.5	2049.59	2022.62	2060.07	2022.47	2060.07	2019.53	2060.07
4/1/2000	1.14E+07	2012.62	2049.59	2022.83	2060.07	2022.71	2060.07	2019.85	2060.07
4/1/2000	1.14E+07	2012.65	2049.59	2022.86	2060.07	2022.75	2060.07	2019.91	2060.07
4/2/2000	1.14E+07	2012.67	2049.59	2022.88	2060.06	2022.78	2060.06	2019.95	2060.07
4/10/2000	1.12E+07	2012.69	2049.59	2022.9	2060.06	2022.79	2060.06	2019.97	2060.07
4/30/2000	1.09E+07	2012.69	2049.57	2022.9	2060.05	2022.8	2060.05	2019.98	2060.05
5/1/2000	1.09E+07	2012.69	2049.57	2022.9	2060.05	2022.8	2060.05	2019.98	2060.05
5/1/2000	1.09E+07	2027.66	2049.57	2038.02	2060.05	2038.1	2060.05	2037.35	2060.05
5/1/2000	1.09E+07	2013.14	2049.57	2023.28	2060.05	2023.16	2060.05	2020.56	2060.05
5/1/2000	1.09E+07	2013.3	2049.57	2023.53	2060.05	2023.44	2060.05	2020.97	2060.05
5/1/2000	1.09E+07	2013.36	2049.57	2023.6	2060.04	2023.52	2060.04	2021.08	2060.05
5/2/2000	1.08E+07	2013.43	2049.57	2023.66	2060.04	2023.58	2060.04	2021.17	2060.05
5/10/2000	1.05E+07	2013.48	2049.57	2023.72	2060.04	2023.64	2060.04	2021.24	2060.04
5/31/2000	9.53E+06	2013.52	2049.55	2023.76	2060.02	2023.68	2060.02	2021.28	2060.03
6/1/2000	9.53E+06	2013.52	2049.55	2023.76	2060.02	2023.68	2060.02	2021.28	2060.03
6/1/2000	9.53E+06	2027.88	2049.55	2038.24	2060.02	2038.31	2060.02	2037.7	2060.03
6/1/2000	9.53E+06	2013.26	2049.55	2023.4	2060.02	2023.27	2060.02	2020.65	2060.03
6/1/2000	9.54E+06	2013.34	2049.55	2023.57	2060.02	2023.47	2060.02	2020.94	2060.03
6/1/2000	9.54E+06	2013.33	2049.55	2023.56	2060.02	2023.47	2060.02	2020.95	2060.03

6/2/2000	9.56E+06	2013.31	2049.55	2023.54	2060.02	2023.45	2060.02	2020.94	2060.03
6/10/2000	9.66E+06	2013.3	2049.55	2023.53	2060.02	2023.44	2060.02	2020.93	2060.02
6/30/2000	9.92E+06	2013.29	2049.53	2023.52	2060	2023.43	2060	2020.92	2060.01
7/1/2000	9.92E+06	2013.29	2049.53	2023.52	2060	2023.43	2060	2020.92	2060.01
7/1/2000	9.92E+06	2027.66	2049.53	2038.01	2060	2038.08	2060	2037.34	2060.01
7/1/2000	9.92E+06	2013.04	2049.53	2023.17	2060	2023.04	2060	2020.32	2060.01
7/1/2000	9.92E+06	2013.12	2049.53	2023.34	2060	2023.24	2060	2020.6	2060.01
7/1/2000	9.93E+06	2013.11	2049.53	2023.33	2060	2023.23	2060	2020.61	2060.01
7/2/2000	9.95E+06	2013.09	2049.53	2023.31	2060	2023.22	2060	2020.59	2060.01
7/10/2000	1.00E+07	2013.07	2049.52	2023.29	2060	2023.2	2060	2020.57	2060
7/31/2000	1.03E+07	2013.05	2049.51	2023.27	2059.98	2023.18	2059.98	2020.55	2059.99
8/1/2000	1.03E+07	2013.05	2049.51	2023.27	2059.98	2023.18	2059.98	2020.55	2059.99
8/1/2000	1.03E+07	2027.56	2049.51	2037.92	2059.98	2037.99	2059.98	2037.2	2059.99
8/1/2000	1.03E+07	2012.97	2049.51	2023.1	2059.98	2022.97	2059.98	2020.24	2059.99
8/1/2000	1.03E+07	2013.07	2049.51	2023.29	2059.98	2023.19	2059.98	2020.55	2059.99
8/1/2000	1.03E+07	2013.08	2049.51	2023.3	2059.98	2023.2	2059.98	2020.59	2059.99
8/2/2000	1.03E+07	2013.08	2049.51	2023.3	2059.98	2023.21	2059.98	2020.6	2059.99
8/10/2000	1.03E+07	2013.08	2049.5	2023.3	2059.97	2023.2	2059.97	2020.6	2059.98
8/31/2000	1.02E+07	2013.06	2049.49	2023.29	2059.96	2023.19	2059.96	2020.58	2059.97
9/1/2000	1.02E+07	2013.06	2049.49	2023.29	2059.96	2023.19	2059.96	2020.58	2059.97
9/1/2000	1.02E+07	2028	2049.49	2038.37	2059.96	2038.45	2059.96	2037.92	2059.97
9/1/2000	1.02E+07	2013.47	2049.49	2023.63	2059.96	2023.51	2059.96	2021.08	2059.97
9/1/2000	1.02E+07	2013.63	2049.49	2023.87	2059.96	2023.79	2059.96	2021.5	2059.97
9/1/2000	1.02E+07	2013.69	2049.49	2023.94	2059.96	2023.86	2059.96	2021.61	2059.96
9/2/2000	1.02E+07	2013.74	2049.49	2023.99	2059.96	2023.92	2059.96	2021.68	2059.96
9/10/2000	9.83E+06	2013.8	2049.48	2024.05	2059.95	2023.97	2059.95	2021.75	2059.96
9/30/2000	8.98E+06	2013.83	2049.47	2024.08	2059.94	2024	2059.94	2021.78	2059.94
10/1/2000	8.98E+06	2013.83	2049.47	2024.08	2059.94	2024	2059.94	2021.78	2059.94
10/1/2000	8.98E+06	2028.94	2049.47	2039.34	2059.94	2039.43	2059.94	2039.41	2059.94
10/1/2000	8.98E+06	2014.43	2049.47	2024.62	2059.94	2024.52	2059.94	2022.55	2059.94
10/1/2000	8.98E+06	2014.61	2049.47	2024.89	2059.94	2024.83	2059.94	2023.03	2059.94
10/1/2000	8.96E+06	2014.69	2049.47	2024.97	2059.94	2024.92	2059.94	2023.17	2059.94
10/2/2000	8.87E+06	2014.77	2049.47	2025.05	2059.94	2025	2059.94	2023.27	2059.94
10/10/2000	8.43E+06	2014.86	2049.46	2025.14	2059.93	2025.09	2059.93	2023.37	2059.94
10/31/2000	7.25E+06	2014.92	2049.45	2025.2	2059.92	2025.15	2059.92	2023.45	2059.92
11/1/2000	7.25E+06	2014.92	2049.45	2025.2	2059.92	2025.15	2059.92	2023.45	2059.92
11/1/2000	7.25E+06	2029.35	2049.45	2039.74	2059.92	2039.83	2059.92	2040.01	2059.92
11/1/2000	7.25E+06	2014.73	2049.45	2024.92	2059.92	2024.82	2059.92	2022.89	2059.92
11/1/2000	7.25E+06	2014.82	2049.45	2025.09	2059.92	2025.03	2059.92	2023.24	2059.92
11/1/2000	7.25E+06	2014.81	2049.45	2025.09	2059.92	2025.03	2059.92	2023.26	2059.92
11/2/2000	7.26E+06	2014.8	2049.44	2025.08	2059.92	2025.03	2059.92	2023.26	2059.92
11/10/2000	7.32E+06	2014.81	2049.44	2025.08	2059.91	2025.03	2059.91	2023.27	2059.92
11/30/2000	7.47E+06	2014.82	2049.43	2025.09	2059.9	2025.04	2059.9	2023.28	2059.9
12/1/2000	7.47E+06	2014.82	2049.43	2025.09	2059.9	2025.04	2059.9	2023.28	2059.9
12/1/2000	7.47E+06	2029.62	2049.43	2040.02	2059.9	2040.11	2059.9	2040.42	2059.9
12/1/2000	7.47E+06	2015.05	2049.43	2025.26	2059.9	2025.17	2059.9	2023.42	2059.9
12/1/2000	7.47E+06	2015.19	2049.43	2025.48	2059.9	2025.43	2059.9	2023.85	2059.9
12/1/2000	7.46E+06	2015.23	2049.43	2025.52	2059.9	2025.48	2059.9	2023.93	2059.9
12/2/2000	7.42E+06	2015.27	2049.43	2025.56	2059.9	2025.52	2059.9	2023.98	2059.9
12/10/2000	7.21E+06	2015.31	2049.42	2025.6	2059.89	2025.56	2059.89	2024.03	2059.9
12/31/2000	6.64E+06	2015.35	2049.41	2025.64	2059.88	2025.59	2059.88	2024.07	2059.88
1/1/2001	6.64E+06	2015.35	2049.41	2025.64	2059.88	2025.59	2059.88	2024.07	2059.88
1/1/2001	6.64E+06	2030.07	2049.41	2040.48	2059.88	2040.57	2059.88	2041.09	2059.88
1/1/2001	6.64E+06	2015.49	2049.41	2025.71	2059.88	2025.62	2059.88	2024.05	2059.88
1/1/2001	6.63E+06	2015.62	2049.41	2025.91	2059.88	2025.87	2059.88	2024.46	2059.88
1/1/2001	6.63E+06	2015.65	2049.41	2025.94	2059.88	2025.91	2059.88	2024.53	2059.88
1/2/2001	6.60E+06	2015.68	2049.41	2025.97	2059.88	2025.94	2059.88	2024.57	2059.88
1/10/2001	6.45E+06	2015.71	2049.4	2026.01	2059.87	2025.97	2059.87	2024.62	2059.88

1/31/2001	6.04E+06	2015.74	2049.39	2026.04	2059.86	2026	2059.86	2024.65	2059.86
2/1/2001	6.04E+06	2015.74	2049.39	2026.04	2059.86	2026	2059.86	2024.65	2059.86
2/1/2001	6.04E+06	2030.13	2049.39	2040.54	2059.86	2040.62	2059.86	2041.17	2059.86
2/1/2001	6.04E+06	2015.5	2049.39	2025.72	2059.86	2025.63	2059.86	2024.02	2059.86
2/1/2001	6.04E+06	2015.59	2049.39	2025.88	2059.86	2025.83	2059.86	2024.37	2059.86
2/1/2001	6.04E+06	2015.57	2049.39	2025.87	2059.86	2025.83	2059.86	2024.38	2059.86
2/2/2001	6.06E+06	2015.56	2049.39	2025.85	2059.86	2025.81	2059.86	2024.37	2059.86
2/10/2001	6.16E+06	2015.55	2049.38	2025.85	2059.85	2025.81	2059.85	2024.37	2059.86
2/28/2001	6.37E+06	2015.55	2049.37	2025.85	2059.84	2025.81	2059.84	2024.37	2059.85
3/1/2001	6.37E+06	2015.55	2049.37	2025.85	2059.84	2025.81	2059.84	2024.37	2059.85
3/1/2001	6.37E+06	2030.24	2049.37	2040.65	2059.84	2040.74	2059.84	2041.33	2059.85
3/1/2001	6.37E+06	2015.66	2049.37	2025.88	2059.84	2025.8	2059.84	2024.29	2059.85
3/1/2001	6.37E+06	2015.78	2049.37	2026.08	2059.84	2026.04	2059.84	2024.69	2059.85
3/1/2001	6.37E+06	2015.8	2049.37	2026.1	2059.84	2026.07	2059.84	2024.75	2059.85
3/2/2001	6.34E+06	2015.83	2049.37	2026.13	2059.84	2026.09	2059.84	2024.79	2059.85
3/10/2001	6.22E+06	2015.85	2049.37	2026.15	2059.84	2026.12	2059.84	2024.81	2059.84
3/31/2001	5.87E+06	2015.87	2049.35	2026.17	2059.82	2026.14	2059.82	2024.84	2059.83
4/1/2001	0	2015.87	2049.35	2026.17	2059.82	2026.14	2059.82	2024.84	2059.83

Table C.2: CMG IMEX Numerical simulation results for assumed Skin 5.

		Skin 5							
		Darcy Flow		Non-Darcy Flow FG1		Non-Darcy Flow FG2		Non-Darcy Flow Geertsma	
DATE	Gas Rate SC - Monthly	Pbh	Pr	Pbh	Pr	Pbh	Pr	Pbh	Pr
	(ft3/day)	(psi)	(psi)	(psi)	(psi)	(psi)	(psi)	(psi)	(psi)
8/31/1997	0	0	0	0	0	0	0	0	0
9/1/1997	90.2957	0	2050.01	0	2060.53	0	2060.53	0	2060.53
9/1/1997	112.87	2034.99	2050.01	2045.4	2060.53	2045.4	2060.53	2045.83	2060.53
9/1/1997	225.739	2020.41	2050.01	2030.75	2060.53	2030.75	2060.53	2030.65	2060.53
9/1/1997	790.087	2020.5	2050.01	2030.84	2060.53	2030.84	2060.53	2030.79	2060.53
9/1/1997	3611.83	2020.49	2050.01	2030.83	2060.53	2030.83	2060.53	2030.79	2060.53
9/2/1997	17720.5	2020.48	2050.01	2030.82	2060.53	2030.82	2060.53	2030.77	2060.53
9/10/1997	88264.1	2020.46	2050.01	2030.8	2060.52	2030.8	2060.52	2030.76	2060.52
9/30/1997	270887	2020.45	2050.01	2030.79	2060.48	2030.79	2060.48	2030.75	2060.48
10/1/1997	272432	2020.45	2050.01	2030.79	2060.48	2030.79	2060.48	2030.75	2060.48
10/1/1997	272819	2031.87	2050.01	2042.27	2060.48	2042.27	2060.48	2043.03	2060.48
10/1/1997	274750	2017.05	2050.01	2027.33	2060.48	2027.29	2060.48	2025.85	2060.48
10/1/1997	284406	2016.92	2050.01	2027.23	2060.48	2027.2	2060.48	2025.79	2060.48
10/1/1997	332688	2016.71	2050.01	2027.02	2060.48	2026.99	2060.48	2025.54	2060.48
10/2/1997	574098	2016.49	2050.01	2026.8	2060.48	2026.77	2060.48	2025.29	2060.48
10/10/1997	1.78E+06	2016.27	2050.01	2026.58	2060.48	2026.55	2060.48	2025.04	2060.48
10/31/1997	5.06E+06	2016.1	2050.01	2026.41	2060.48	2026.38	2060.48	2024.86	2060.48
11/1/1997	5.06E+06	2016.1	2050.01	2026.41	2060.48	2026.38	2060.48	2024.86	2060.48
11/1/1997	5.06E+06	2030.03	2050.01	2040.43	2060.48	2040.45	2060.48	2040.74	2060.48
11/1/1997	5.06E+06	2015.45	2050.01	2025.72	2060.48	2025.66	2060.48	2023.71	2060.48
11/1/1997	5.06E+06	2015.51	2050.01	2025.81	2060.48	2025.77	2060.48	2023.93	2060.48
11/1/1997	5.07E+06	2015.47	2050.01	2025.77	2060.48	2025.73	2060.48	2023.91	2060.48
11/2/1997	5.11E+06	2015.42	2050.01	2025.72	2060.48	2025.69	2060.48	2023.86	2060.48
11/10/1997	5.32E+06	2015.35	2050.01	2025.65	2060.48	2025.61	2060.48	2023.78	2060.48
11/30/1997	5.86E+06	2015.26	2050.01	2025.56	2060.48	2025.52	2060.48	2023.68	2060.48
12/1/1997	5.86E+06	2015.26	2050.01	2025.56	2060.48	2025.52	2060.48	2023.68	2060.48
12/1/1997	5.86E+06	2029.48	2050.01	2039.87	2060.48	2039.9	2060.48	2039.98	2060.48
12/1/1997	5.87E+06	2014.93	2050.01	2025.19	2060.48	2025.13	2060.48	2023.02	2060.48
12/1/1997	5.87E+06	2015	2050.01	2025.3	2060.48	2025.25	2060.48	2023.26	2060.48
12/1/1997	5.87E+06	2014.99	2050.01	2025.28	2060.48	2025.24	2060.48	2023.27	2060.48
12/2/1997	5.89E+06	2014.97	2050.01	2025.26	2060.48	2025.22	2060.48	2023.25	2060.48
12/10/1997	5.97E+06	2014.92	2050.01	2025.22	2060.48	2025.18	2060.48	2023.2	2060.48
12/31/1997	6.21E+06	2014.86	2050.01	2025.16	2060.48	2025.12	2060.48	2023.14	2060.48
1/1/1998	6.21E+06	2014.86	2050.01	2025.16	2060.48	2025.12	2060.48	2023.14	2060.48
1/1/1998	6.21E+06	2029.35	2050.01	2039.73	2060.48	2039.76	2060.48	2039.81	2060.48
1/1/1998	6.21E+06	2014.81	2050.01	2025.08	2060.48	2025.02	2060.48	2022.9	2060.48
1/1/1998	6.21E+06	2014.91	2050.01	2025.21	2060.48	2025.16	2060.48	2023.17	2060.48
1/1/1998	6.21E+06	2014.92	2050.01	2025.21	2060.48	2025.17	2060.48	2023.21	2060.48
1/2/1998	6.21E+06	2014.91	2050.01	2025.21	2060.48	2025.17	2060.48	2023.21	2060.48
1/10/1998	6.19E+06	2014.9	2050.01	2025.19	2060.48	2025.15	2060.48	2023.2	2060.48
1/31/1998	6.14E+06	2014.86	2050.01	2025.16	2060.48	2025.12	2060.48	2023.16	2060.48
2/1/1998	6.14E+06	2014.86	2050.01	2025.16	2060.48	2025.12	2060.48	2023.16	2060.48
2/1/1998	6.14E+06	2029.34	2050.01	2039.72	2060.48	2039.76	2060.48	2039.82	2060.48
2/1/1998	6.14E+06	2014.81	2050.01	2025.07	2060.48	2025.01	2060.48	2022.91	2060.48
2/1/1998	6.14E+06	2014.9	2050.01	2025.2	2060.48	2025.16	2060.48	2023.19	2060.48
2/1/1998	6.14E+06	2014.91	2050.01	2025.2	2060.48	2025.16	2060.48	2023.22	2060.48
2/2/1998	6.14E+06	2014.91	2050.01	2025.2	2060.48	2025.16	2060.48	2023.23	2060.48
2/10/1998	6.12E+06	2014.9	2050	2025.19	2060.48	2025.15	2060.48	2023.22	2060.48

2/28/1998	6.09E+06	2014.87	2050	2025.17	2060.47	2025.13	2060.47	2023.19	2060.47
3/1/1998	6.08E+06	2014.87	2050	2025.17	2060.47	2025.13	2060.47	2023.19	2060.47
3/1/1998	6.08E+06	2029.59	2050	2039.98	2060.47	2040.02	2060.47	2040.21	2060.47
3/1/1998	6.08E+06	2015.08	2050	2025.35	2060.47	2025.29	2060.47	2023.33	2060.47
3/1/1998	6.08E+06	2015.19	2050	2025.49	2060.47	2025.46	2060.47	2023.64	2060.47
3/1/1998	6.08E+06	2015.21	2050	2025.52	2060.47	2025.48	2060.47	2023.69	2060.47
3/2/1998	6.06E+06	2015.23	2050	2025.53	2060.47	2025.5	2060.47	2023.72	2060.47
3/10/1998	5.95E+06	2015.24	2050	2025.54	2060.47	2025.51	2060.47	2023.74	2060.47
3/31/1998	5.65E+06	2015.23	2050	2025.54	2060.47	2025.5	2060.47	2023.73	2060.47
4/1/1998	5.65E+06	2015.23	2050	2025.54	2060.47	2025.5	2060.47	2023.73	2060.47
4/1/1998	5.65E+06	2028.61	2050	2038.99	2060.47	2039.01	2060.47	2038.79	2060.47
4/1/1998	5.65E+06	2013.98	2050	2024.23	2060.47	2024.16	2060.47	2021.7	2060.47
4/1/1998	5.66E+06	2014	2050	2024.28	2060.47	2024.22	2060.47	2021.81	2060.47
4/1/1998	5.67E+06	2013.93	2050	2024.2	2060.47	2024.15	2060.47	2021.74	2060.47
4/2/1998	5.76E+06	2013.85	2050	2024.13	2060.47	2024.07	2060.47	2021.65	2060.47
4/10/1998	6.20E+06	2013.77	2049.99	2024.05	2060.46	2023.99	2060.46	2021.56	2060.47
4/30/1998	7.32E+06	2013.7	2049.99	2023.98	2060.46	2023.92	2060.46	2021.48	2060.46
5/1/1998	7.32E+06	2013.7	2049.99	2023.98	2060.46	2023.92	2060.46	2021.48	2060.46
5/1/1998	7.32E+06	2028.27	2049.99	2038.64	2060.46	2038.67	2060.46	2038.29	2060.46
5/1/1998	7.32E+06	2013.75	2049.99	2024	2060.46	2023.93	2060.46	2021.45	2060.46
5/1/1998	7.32E+06	2013.86	2049.99	2024.14	2060.46	2024.08	2060.46	2021.7	2060.46
5/1/1998	7.32E+06	2013.87	2049.99	2024.15	2060.46	2024.1	2060.46	2021.74	2060.46
5/2/1998	7.31E+06	2013.87	2049.99	2024.16	2060.46	2024.1	2060.46	2021.75	2060.46
5/10/1998	7.25E+06	2013.87	2049.99	2024.15	2060.46	2024.09	2060.46	2021.74	2060.46
5/31/1998	7.11E+06	2013.84	2049.98	2024.12	2060.45	2024.07	2060.45	2021.71	2060.45
6/1/1998	7.11E+06	2013.84	2049.98	2024.12	2060.45	2024.07	2060.45	2021.71	2060.45
6/1/1998	7.11E+06	2026.82	2049.98	2037.17	2060.45	2037.18	2060.45	2036.17	2060.45
6/1/1998	7.11E+06	2012.17	2049.98	2022.39	2060.45	2022.31	2060.45	2019.15	2060.45
6/1/1998	7.11E+06	2012.16	2049.98	2022.4	2060.45	2022.32	2060.45	2019.08	2060.45
6/1/1998	7.14E+06	2012.06	2049.98	2022.3	2060.45	2022.21	2060.45	2018.94	2060.45
6/2/1998	7.25E+06	2011.95	2049.98	2022.19	2060.45	2022.11	2060.45	2018.82	2060.45
6/10/1998	7.85E+06	2011.84	2049.98	2022.08	2060.45	2021.99	2060.45	2018.69	2060.45
6/30/1998	9.38E+06	2011.74	2049.97	2021.98	2060.44	2021.9	2060.44	2018.58	2060.45
7/1/1998	9.38E+06	2011.74	2049.97	2021.98	2060.44	2021.9	2060.44	2018.58	2060.45
7/1/1998	9.38E+06	2025.83	2049.97	2036.16	2060.44	2036.15	2060.44	2034.62	2060.45
7/1/1998	9.38E+06	2011.28	2049.97	2021.49	2060.44	2021.41	2060.44	2017.98	2060.45
7/1/1998	9.38E+06	2011.36	2049.97	2021.58	2060.44	2021.49	2060.44	2017.96	2060.45
7/1/1998	9.39E+06	2011.33	2049.97	2021.56	2060.44	2021.46	2060.44	2017.92	2060.45
7/2/1998	9.41E+06	2011.3	2049.97	2021.53	2060.44	2021.43	2060.44	2017.88	2060.44
7/10/1998	9.54E+06	2011.25	2049.97	2021.48	2060.44	2021.38	2060.44	2017.83	2060.44
7/31/1998	9.91E+06	2011.18	2049.96	2021.41	2060.43	2021.31	2060.43	2017.75	2060.44
8/1/1998	9.91E+06	2011.18	2049.96	2021.41	2060.43	2021.31	2060.43	2017.75	2060.44
8/1/1998	9.91E+06	2026.84	2049.96	2037.19	2060.43	2037.21	2060.43	2036.19	2060.44
8/1/1998	9.91E+06	2012.43	2049.96	2022.66	2060.43	2022.59	2060.43	2019.69	2060.44
8/1/1998	9.90E+06	2012.61	2049.96	2022.88	2060.43	2022.81	2060.43	2020	2060.44
8/1/1998	9.88E+06	2012.7	2049.96	2022.97	2060.43	2022.9	2060.43	2020.13	2060.44
8/2/1998	9.78E+06	2012.78	2049.96	2023.05	2060.43	2022.99	2060.43	2020.24	2060.43
8/10/1998	9.29E+06	2012.85	2049.96	2023.12	2060.43	2023.06	2060.43	2020.32	2060.43
8/31/1998	7.97E+06	2012.88	2049.95	2023.14	2060.42	2023.08	2060.42	2020.35	2060.42
9/1/1998	7.97E+06	2012.88	2049.95	2023.14	2060.42	2023.08	2060.42	2020.35	2060.42
9/1/1998	7.97E+06	2025.5	2049.95	2035.83	2060.42	2035.82	2060.42	2034.23	2060.42
9/1/1998	7.97E+06	2010.83	2049.95	2021.02	2060.42	2020.94	2060.42	2017.29	2060.42
9/1/1998	7.97E+06	2010.79	2049.95	2021	2060.42	2020.89	2060.42	2017.04	2060.42
9/1/1998	8.00E+06	2010.66	2049.95	2020.87	2060.42	2020.76	2060.42	2016.86	2060.42
9/2/1998	8.15E+06	2010.53	2049.95	2020.74	2060.42	2020.63	2060.42	2016.7	2060.42
9/10/1998	8.89E+06	2010.41	2049.95	2020.61	2060.42	2020.5	2060.42	2016.55	2060.42
9/30/1998	1.08E+07	2010.3	2049.94	2020.51	2060.41	2020.4	2060.41	2016.43	2060.41
10/1/1998	1.08E+07	2010.3	2049.94	2020.51	2060.41	2020.4	2060.41	2016.43	2060.41

10/1/1998	1.08E+07	2024.66	2049.94	2034.96	2060.41	2034.94	2060.41	2032.86	2060.41
10/1/1998	1.08E+07	2010.14	2049.94	2020.34	2060.41	2020.25	2060.41	2016.43	2060.41
10/1/1998	1.08E+07	2010.24	2049.94	2020.44	2060.41	2020.33	2060.41	2016.35	2060.41
10/1/1998	1.08E+07	2010.23	2049.94	2020.44	2060.41	2020.32	2060.41	2016.32	2060.41
10/2/1998	1.08E+07	2010.22	2049.94	2020.43	2060.41	2020.31	2060.41	2016.3	2060.41
10/10/1998	1.08E+07	2010.19	2049.94	2020.4	2060.41	2020.28	2060.41	2016.27	2060.41
10/31/1998	1.09E+07	2010.14	2049.93	2020.34	2060.4	2020.23	2060.4	2016.21	2060.4
11/1/1998	1.09E+07	2010.14	2049.93	2020.34	2060.4	2020.23	2060.4	2016.21	2060.4
11/1/1998	1.09E+07	2024.26	2049.93	2034.55	2060.4	2034.52	2060.4	2032.28	2060.4
11/1/1998	1.09E+07	2009.72	2049.93	2019.91	2060.4	2019.83	2060.4	2015.86	2060.4
11/1/1998	1.09E+07	2009.8	2049.93	2019.99	2060.4	2019.88	2060.4	2015.7	2060.4
11/1/1998	1.09E+07	2009.78	2049.93	2019.97	2060.4	2019.85	2060.4	2015.64	2060.4
11/2/1998	1.09E+07	2009.75	2049.93	2019.95	2060.4	2019.82	2060.4	2015.6	2060.4
11/10/1998	1.10E+07	2009.72	2049.92	2019.91	2060.39	2019.78	2060.39	2015.56	2060.39
11/30/1998	1.14E+07	2009.67	2049.91	2019.86	2060.38	2019.73	2060.38	2015.5	2060.39
12/1/1998	1.14E+07	2009.67	2049.91	2019.86	2060.38	2019.73	2060.38	2015.5	2060.39
12/1/1998	1.14E+07	2023.78	2049.91	2034.06	2060.38	2034.02	2060.38	2031.55	2060.39
12/1/1998	1.14E+07	2009.25	2049.91	2019.42	2060.38	2019.34	2060.38	2015.23	2060.39
12/1/1998	1.14E+07	2009.32	2049.91	2019.5	2060.38	2019.38	2060.38	2015	2060.39
12/1/1998	1.14E+07	2009.3	2049.91	2019.48	2060.38	2019.35	2060.38	2014.92	2060.39
12/2/1998	1.14E+07	2009.27	2049.91	2019.46	2060.38	2019.32	2060.38	2014.88	2060.38
12/10/1998	1.15E+07	2009.24	2049.91	2019.42	2060.38	2019.28	2060.38	2014.83	2060.38
12/31/1998	1.18E+07	2009.19	2049.9	2019.37	2060.37	2019.23	2060.37	2014.78	2060.37
1/1/1999	1.18E+07	2009.19	2049.9	2019.37	2060.37	2019.23	2060.37	2014.78	2060.37
1/1/1999	1.18E+07	2024	2049.9	2034.29	2060.37	2034.26	2060.37	2031.91	2060.37
1/1/1999	1.18E+07	2009.54	2049.9	2019.72	2060.37	2019.64	2060.37	2015.67	2060.37
1/1/1999	1.18E+07	2009.66	2049.9	2019.86	2060.37	2019.75	2060.37	2015.6	2060.37
1/1/1999	1.18E+07	2009.69	2049.9	2019.89	2060.37	2019.77	2060.37	2015.6	2060.37
1/2/1999	1.18E+07	2009.72	2049.89	2019.92	2060.37	2019.79	2060.37	2015.63	2060.37
1/10/1999	1.16E+07	2009.73	2049.89	2019.93	2060.36	2019.81	2060.36	2015.64	2060.36
1/31/1999	1.12E+07	2009.72	2049.88	2019.92	2060.35	2019.79	2060.35	2015.63	2060.35
2/1/1999	1.12E+07	2009.72	2049.88	2019.92	2060.35	2019.79	2060.35	2015.63	2060.35
2/1/1999	1.12E+07	2023.91	2049.88	2034.2	2060.35	2034.16	2060.35	2031.8	2060.35
2/1/1999	1.12E+07	2009.38	2049.88	2019.56	2060.35	2019.48	2060.35	2015.44	2060.35
2/1/1999	1.12E+07	2009.46	2049.88	2019.65	2060.35	2019.53	2060.35	2015.27	2060.35
2/1/1999	1.12E+07	2009.45	2049.88	2019.64	2060.35	2019.51	2060.35	2015.21	2060.35
2/2/1999	1.12E+07	2009.43	2049.88	2019.62	2060.35	2019.49	2060.35	2015.18	2060.35
2/10/1999	1.13E+07	2009.41	2049.87	2019.6	2060.34	2019.47	2060.34	2015.15	2060.35
2/28/1999	1.15E+07	2009.38	2049.86	2019.57	2060.33	2019.44	2060.33	2015.12	2060.34
3/1/1999	1.15E+07	2009.38	2049.86	2019.57	2060.33	2019.44	2060.33	2015.12	2060.34
3/1/1999	1.15E+07	2023.85	2049.86	2034.13	2060.33	2034.1	2060.33	2031.72	2060.34
3/1/1999	1.15E+07	2009.35	2049.86	2019.53	2060.33	2019.45	2060.33	2015.42	2060.34
3/1/1999	1.15E+07	2009.45	2049.86	2019.64	2060.33	2019.52	2060.33	2015.28	2060.34
3/1/1999	1.15E+07	2009.45	2049.86	2019.65	2060.33	2019.52	2060.33	2015.25	2060.34
3/2/1999	1.15E+07	2009.45	2049.86	2019.65	2060.33	2019.52	2060.33	2015.24	2060.34
3/10/1999	1.15E+07	2009.45	2049.86	2019.64	2060.33	2019.51	2060.33	2015.24	2060.33
3/31/1999	1.14E+07	2009.43	2049.84	2019.62	2060.31	2019.49	2060.31	2015.21	2060.32
4/1/1999	1.14E+07	2009.43	2049.84	2019.62	2060.31	2019.49	2060.31	2015.21	2060.32
4/1/1999	1.14E+07	2024.2	2049.84	2034.49	2060.31	2034.47	2060.31	2032.28	2060.32
4/1/1999	1.14E+07	2009.72	2049.84	2019.91	2060.31	2019.83	2060.31	2015.96	2060.32
4/1/1999	1.14E+07	2009.84	2049.84	2020.05	2060.31	2019.94	2060.31	2015.92	2060.32
4/1/1999	1.14E+07	2009.87	2049.84	2020.08	2060.31	2019.96	2060.31	2015.93	2060.32
4/2/1999	1.14E+07	2009.89	2049.84	2020.1	2060.31	2019.98	2060.31	2015.96	2060.32
4/10/1999	1.12E+07	2009.91	2049.84	2020.12	2060.31	2020	2060.31	2015.98	2060.31
4/30/1999	1.09E+07	2009.91	2049.82	2020.12	2060.3	2020	2060.3	2015.98	2060.3
5/1/1999	1.09E+07	2009.91	2049.82	2020.12	2060.3	2020	2060.3	2015.98	2060.3
5/1/1999	1.09E+07	2024.2	2049.82	2034.5	2060.3	2034.48	2060.3	2032.32	2060.3
5/1/1999	1.09E+07	2009.69	2049.82	2019.87	2060.3	2019.79	2060.3	2015.9	2060.3

5/1/1999	1.09E+07	2009.77	2049.82	2019.97	2060.3	2019.86	2060.3	2015.79	2060.3
5/1/1999	1.09E+07	2009.76	2049.82	2019.97	2060.3	2019.85	2060.3	2015.75	2060.3
5/2/1999	1.09E+07	2009.76	2049.82	2019.96	2060.29	2019.84	2060.29	2015.74	2060.3
5/10/1999	1.09E+07	2009.74	2049.82	2019.95	2060.29	2019.83	2060.29	2015.72	2060.29
5/31/1999	1.10E+07	2009.73	2049.8	2019.93	2060.27	2019.81	2060.27	2015.7	2060.28
6/1/1999	1.10E+07	2009.73	2049.8	2019.93	2060.27	2019.81	2060.27	2015.7	2060.28
6/1/1999	1.10E+07	2024.27	2049.8	2034.57	2060.27	2034.54	2060.27	2032.42	2060.28
6/1/1999	1.10E+07	2009.77	2049.8	2019.96	2060.27	2019.88	2060.27	2016.03	2060.28
6/1/1999	1.10E+07	2009.88	2049.8	2020.08	2060.27	2019.97	2060.27	2015.98	2060.28
6/1/1999	1.10E+07	2009.89	2049.8	2020.09	2060.27	2019.98	2060.27	2015.97	2060.28
6/2/1999	1.10E+07	2009.89	2049.8	2020.1	2060.27	2019.98	2060.27	2015.97	2060.28
6/10/1999	1.10E+07	2009.9	2049.8	2020.1	2060.27	2019.99	2060.27	2015.97	2060.27
6/30/1999	1.08E+07	2009.89	2049.78	2020.09	2060.25	2019.98	2060.25	2015.96	2060.26
7/1/1999	1.08E+07	2009.89	2049.78	2020.09	2060.25	2019.98	2060.25	2015.96	2060.26
7/1/1999	1.08E+07	2024.52	2049.78	2034.82	2060.25	2034.81	2060.25	2032.82	2060.26
7/1/1999	1.08E+07	2010.03	2049.78	2020.22	2060.25	2020.14	2060.25	2016.41	2060.26
7/1/1999	1.08E+07	2010.14	2049.78	2020.35	2060.25	2020.25	2060.25	2016.4	2060.26
7/1/1999	1.08E+07	2010.16	2049.78	2020.37	2060.25	2020.26	2060.25	2016.4	2060.26
7/2/1999	1.08E+07	2010.17	2049.78	2020.39	2060.25	2020.28	2060.25	2016.42	2060.26
7/10/1999	1.07E+07	2010.18	2049.78	2020.4	2060.25	2020.29	2060.25	2016.43	2060.25
7/31/1999	1.05E+07	2010.18	2049.76	2020.39	2060.23	2020.28	2060.23	2016.43	2060.24
8/1/1999	1.05E+07	2010.18	2049.76	2020.39	2060.23	2020.28	2060.23	2016.43	2060.24
8/1/1999	1.05E+07	2024.81	2049.76	2035.13	2060.23	2035.11	2060.23	2033.29	2060.24
8/1/1999	1.05E+07	2010.32	2049.76	2020.52	2060.23	2020.44	2060.23	2016.84	2060.24
8/1/1999	1.05E+07	2010.43	2049.76	2020.65	2060.23	2020.56	2060.23	2016.85	2060.24
8/1/1999	1.05E+07	2010.45	2049.76	2020.67	2060.23	2020.57	2060.23	2016.86	2060.24
8/2/1999	1.05E+07	2010.46	2049.76	2020.69	2060.23	2020.58	2060.23	2016.88	2060.24
8/10/1999	1.04E+07	2010.48	2049.76	2020.7	2060.23	2020.6	2060.23	2016.89	2060.23
8/31/1999	1.02E+07	2010.48	2049.74	2020.7	2060.21	2020.6	2060.21	2016.9	2060.22
9/1/1999	1.02E+07	2010.48	2049.74	2020.7	2060.21	2020.6	2060.21	2016.9	2060.22
9/1/1999	1.02E+07	2024.6	2049.74	2034.91	2060.21	2034.89	2060.21	2032.98	2060.22
9/1/1999	1.02E+07	2010.06	2049.74	2020.26	2060.21	2020.18	2060.21	2016.45	2060.22
9/1/1999	1.02E+07	2010.14	2049.74	2020.35	2060.21	2020.24	2060.21	2016.37	2060.22
9/1/1999	1.02E+07	2010.12	2049.74	2020.33	2060.21	2020.22	2060.21	2016.33	2060.22
9/2/1999	1.02E+07	2010.1	2049.74	2020.31	2060.21	2020.2	2060.21	2016.3	2060.22
9/10/1999	1.03E+07	2010.07	2049.73	2020.29	2060.21	2020.17	2060.21	2016.27	2060.21
9/30/1999	1.06E+07	2010.05	2049.72	2020.26	2060.19	2020.15	2060.19	2016.24	2060.2
10/1/1999	1.06E+07	2010.05	2049.72	2020.26	2060.19	2020.15	2060.19	2016.24	2060.2
10/1/1999	1.06E+07	2024.51	2049.72	2034.82	2060.19	2034.8	2060.19	2032.84	2060.2
10/1/1999	1.06E+07	2010.01	2049.72	2020.2	2060.19	2020.12	2060.19	2016.39	2060.2
10/1/1999	1.06E+07	2010.1	2049.72	2020.32	2060.19	2020.21	2060.19	2016.36	2060.2
10/1/1999	1.06E+07	2010.11	2049.72	2020.32	2060.19	2020.21	2060.19	2016.34	2060.2
10/2/1999	1.06E+07	2010.11	2049.72	2020.32	2060.19	2020.21	2060.19	2016.34	2060.2
10/10/1999	1.06E+07	2010.11	2049.71	2020.32	2060.19	2020.21	2060.19	2016.34	2060.19
10/31/1999	1.05E+07	2010.09	2049.7	2020.31	2060.17	2020.2	2060.17	2016.32	2060.18
11/1/1999	1.05E+07	2010.09	2049.7	2020.31	2060.17	2020.2	2060.17	2016.32	2060.18
11/1/1999	1.05E+07	2024.42	2049.7	2034.72	2060.17	2034.71	2060.17	2032.71	2060.18
11/1/1999	1.05E+07	2009.9	2049.7	2020.1	2060.17	2020.01	2060.17	2016.25	2060.18
11/1/1999	1.05E+07	2009.99	2049.7	2020.2	2060.17	2020.09	2060.17	2016.18	2060.18
11/1/1999	1.05E+07	2009.98	2049.7	2020.19	2060.17	2020.08	2060.17	2016.15	2060.18
11/2/1999	1.05E+07	2009.98	2049.7	2020.19	2060.17	2020.08	2060.17	2016.14	2060.18
11/10/1999	1.06E+07	2009.96	2049.69	2020.18	2060.16	2020.06	2060.16	2016.13	2060.17
11/30/1999	1.07E+07	2009.95	2049.68	2020.16	2060.15	2020.04	2060.15	2016.11	2060.16
12/1/1999	1.07E+07	2009.95	2049.68	2020.16	2060.15	2020.04	2060.15	2016.11	2060.16
12/1/1999	1.07E+07	2024.21	2049.68	2034.51	2060.15	2034.49	2060.15	2032.4	2060.16
12/1/1999	1.07E+07	2009.69	2049.68	2019.88	2060.15	2019.8	2060.15	2015.95	2060.16
12/1/1999	1.07E+07	2009.78	2049.68	2019.98	2060.15	2019.87	2060.15	2015.86	2060.16
12/1/1999	1.07E+07	2009.77	2049.68	2019.97	2060.15	2019.86	2060.15	2015.82	2060.16

12/2/1999	1.07E+07	2009.75	2049.68	2019.96	2060.15	2019.84	2060.15	2015.8	2060.15
12/10/1999	1.08E+07	2009.74	2049.67	2019.94	2060.14	2019.82	2060.14	2015.78	2060.15
12/31/1999	1.09E+07	2009.71	2049.66	2019.92	2060.13	2019.8	2060.13	2015.76	2060.13
1/1/2000	1.09E+07	2009.71	2049.66	2019.92	2060.13	2019.8	2060.13	2015.76	2060.13
1/1/2000	1.09E+07	2023.83	2049.66	2034.13	2060.13	2034.1	2060.13	2031.83	2060.13
1/1/2000	1.09E+07	2009.31	2049.66	2019.49	2060.13	2019.41	2060.13	2015.42	2060.13
1/1/2000	1.09E+07	2009.38	2049.66	2019.57	2060.13	2019.46	2060.13	2015.26	2060.13
1/1/2000	1.09E+07	2009.36	2049.66	2019.55	2060.13	2019.43	2060.13	2015.2	2060.13
1/2/2000	1.09E+07	2009.34	2049.66	2019.53	2060.13	2019.41	2060.13	2015.16	2060.13
1/10/2000	1.11E+07	2009.31	2049.65	2019.5	2060.12	2019.38	2060.12	2015.13	2060.13
1/31/2000	1.14E+07	2009.28	2049.64	2019.47	2060.11	2019.34	2060.11	2015.09	2060.11
2/1/2000	1.14E+07	2009.28	2049.64	2019.47	2060.11	2019.34	2060.11	2015.09	2060.11
2/1/2000	1.14E+07	2023.51	2049.64	2033.79	2060.11	2033.76	2060.11	2031.33	2060.11
2/1/2000	1.14E+07	2008.99	2049.64	2019.17	2060.11	2019.08	2060.11	2015.01	2060.11
2/1/2000	1.14E+07	2009.07	2049.64	2019.26	2060.11	2019.14	2060.11	2014.82	2060.11
2/1/2000	1.14E+07	2009.06	2049.64	2019.25	2060.11	2019.12	2060.11	2014.76	2060.11
2/2/2000	1.14E+07	2009.05	2049.64	2019.23	2060.11	2019.1	2060.11	2014.73	2060.11
2/10/2000	1.15E+07	2009.02	2049.63	2019.21	2060.1	2019.08	2060.1	2014.7	2060.11
2/29/2000	1.16E+07	2009	2049.62	2019.18	2060.09	2019.05	2060.09	2014.67	2060.09
3/1/2000	1.16E+07	2009	2049.62	2019.18	2060.09	2019.05	2060.09	2014.67	2060.09
3/1/2000	1.16E+07	2023.53	2049.62	2033.82	2060.09	2033.79	2060.09	2031.37	2060.09
3/1/2000	1.16E+07	2009.04	2049.62	2019.22	2060.09	2019.14	2060.09	2015.1	2060.09
3/1/2000	1.16E+07	2009.15	2049.62	2019.34	2060.09	2019.22	2060.09	2014.97	2060.09
3/1/2000	1.16E+07	2009.16	2049.62	2019.35	2060.09	2019.22	2060.09	2014.94	2060.09
3/2/2000	1.16E+07	2009.16	2049.61	2019.36	2060.09	2019.23	2060.09	2014.94	2060.09
3/10/2000	1.16E+07	2009.16	2049.61	2019.35	2060.08	2019.23	2060.08	2014.94	2060.09
3/31/2000	1.14E+07	2009.15	2049.59	2019.34	2060.07	2019.21	2060.07	2014.92	2060.07
4/1/2000	1.14E+07	2009.15	2049.59	2019.34	2060.07	2019.21	2060.07	2014.92	2060.07
4/1/2000	1.14E+07	2023.9	2049.59	2034.2	2060.07	2034.17	2060.07	2031.97	2060.07
4/1/2000	1.14E+07	2009.43	2049.59	2019.62	2060.07	2019.53	2060.07	2015.65	2060.07
4/1/2000	1.14E+07	2009.55	2049.59	2019.75	2060.07	2019.64	2060.07	2015.61	2060.07
4/1/2000	1.14E+07	2009.57	2049.59	2019.78	2060.07	2019.66	2060.07	2015.62	2060.07
4/2/2000	1.14E+07	2009.6	2049.59	2019.8	2060.06	2019.69	2060.06	2015.65	2060.07
4/10/2000	1.12E+07	2009.62	2049.59	2019.82	2060.06	2019.7	2060.06	2015.67	2060.07
4/30/2000	1.09E+07	2009.62	2049.57	2019.82	2060.05	2019.71	2060.05	2015.67	2060.05
5/1/2000	1.09E+07	2009.62	2049.57	2019.82	2060.05	2019.71	2060.05	2015.67	2060.05
5/1/2000	1.09E+07	2024.88	2049.57	2035.2	2060.05	2035.2	2060.05	2033.51	2060.05
5/1/2000	1.09E+07	2010.45	2049.57	2020.66	2060.05	2020.58	2060.05	2017.13	2060.05
5/1/2000	1.09E+07	2010.61	2049.57	2020.84	2060.05	2020.75	2060.05	2017.27	2060.05
5/1/2000	1.09E+07	2010.67	2049.57	2020.9	2060.04	2020.81	2060.04	2017.35	2060.05
5/2/2000	1.08E+07	2010.73	2049.57	2020.97	2060.04	2020.87	2060.04	2017.43	2060.05
5/10/2000	1.05E+07	2010.79	2049.57	2021.02	2060.04	2020.93	2060.04	2017.5	2060.04
5/31/2000	9.53E+06	2010.82	2049.55	2021.06	2060.02	2020.97	2060.02	2017.54	2060.03
6/1/2000	9.53E+06	2010.82	2049.55	2021.06	2060.02	2020.97	2060.02	2017.54	2060.03
6/1/2000	9.53E+06	2024.99	2049.55	2035.32	2060.02	2035.31	2060.02	2033.71	2060.03
6/1/2000	9.53E+06	2010.46	2049.55	2020.67	2060.02	2020.58	2060.02	2017.1	2060.03
6/1/2000	9.54E+06	2010.54	2049.55	2020.76	2060.02	2020.67	2060.02	2017.09	2060.03
6/1/2000	9.54E+06	2010.52	2049.55	2020.75	2060.02	2020.65	2060.02	2017.06	2060.03
6/2/2000	9.56E+06	2010.51	2049.55	2020.73	2060.02	2020.63	2060.02	2017.04	2060.03
6/10/2000	9.66E+06	2010.49	2049.55	2020.72	2060.02	2020.62	2060.02	2017.02	2060.02
6/30/2000	9.92E+06	2010.48	2049.53	2020.71	2060	2020.61	2060	2017.02	2060.01
7/1/2000	9.92E+06	2010.48	2049.53	2020.71	2060	2020.61	2060	2017.02	2060.01
7/1/2000	9.92E+06	2024.66	2049.53	2034.98	2060	2034.97	2060	2033.2	2060.01
7/1/2000	9.92E+06	2010.14	2049.53	2020.34	2060	2020.25	2060	2016.64	2060.01
7/1/2000	9.92E+06	2010.21	2049.53	2020.43	2060	2020.33	2060	2016.59	2060.01
7/1/2000	9.93E+06	2010.2	2049.53	2020.42	2060	2020.31	2060	2016.56	2060.01
7/2/2000	9.95E+06	2010.18	2049.53	2020.4	2060	2020.29	2060	2016.54	2060.01
7/10/2000	1.00E+07	2010.16	2049.52	2020.38	2060	2020.27	2060	2016.51	2060

7/31/2000	1.03E+07	2010.14	2049.51	2020.36	2059.98	2020.25	2059.98	2016.49	2059.99
8/1/2000	1.03E+07	2010.14	2049.51	2020.36	2059.98	2020.25	2059.98	2016.49	2059.99
8/1/2000	1.03E+07	2024.59	2049.51	2034.9	2059.98	2034.89	2059.98	2033.08	2059.99
8/1/2000	1.03E+07	2010.08	2049.51	2020.28	2059.98	2020.2	2059.98	2016.59	2059.99
8/1/2000	1.03E+07	2010.18	2049.51	2020.4	2059.98	2020.3	2059.98	2016.57	2059.99
8/1/2000	1.03E+07	2010.18	2049.51	2020.4	2059.98	2020.3	2059.98	2016.57	2059.99
8/2/2000	1.03E+07	2010.19	2049.51	2020.41	2059.98	2020.3	2059.98	2016.57	2059.99
8/10/2000	1.03E+07	2010.18	2049.5	2020.4	2059.97	2020.3	2059.97	2016.56	2059.98
8/31/2000	1.02E+07	2010.17	2049.49	2020.39	2059.96	2020.29	2059.96	2016.55	2059.97
9/1/2000	1.02E+07	2010.17	2049.49	2020.39	2059.96	2020.29	2059.96	2016.55	2059.97
9/1/2000	1.02E+07	2025.38	2049.49	2035.71	2059.96	2035.72	2059.96	2034.3	2059.97
9/1/2000	1.02E+07	2010.94	2049.49	2021.16	2059.96	2021.08	2059.96	2017.83	2059.97
9/1/2000	1.02E+07	2011.09	2049.49	2021.34	2059.96	2021.26	2059.96	2018.02	2059.97
9/1/2000	1.02E+07	2011.15	2049.49	2021.4	2059.96	2021.31	2059.96	2018.1	2059.96
9/2/2000	1.02E+07	2011.21	2049.49	2021.45	2059.96	2021.37	2059.96	2018.17	2059.96
9/10/2000	9.83E+06	2011.26	2049.48	2021.5	2059.95	2021.42	2059.95	2018.23	2059.96
9/30/2000	8.98E+06	2011.29	2049.47	2021.53	2059.94	2021.45	2059.94	2018.27	2059.94
10/1/2000	8.98E+06	2011.29	2049.47	2021.53	2059.94	2021.45	2059.94	2018.27	2059.94
10/1/2000	8.98E+06	2026.81	2049.47	2037.17	2059.94	2037.2	2059.94	2036.5	2059.94
10/1/2000	8.98E+06	2012.39	2049.47	2022.63	2059.94	2022.56	2059.94	2019.91	2059.94
10/1/2000	8.98E+06	2012.56	2049.47	2022.84	2059.94	2022.78	2059.94	2020.25	2059.94
10/1/2000	8.96E+06	2012.64	2049.47	2022.92	2059.94	2022.87	2059.94	2020.37	2059.94
10/2/2000	8.87E+06	2012.72	2049.47	2023	2059.94	2022.95	2059.94	2020.48	2059.94
10/10/2000	8.43E+06	2012.81	2049.46	2023.09	2059.93	2023.03	2059.93	2020.58	2059.94
10/31/2000	7.25E+06	2012.87	2049.45	2023.15	2059.92	2023.1	2059.92	2020.65	2059.92
11/1/2000	7.25E+06	2012.87	2049.45	2023.15	2059.92	2023.1	2059.92	2020.65	2059.92
11/1/2000	7.25E+06	2027.16	2049.45	2037.52	2059.92	2037.55	2059.92	2037.03	2059.92
11/1/2000	7.25E+06	2012.62	2049.45	2022.86	2059.92	2022.79	2059.92	2020.16	2059.92
11/1/2000	7.25E+06	2012.71	2049.45	2022.98	2059.92	2022.92	2059.92	2020.36	2059.92
11/1/2000	7.25E+06	2012.7	2049.45	2022.97	2059.92	2022.91	2059.92	2020.37	2059.92
11/2/2000	7.26E+06	2012.69	2049.44	2022.96	2059.92	2022.91	2059.92	2020.37	2059.92
11/10/2000	7.32E+06	2012.69	2049.44	2022.97	2059.91	2022.91	2059.91	2020.38	2059.92
11/30/2000	7.47E+06	2012.7	2049.43	2022.98	2059.9	2022.92	2059.9	2020.39	2059.9
12/1/2000	7.47E+06	2012.7	2049.43	2022.98	2059.9	2022.92	2059.9	2020.39	2059.9
12/1/2000	7.47E+06	2027.66	2049.43	2038.04	2059.9	2038.07	2059.9	2037.77	2059.9
12/1/2000	7.47E+06	2013.18	2049.43	2023.44	2059.9	2023.37	2059.9	2021	2059.9
12/1/2000	7.47E+06	2013.32	2049.43	2023.6	2059.9	2023.56	2059.9	2021.3	2059.9
12/1/2000	7.46E+06	2013.36	2049.43	2023.65	2059.9	2023.6	2059.9	2021.38	2059.9
12/2/2000	7.42E+06	2013.4	2049.43	2023.68	2059.9	2023.64	2059.9	2021.43	2059.9
12/10/2000	7.21E+06	2013.44	2049.42	2023.73	2059.89	2023.68	2059.89	2021.48	2059.9
12/31/2000	6.64E+06	2013.47	2049.41	2023.76	2059.88	2023.71	2059.88	2021.52	2059.88
1/1/2001	6.64E+06	2013.47	2049.41	2023.76	2059.88	2023.71	2059.88	2021.52	2059.88
1/1/2001	6.64E+06	2028.28	2049.41	2038.67	2059.88	2038.7	2059.88	2038.68	2059.88
1/1/2001	6.64E+06	2013.79	2049.41	2024.05	2059.88	2023.99	2059.88	2021.85	2059.88
1/1/2001	6.63E+06	2013.91	2049.41	2024.2	2059.88	2024.16	2059.88	2022.16	2059.88
1/1/2001	6.63E+06	2013.94	2049.41	2024.23	2059.88	2024.2	2059.88	2022.22	2059.88
1/2/2001	6.60E+06	2013.97	2049.41	2024.26	2059.88	2024.23	2059.88	2022.26	2059.88
1/10/2001	6.45E+06	2014	2049.4	2024.3	2059.87	2024.26	2059.87	2022.31	2059.88
1/31/2001	6.04E+06	2014.03	2049.39	2024.33	2059.86	2024.29	2059.86	2022.34	2059.86
2/1/2001	6.04E+06	2014.03	2049.39	2024.33	2059.86	2024.29	2059.86	2022.34	2059.86
2/1/2001	6.04E+06	2028.25	2049.39	2038.64	2059.86	2038.67	2059.86	2038.63	2059.86
2/1/2001	6.04E+06	2013.7	2049.39	2023.96	2059.86	2023.9	2059.86	2021.69	2059.86
2/1/2001	6.04E+06	2013.78	2049.39	2024.08	2059.86	2024.03	2059.86	2021.93	2059.86
2/1/2001	6.04E+06	2013.77	2049.39	2024.06	2059.86	2024.02	2059.86	2021.94	2059.86
2/2/2001	6.06E+06	2013.76	2049.39	2024.05	2059.86	2024.01	2059.86	2021.93	2059.86
2/10/2001	6.16E+06	2013.75	2049.38	2024.04	2059.85	2024	2059.85	2021.92	2059.86
2/28/2001	6.37E+06	2013.75	2049.37	2024.04	2059.84	2024	2059.84	2021.92	2059.85
3/1/2001	6.37E+06	2013.75	2049.37	2024.04	2059.84	2024	2059.84	2021.92	2059.85

3/1/2001	6.37E+06	2028.5	2049.37	2038.89	2059.84	2038.93	2059.84	2039	2059.85
3/1/2001	6.37E+06	2014	2049.37	2024.27	2059.84	2024.21	2059.84	2022.14	2059.85
3/1/2001	6.37E+06	2014.12	2049.37	2024.42	2059.84	2024.38	2059.84	2022.45	2059.85
3/1/2001	6.37E+06	2014.14	2049.37	2024.44	2059.84	2024.41	2059.84	2022.51	2059.85
3/2/2001	6.34E+06	2014.17	2049.37	2024.47	2059.84	2024.43	2059.84	2022.54	2059.85
3/10/2001	6.22E+06	2014.19	2049.37	2024.49	2059.84	2024.45	2059.84	2022.57	2059.84
3/31/2001	5.87E+06	2014.21	2049.35	2024.51	2059.82	2024.47	2059.82	2022.6	2059.83
4/1/2001	0	2014.21	2049.35	2024.51	2059.82	2024.47	2059.82	2022.6	2059.83

Table C.3: CMG IMEX Numerical simulation results for assumed Skin 10.

		Skin 10							
		Darcy Flow		Non-Darcy Flow FG1		Non-Darcy Flow FG2		Non-Darcy Flow Geertsma	
DATE	Gas Rate SC - Monthly	Pbh	Pr	Pbh	Pr	Pbh	Pr	Pbh	Pr
	(ft3/day)	(psi)	(psi)	(psi)	(psi)	(psi)	(psi)	(psi)	(psi)
8/31/1997	0	0	0	0	0	0	0	0	0
9/1/1997	90.2957	0	2050.01	0	2060.53	0	2060.53	0	2060.53
9/1/1997	112.87	2034.89	2050.01	2045.29	2060.53	2045.29	2060.53	2045.65	2060.53
9/1/1997	225.739	2020.34	2050.01	2030.68	2060.53	2030.67	2060.53	2030.57	2060.53
9/1/1997	790.087	2020.42	2050.01	2030.76	2060.53	2030.76	2060.53	2030.7	2060.53
9/1/1997	3611.83	2020.41	2050.01	2030.75	2060.53	2030.75	2060.53	2030.69	2060.53
9/2/1997	17720.5	2020.4	2050.01	2030.74	2060.53	2030.74	2060.53	2030.68	2060.53
9/10/1997	88264.1	2020.39	2050.01	2030.73	2060.52	2030.73	2060.52	2030.67	2060.52
9/30/1997	270887	2020.38	2050.01	2030.72	2060.48	2030.72	2060.48	2030.66	2060.48
10/1/1997	272432	2020.38	2050.01	2030.72	2060.48	2030.72	2060.48	2030.66	2060.48
10/1/1997	272819	2030.4	2050.01	2040.8	2060.48	2040.8	2060.48	2041.2	2060.48
10/1/1997	274750	2015.62	2050.01	2025.92	2060.48	2025.89	2060.48	2024.13	2060.48
10/1/1997	284406	2015.49	2050.01	2025.8	2060.48	2025.77	2060.48	2023.94	2060.48
10/1/1997	332688	2015.27	2050.01	2025.58	2060.48	2025.55	2060.48	2023.67	2060.48
10/2/1997	574098	2015.05	2050.01	2025.36	2060.48	2025.34	2060.48	2023.41	2060.48
10/10/1997	1.78E+06	2014.83	2050.01	2025.14	2060.48	2025.11	2060.48	2023.17	2060.48
10/31/1997	5.06E+06	2014.67	2050.01	2024.97	2060.48	2024.95	2060.48	2022.98	2060.48
11/1/1997	5.06E+06	2014.67	2050.01	2024.97	2060.48	2024.95	2060.48	2022.98	2060.48
11/1/1997	5.06E+06	2028.34	2050.01	2038.72	2060.48	2038.73	2060.48	2038.47	2060.48
11/1/1997	5.06E+06	2013.79	2050.01	2024.08	2060.48	2024.04	2060.48	2021.66	2060.48
11/1/1997	5.06E+06	2013.85	2050.01	2024.15	2060.48	2024.11	2060.48	2021.76	2060.48
11/1/1997	5.07E+06	2013.81	2050.01	2024.11	2060.48	2024.07	2060.48	2021.73	2060.48
11/2/1997	5.11E+06	2013.76	2050.01	2024.06	2060.48	2024.02	2060.48	2021.67	2060.48
11/10/1997	5.32E+06	2013.69	2050.01	2023.99	2060.48	2023.95	2060.48	2021.59	2060.48
11/30/1997	5.86E+06	2013.6	2050.01	2023.9	2060.48	2023.86	2060.48	2021.5	2060.48
12/1/1997	5.86E+06	2013.6	2050.01	2023.9	2060.48	2023.86	2060.48	2021.5	2060.48
12/1/1997	5.86E+06	2027.69	2050.01	2038.06	2060.48	2038.07	2060.48	2037.56	2060.48
12/1/1997	5.87E+06	2013.17	2050.01	2023.45	2060.48	2023.41	2060.48	2020.86	2060.48
12/1/1997	5.87E+06	2013.25	2050.01	2023.54	2060.48	2023.5	2060.48	2020.96	2060.48
12/1/1997	5.87E+06	2013.23	2050.01	2023.52	2060.48	2023.48	2060.48	2020.95	2060.48
12/2/1997	5.89E+06	2013.21	2050.01	2023.5	2060.48	2023.46	2060.48	2020.93	2060.48
12/10/1997	5.97E+06	2013.17	2050.01	2023.46	2060.48	2023.42	2060.48	2020.88	2060.48
12/31/1997	6.21E+06	2013.11	2050.01	2023.4	2060.48	2023.36	2060.48	2020.81	2060.48
1/1/1998	6.21E+06	2013.11	2050.01	2023.4	2060.48	2023.36	2060.48	2020.81	2060.48
1/1/1998	6.21E+06	2027.57	2050.01	2037.95	2060.48	2037.95	2060.48	2037.42	2060.48
1/1/1998	6.21E+06	2013.08	2050.01	2023.36	2060.48	2023.32	2060.48	2020.76	2060.48
1/1/1998	6.21E+06	2013.17	2050.01	2023.47	2060.48	2023.43	2060.48	2020.9	2060.48
1/1/1998	6.21E+06	2013.18	2050.01	2023.47	2060.48	2023.43	2060.48	2020.91	2060.48
1/2/1998	6.21E+06	2013.18	2050.01	2023.47	2060.48	2023.43	2060.48	2020.92	2060.48
1/10/1998	6.19E+06	2013.16	2050.01	2023.45	2060.48	2023.41	2060.48	2020.9	2060.48
1/31/1998	6.14E+06	2013.12	2050.01	2023.42	2060.48	2023.38	2060.48	2020.86	2060.48
2/1/1998	6.14E+06	2013.12	2050.01	2023.42	2060.48	2023.38	2060.48	2020.86	2060.48
2/1/1998	6.14E+06	2027.58	2050.01	2037.96	2060.48	2037.96	2060.48	2037.45	2060.48
2/1/1998	6.14E+06	2013.09	2050.01	2023.37	2060.48	2023.33	2060.48	2020.79	2060.48
2/1/1998	6.14E+06	2013.18	2050.01	2023.48	2060.48	2023.44	2060.48	2020.93	2060.48
2/1/1998	6.14E+06	2013.19	2050.01	2023.48	2060.48	2023.44	2060.48	2020.95	2060.48
2/2/1998	6.14E+06	2013.19	2050.01	2023.48	2060.48	2023.44	2060.48	2020.95	2060.48
2/10/1998	6.12E+06	2013.18	2050	2023.47	2060.48	2023.43	2060.48	2020.94	2060.48

2/28/1998	6.09E+06	2013.15	2050	2023.45	2060.47	2023.41	2060.47	2020.92	2060.47
3/1/1998	6.08E+06	2013.15	2050	2023.45	2060.47	2023.41	2060.47	2020.92	2060.47
3/1/1998	6.08E+06	2027.96	2050	2038.34	2060.47	2038.35	2060.47	2038.01	2060.47
3/1/1998	6.08E+06	2013.48	2050	2023.77	2060.47	2023.73	2060.47	2021.35	2060.47
3/1/1998	6.08E+06	2013.6	2050	2023.9	2060.47	2023.86	2060.47	2021.55	2060.47
3/1/1998	6.08E+06	2013.62	2050	2023.92	2060.47	2023.88	2060.47	2021.59	2060.47
3/2/1998	6.06E+06	2013.63	2050	2023.93	2060.47	2023.9	2060.47	2021.62	2060.47
3/10/1998	5.95E+06	2013.64	2050	2023.94	2060.47	2023.91	2060.47	2021.63	2060.47
3/31/1998	5.65E+06	2013.64	2050	2023.94	2060.47	2023.9	2060.47	2021.63	2060.47
4/1/1998	5.65E+06	2013.64	2050	2023.94	2060.47	2023.9	2060.47	2021.63	2060.47
4/1/1998	5.65E+06	2026.5	2050	2036.87	2060.47	2036.86	2060.47	2035.96	2060.47
4/1/1998	5.65E+06	2011.91	2050	2022.18	2060.47	2022.14	2060.47	2019.23	2060.47
4/1/1998	5.66E+06	2011.93	2050	2022.21	2060.47	2022.15	2060.47	2019.09	2060.47
4/1/1998	5.67E+06	2011.85	2050	2022.13	2060.47	2022.07	2060.47	2018.98	2060.47
4/2/1998	5.76E+06	2011.78	2050	2022.05	2060.47	2022	2060.47	2018.89	2060.47
4/10/1998	6.20E+06	2011.7	2049.99	2021.97	2060.46	2021.92	2060.46	2018.8	2060.47
4/30/1998	7.32E+06	2011.63	2049.99	2021.9	2060.46	2021.85	2060.46	2018.72	2060.46
5/1/1998	7.32E+06	2011.63	2049.99	2021.9	2060.46	2021.85	2060.46	2018.72	2060.46
5/1/1998	7.32E+06	2026.22	2049.99	2036.58	2060.46	2036.58	2060.46	2035.51	2060.46
5/1/1998	7.32E+06	2011.75	2049.99	2022.01	2060.46	2021.97	2060.46	2019.03	2060.46
5/1/1998	7.32E+06	2011.85	2049.99	2022.13	2060.46	2022.08	2060.46	2019.06	2060.46
5/1/1998	7.32E+06	2011.86	2049.99	2022.14	2060.46	2022.08	2060.46	2019.07	2060.46
5/2/1998	7.31E+06	2011.86	2049.99	2022.14	2060.46	2022.09	2060.46	2019.07	2060.46
5/10/1998	7.25E+06	2011.86	2049.99	2022.14	2060.46	2022.08	2060.46	2019.07	2060.46
5/31/1998	7.11E+06	2011.83	2049.98	2022.11	2060.45	2022.05	2060.45	2019.04	2060.45
6/1/1998	7.11E+06	2011.83	2049.98	2022.11	2060.45	2022.05	2060.45	2019.04	2060.45
6/1/1998	7.11E+06	2024.13	2049.98	2034.47	2060.45	2034.44	2060.45	2032.52	2060.45
6/1/1998	7.11E+06	2009.52	2049.98	2019.76	2060.45	2019.72	2060.45	2016.02	2060.45
6/1/1998	7.11E+06	2009.51	2049.98	2019.75	2060.45	2019.67	2060.45	2015.58	2060.45
6/1/1998	7.14E+06	2009.41	2049.98	2019.65	2060.45	2019.56	2060.45	2015.38	2060.45
6/2/1998	7.25E+06	2009.3	2049.98	2019.54	2060.45	2019.45	2060.45	2015.24	2060.45
6/10/1998	7.85E+06	2009.19	2049.98	2019.43	2060.45	2019.33	2060.45	2015.11	2060.45
6/30/1998	9.38E+06	2009.09	2049.97	2019.33	2060.44	2019.24	2060.44	2014.99	2060.45
7/1/1998	9.38E+06	2009.09	2049.97	2019.33	2060.44	2019.24	2060.44	2014.99	2060.45
7/1/1998	9.38E+06	2022.99	2049.97	2033.3	2060.44	2033.26	2060.44	2030.74	2060.45
7/1/1998	9.38E+06	2008.49	2049.97	2018.72	2060.44	2018.66	2060.44	2014.68	2060.45
7/1/1998	9.38E+06	2008.55	2049.97	2018.78	2060.44	2018.69	2060.44	2014.28	2060.45
7/1/1998	9.39E+06	2008.53	2049.97	2018.75	2060.44	2018.66	2060.44	2014.15	2060.45
7/2/1998	9.41E+06	2008.5	2049.97	2018.72	2060.44	2018.62	2060.44	2014.1	2060.44
7/10/1998	9.54E+06	2008.45	2049.97	2018.67	2060.44	2018.57	2060.44	2014.03	2060.44
7/31/1998	9.91E+06	2008.38	2049.96	2018.61	2060.43	2018.51	2060.43	2013.96	2060.44
8/1/1998	9.91E+06	2008.38	2049.96	2018.61	2060.43	2018.51	2060.43	2013.96	2060.44
8/1/1998	9.91E+06	2024.55	2049.96	2034.88	2060.43	2034.86	2060.43	2033.05	2060.44
8/1/1998	9.91E+06	2010.18	2049.96	2020.43	2060.43	2020.39	2060.43	2016.99	2060.44
8/1/1998	9.90E+06	2010.36	2049.96	2020.62	2060.43	2020.56	2060.43	2017.03	2060.44
8/1/1998	9.88E+06	2010.45	2049.96	2020.71	2060.43	2020.65	2060.43	2017.13	2060.44
8/2/1998	9.78E+06	2010.53	2049.96	2020.8	2060.43	2020.73	2060.43	2017.23	2060.43
8/10/1998	9.29E+06	2010.6	2049.96	2020.86	2060.43	2020.8	2060.43	2017.31	2060.43
8/31/1998	7.97E+06	2010.63	2049.95	2020.89	2060.42	2020.82	2060.42	2017.34	2060.42
9/1/1998	7.97E+06	2010.63	2049.95	2020.89	2060.42	2020.82	2060.42	2017.34	2060.42
9/1/1998	7.97E+06	2022.4	2049.95	2032.72	2060.42	2032.67	2060.42	2030.03	2060.42
9/1/1998	7.97E+06	2007.77	2049.95	2017.99	2060.42	2017.93	2060.42	2013.77	2060.42
9/1/1998	7.97E+06	2007.74	2049.95	2017.94	2060.42	2017.84	2060.42	2013.03	2060.42
9/1/1998	8.00E+06	2007.61	2049.95	2017.81	2060.42	2017.7	2060.42	2012.73	2060.42
9/2/1998	8.15E+06	2007.48	2049.95	2017.68	2060.42	2017.56	2060.42	2012.55	2060.42
9/10/1998	8.89E+06	2007.35	2049.95	2017.56	2060.42	2017.44	2060.42	2012.39	2060.42
9/30/1998	1.08E+07	2007.25	2049.94	2017.45	2060.41	2017.33	2060.41	2012.27	2060.41
10/1/1998	1.08E+07	2007.25	2049.94	2017.45	2060.41	2017.33	2060.41	2012.27	2060.41

10/1/1998	1.08E+07	2021.54	2049.94	2031.82	2060.41	2031.76	2060.41	2028.58	2060.41
10/1/1998	1.08E+07	2007.07	2049.94	2017.28	2060.41	2017.21	2060.41	2012.88	2060.41
10/1/1998	1.08E+07	2007.16	2049.94	2017.36	2060.41	2017.25	2060.41	2012.29	2060.41
10/1/1998	1.08E+07	2007.15	2049.94	2017.35	2060.41	2017.23	2060.41	2012.16	2060.41
10/2/1998	1.08E+07	2007.14	2049.94	2017.34	2060.41	2017.22	2060.41	2012.11	2060.41
10/10/1998	1.08E+07	2007.11	2049.94	2017.31	2060.41	2017.19	2060.41	2012.07	2060.41
10/31/1998	1.09E+07	2007.06	2049.93	2017.26	2060.4	2017.14	2060.4	2012.01	2060.4
11/1/1998	1.09E+07	2007.06	2049.93	2017.26	2060.4	2017.14	2060.4	2012.01	2060.4
11/1/1998	1.09E+07	2021	2049.93	2031.28	2060.4	2031.22	2060.4	2027.81	2060.4
11/1/1998	1.09E+07	2006.52	2049.93	2016.72	2060.4	2016.65	2060.4	2011.91	2060.4
11/1/1998	1.09E+07	2006.59	2049.93	2016.78	2060.4	2016.67	2060.4	2011.44	2060.4
11/1/1998	1.09E+07	2006.57	2049.93	2016.76	2060.4	2016.63	2060.4	2011.29	2060.4
11/2/1998	1.09E+07	2006.54	2049.93	2016.73	2060.4	2016.6	2060.4	2011.23	2060.4
11/10/1998	1.10E+07	2006.51	2049.92	2016.7	2060.39	2016.57	2060.39	2011.17	2060.39
11/30/1998	1.14E+07	2006.46	2049.91	2016.65	2060.38	2016.52	2060.38	2011.12	2060.39
12/1/1998	1.14E+07	2006.46	2049.91	2016.65	2060.38	2016.52	2060.38	2011.12	2060.39
12/1/1998	1.14E+07	2020.39	2049.91	2030.66	2060.38	2030.58	2060.38	2026.9	2060.39
12/1/1998	1.14E+07	2005.91	2049.91	2016.1	2060.38	2016.02	2060.38	2010.93	2060.39
12/1/1998	1.14E+07	2005.98	2049.91	2016.16	2060.38	2016.03	2060.38	2010.51	2060.39
12/1/1998	1.14E+07	2005.96	2049.91	2016.14	2060.38	2016	2060.38	2010.37	2060.39
12/2/1998	1.14E+07	2005.93	2049.91	2016.11	2060.38	2015.97	2060.38	2010.31	2060.38
12/10/1998	1.15E+07	2005.89	2049.91	2016.07	2060.38	2015.93	2060.38	2010.26	2060.38
12/31/1998	1.18E+07	2005.84	2049.9	2016.02	2060.37	2015.88	2060.37	2010.2	2060.37
1/1/1999	1.18E+07	2005.84	2049.9	2016.02	2060.37	2015.88	2060.37	2010.2	2060.37
1/1/1999	1.18E+07	2020.8	2049.9	2031.07	2060.37	2031	2060.37	2027.5	2060.37
1/1/1999	1.18E+07	2006.38	2049.9	2016.58	2060.37	2016.51	2060.37	2011.78	2060.37
1/1/1999	1.18E+07	2006.5	2049.9	2016.7	2060.37	2016.58	2060.37	2011.4	2060.37
1/1/1999	1.18E+07	2006.53	2049.9	2016.73	2060.37	2016.6	2060.37	2011.32	2060.37
1/2/1999	1.18E+07	2006.56	2049.89	2016.75	2060.37	2016.62	2060.37	2011.33	2060.37
1/10/1999	1.16E+07	2006.57	2049.89	2016.77	2060.36	2016.64	2060.36	2011.34	2060.36
1/31/1999	1.12E+07	2006.56	2049.88	2016.75	2060.35	2016.62	2060.35	2011.32	2060.35
2/1/1999	1.12E+07	2006.56	2049.88	2016.75	2060.35	2016.62	2060.35	2011.32	2060.35
2/1/1999	1.12E+07	2020.6	2049.88	2030.88	2060.35	2030.81	2060.35	2027.27	2060.35
2/1/1999	1.12E+07	2006.13	2049.88	2016.33	2060.35	2016.25	2060.35	2011.41	2060.35
2/1/1999	1.12E+07	2006.2	2049.88	2016.39	2060.35	2016.27	2060.35	2010.95	2060.35
2/1/1999	1.12E+07	2006.19	2049.88	2016.38	2060.35	2016.24	2060.35	2010.79	2060.35
2/2/1999	1.12E+07	2006.17	2049.88	2016.36	2060.35	2016.22	2060.35	2010.73	2060.35
2/10/1999	1.13E+07	2006.15	2049.87	2016.34	2060.34	2016.2	2060.34	2010.7	2060.35
2/28/1999	1.15E+07	2006.12	2049.86	2016.31	2060.33	2016.17	2060.33	2010.67	2060.34
3/1/1999	1.15E+07	2006.12	2049.86	2016.31	2060.33	2016.17	2060.33	2010.67	2060.34
3/1/1999	1.15E+07	2020.57	2049.86	2030.84	2060.33	2030.77	2060.33	2027.21	2060.34
3/1/1999	1.15E+07	2006.12	2049.86	2016.32	2060.33	2016.24	2060.33	2011.42	2060.34
3/1/1999	1.15E+07	2006.22	2049.86	2016.41	2060.33	2016.29	2060.33	2011	2060.34
3/1/1999	1.15E+07	2006.22	2049.86	2016.41	2060.33	2016.28	2060.33	2010.87	2060.34
3/2/1999	1.15E+07	2006.22	2049.86	2016.41	2060.33	2016.28	2060.33	2010.84	2060.34
3/10/1999	1.15E+07	2006.22	2049.86	2016.41	2060.33	2016.27	2060.33	2010.82	2060.33
3/31/1999	1.14E+07	2006.2	2049.84	2016.39	2060.31	2016.25	2060.31	2010.8	2060.32
4/1/1999	1.14E+07	2006.2	2049.84	2016.39	2060.31	2016.25	2060.31	2010.8	2060.32
4/1/1999	1.14E+07	2021.08	2049.84	2031.36	2060.31	2031.3	2060.31	2027.99	2060.32
4/1/1999	1.14E+07	2006.65	2049.84	2016.86	2060.31	2016.8	2060.31	2012.36	2060.32
4/1/1999	1.14E+07	2006.77	2049.84	2016.98	2060.31	2016.87	2060.31	2011.87	2060.32
4/1/1999	1.14E+07	2006.8	2049.84	2017	2060.31	2016.88	2060.31	2011.78	2060.32
4/2/1999	1.14E+07	2006.82	2049.84	2017.03	2060.31	2016.91	2060.31	2011.78	2060.32
4/10/1999	1.12E+07	2006.84	2049.84	2017.04	2060.31	2016.92	2060.31	2011.8	2060.31
4/30/1999	1.09E+07	2006.84	2049.82	2017.04	2060.3	2016.92	2060.3	2011.8	2060.3
5/1/1999	1.09E+07	2006.84	2049.82	2017.04	2060.3	2016.92	2060.3	2011.8	2060.3
5/1/1999	1.09E+07	2021.04	2049.82	2031.32	2060.3	2031.26	2060.3	2027.97	2060.3
5/1/1999	1.09E+07	2006.56	2049.82	2016.77	2060.3	2016.7	2060.3	2012.16	2060.3

5/1/1999	1.09E+07	2006.65	2049.82	2016.85	2060.3	2016.74	2060.3	2011.65	2060.3
5/1/1999	1.09E+07	2006.64	2049.82	2016.84	2060.3	2016.72	2060.3	2011.53	2060.3
5/2/1999	1.09E+07	2006.63	2049.82	2016.83	2060.29	2016.71	2060.29	2011.49	2060.3
5/10/1999	1.09E+07	2006.62	2049.82	2016.82	2060.29	2016.69	2060.29	2011.47	2060.29
5/31/1999	1.10E+07	2006.6	2049.8	2016.8	2060.27	2016.68	2060.27	2011.44	2060.28
6/1/1999	1.10E+07	2006.6	2049.8	2016.8	2060.27	2016.68	2060.27	2011.44	2060.28
6/1/1999	1.10E+07	2021.16	2049.8	2031.44	2060.27	2031.38	2060.27	2028.15	2060.28
6/1/1999	1.10E+07	2006.71	2049.8	2016.92	2060.27	2016.85	2060.27	2012.49	2060.28
6/1/1999	1.10E+07	2006.81	2049.8	2017.02	2060.27	2016.91	2060.27	2011.93	2060.28
6/1/1999	1.10E+07	2006.82	2049.8	2017.02	2060.27	2016.91	2060.27	2011.83	2060.28
6/2/1999	1.10E+07	2006.83	2049.8	2017.03	2060.27	2016.91	2060.27	2011.81	2060.28
6/10/1999	1.10E+07	2006.83	2049.8	2017.03	2060.27	2016.91	2060.27	2011.8	2060.27
6/30/1999	1.08E+07	2006.82	2049.78	2017.03	2060.25	2016.9	2060.25	2011.79	2060.26
7/1/1999	1.08E+07	2006.82	2049.78	2017.03	2060.25	2016.9	2060.25	2011.79	2060.26
7/1/1999	1.08E+07	2021.51	2049.78	2031.8	2060.25	2031.74	2060.25	2028.69	2060.26
7/1/1999	1.08E+07	2007.06	2049.78	2017.28	2060.25	2017.22	2060.25	2012.93	2060.26
7/1/1999	1.08E+07	2007.17	2049.78	2017.38	2060.25	2017.28	2060.25	2012.49	2060.26
7/1/1999	1.08E+07	2007.19	2049.78	2017.4	2060.25	2017.29	2060.25	2012.4	2060.26
7/2/1999	1.08E+07	2007.2	2049.78	2017.41	2060.25	2017.3	2060.25	2012.39	2060.26
7/10/1999	1.07E+07	2007.21	2049.78	2017.43	2060.25	2017.31	2060.25	2012.4	2060.25
7/31/1999	1.05E+07	2007.21	2049.76	2017.42	2060.23	2017.31	2060.23	2012.4	2060.24
8/1/1999	1.05E+07	2007.21	2049.76	2017.42	2060.23	2017.31	2060.23	2012.4	2060.24
8/1/1999	1.05E+07	2021.9	2049.76	2032.2	2060.23	2032.15	2060.23	2029.29	2060.24
8/1/1999	1.05E+07	2007.45	2049.76	2017.68	2060.23	2017.62	2060.23	2013.53	2060.24
8/1/1999	1.05E+07	2007.56	2049.76	2017.78	2060.23	2017.69	2060.23	2013.09	2060.24
8/1/1999	1.05E+07	2007.58	2049.76	2017.8	2060.23	2017.69	2060.23	2013	2060.24
8/2/1999	1.05E+07	2007.59	2049.76	2017.81	2060.23	2017.71	2060.23	2012.99	2060.24
8/10/1999	1.04E+07	2007.61	2049.76	2017.83	2060.23	2017.72	2060.23	2013	2060.23
8/31/1999	1.02E+07	2007.61	2049.74	2017.83	2060.21	2017.72	2060.21	2013	2060.22
9/1/1999	1.02E+07	2007.61	2049.74	2017.83	2060.21	2017.72	2060.21	2013	2060.22
9/1/1999	1.02E+07	2021.55	2049.74	2031.85	2060.21	2031.8	2060.21	2028.81	2060.22
9/1/1999	1.02E+07	2007.07	2049.74	2017.28	2060.21	2017.22	2060.21	2012.93	2060.22
9/1/1999	1.02E+07	2007.14	2049.74	2017.35	2060.21	2017.25	2060.21	2012.41	2060.22
9/1/1999	1.02E+07	2007.12	2049.74	2017.33	2060.21	2017.21	2060.21	2012.28	2060.22
9/2/1999	1.02E+07	2007.1	2049.74	2017.3	2060.21	2017.19	2060.21	2012.22	2060.22
9/10/1999	1.03E+07	2007.07	2049.73	2017.28	2060.21	2017.17	2060.21	2012.19	2060.21
9/30/1999	1.06E+07	2007.05	2049.72	2017.26	2060.19	2017.14	2060.19	2012.16	2060.2
10/1/1999	1.06E+07	2007.05	2049.72	2017.26	2060.19	2017.14	2060.19	2012.16	2060.2
10/1/1999	1.06E+07	2021.49	2049.72	2031.78	2060.19	2031.73	2060.19	2028.69	2060.2
10/1/1999	1.06E+07	2007.03	2049.72	2017.25	2060.19	2017.18	2060.19	2012.9	2060.2
10/1/1999	1.06E+07	2007.13	2049.72	2017.34	2060.19	2017.24	2060.19	2012.43	2060.2
10/1/1999	1.06E+07	2007.13	2049.72	2017.34	2060.19	2017.23	2060.19	2012.32	2060.2
10/2/1999	1.06E+07	2007.13	2049.72	2017.34	2060.19	2017.23	2060.19	2012.3	2060.2
10/10/1999	1.06E+07	2007.13	2049.71	2017.34	2060.19	2017.22	2060.19	2012.29	2060.19
10/31/1999	1.05E+07	2007.11	2049.7	2017.32	2060.17	2017.21	2060.17	2012.27	2060.18
11/1/1999	1.05E+07	2007.11	2049.7	2017.32	2060.17	2017.21	2060.17	2012.27	2060.18
11/1/1999	1.05E+07	2021.35	2049.7	2031.64	2060.17	2031.59	2060.17	2028.51	2060.18
11/1/1999	1.05E+07	2006.88	2049.7	2017.1	2060.17	2017.04	2060.17	2012.69	2060.18
11/1/1999	1.05E+07	2006.97	2049.7	2017.18	2060.17	2017.08	2060.17	2012.19	2060.18
11/1/1999	1.05E+07	2006.96	2049.7	2017.17	2060.17	2017.06	2060.17	2012.08	2060.18
11/2/1999	1.05E+07	2006.96	2049.7	2017.17	2060.17	2017.05	2060.17	2012.04	2060.18
11/10/1999	1.06E+07	2006.95	2049.69	2017.15	2060.16	2017.04	2060.16	2012.02	2060.17
11/30/1999	1.07E+07	2006.93	2049.68	2017.14	2060.15	2017.02	2060.15	2012	2060.16
12/1/1999	1.07E+07	2006.93	2049.68	2017.14	2060.15	2017.02	2060.15	2012	2060.16
12/1/1999	1.07E+07	2021.08	2049.68	2031.37	2060.15	2031.31	2060.15	2028.11	2060.16
12/1/1999	1.07E+07	2006.61	2049.68	2016.82	2060.15	2016.75	2060.15	2012.4	2060.16
12/1/1999	1.07E+07	2006.69	2049.68	2016.89	2060.15	2016.79	2060.15	2011.79	2060.16
12/1/1999	1.07E+07	2006.68	2049.68	2016.88	2060.15	2016.76	2060.15	2011.65	2060.16

12/2/1999	1.07E+07	2006.67	2049.68	2016.87	2060.15	2016.75	2060.15	2011.61	2060.15
12/10/1999	1.08E+07	2006.65	2049.67	2016.85	2060.14	2016.73	2060.14	2011.58	2060.15
12/31/1999	1.09E+07	2006.63	2049.66	2016.83	2060.13	2016.71	2060.13	2011.55	2060.13
1/1/2000	1.09E+07	2006.63	2049.66	2016.83	2060.13	2016.71	2060.13	2011.55	2060.13
1/1/2000	1.09E+07	2020.58	2049.66	2030.86	2060.13	2030.79	2060.13	2027.36	2060.13
1/1/2000	1.09E+07	2006.1	2049.66	2016.3	2060.13	2016.22	2060.13	2011.47	2060.13
1/1/2000	1.09E+07	2006.17	2049.66	2016.36	2060.13	2016.24	2060.13	2010.99	2060.13
1/1/2000	1.09E+07	2006.15	2049.66	2016.34	2060.13	2016.21	2060.13	2010.84	2060.13
1/2/2000	1.09E+07	2006.13	2049.66	2016.32	2060.13	2016.19	2060.13	2010.79	2060.13
1/10/2000	1.11E+07	2006.1	2049.65	2016.29	2060.12	2016.16	2060.12	2010.74	2060.13
1/31/2000	1.14E+07	2006.06	2049.64	2016.25	2060.11	2016.12	2060.11	2010.71	2060.11
2/1/2000	1.14E+07	2006.06	2049.64	2016.25	2060.11	2016.12	2060.11	2010.71	2060.11
2/1/2000	1.14E+07	2020.18	2049.64	2030.44	2060.11	2030.37	2060.11	2026.75	2060.11
2/1/2000	1.14E+07	2005.7	2049.64	2015.9	2060.11	2015.82	2060.11	2010.88	2060.11
2/1/2000	1.14E+07	2005.79	2049.64	2015.97	2060.11	2015.85	2060.11	2010.44	2060.11
2/1/2000	1.14E+07	2005.77	2049.64	2015.96	2060.11	2015.82	2060.11	2010.29	2060.11
2/2/2000	1.14E+07	2005.76	2049.64	2015.94	2060.11	2015.8	2060.11	2010.24	2060.11
2/10/2000	1.15E+07	2005.74	2049.63	2015.92	2060.1	2015.78	2060.1	2010.21	2060.11
2/29/2000	1.16E+07	2005.71	2049.62	2015.89	2060.09	2015.75	2060.09	2010.17	2060.09
3/1/2000	1.16E+07	2005.71	2049.62	2015.89	2060.09	2015.75	2060.09	2010.17	2060.09
3/1/2000	1.16E+07	2020.26	2049.62	2030.53	2060.09	2030.46	2060.09	2026.87	2060.09
3/1/2000	1.16E+07	2005.81	2049.62	2016.01	2060.09	2015.94	2060.09	2011.1	2060.09
3/1/2000	1.16E+07	2005.92	2049.62	2016.11	2060.09	2015.99	2060.09	2010.68	2060.09
3/1/2000	1.16E+07	2005.92	2049.62	2016.11	2060.09	2015.98	2060.09	2010.56	2060.09
3/2/2000	1.16E+07	2005.93	2049.61	2016.12	2060.09	2015.99	2060.09	2010.54	2060.09
3/10/2000	1.16E+07	2005.93	2049.61	2016.12	2060.08	2015.99	2060.08	2010.53	2060.09
3/31/2000	1.14E+07	2005.91	2049.59	2016.1	2060.07	2015.97	2060.07	2010.51	2060.07
4/1/2000	1.14E+07	2005.91	2049.59	2016.1	2060.07	2015.97	2060.07	2010.51	2060.07
4/1/2000	1.14E+07	2020.78	2049.59	2031.06	2060.07	2031	2060.07	2027.68	2060.07
4/1/2000	1.14E+07	2006.35	2049.59	2016.56	2060.07	2016.5	2060.07	2012.02	2060.07
4/1/2000	1.14E+07	2006.47	2049.59	2016.68	2060.07	2016.57	2060.07	2011.54	2060.07
4/1/2000	1.14E+07	2006.5	2049.59	2016.7	2060.07	2016.58	2060.07	2011.46	2060.07
4/2/2000	1.14E+07	2006.52	2049.59	2016.72	2060.06	2016.6	2060.06	2011.46	2060.07
4/10/2000	1.12E+07	2006.54	2049.59	2016.74	2060.06	2016.62	2060.06	2011.48	2060.07
4/30/2000	1.09E+07	2006.54	2049.57	2016.74	2060.05	2016.62	2060.05	2011.48	2060.05
5/1/2000	1.09E+07	2006.54	2049.57	2016.74	2060.05	2016.62	2060.05	2011.48	2060.05
5/1/2000	1.09E+07	2022.15	2049.57	2032.45	2060.05	2032.41	2060.05	2029.74	2060.05
5/1/2000	1.09E+07	2007.75	2049.57	2017.99	2060.05	2017.94	2060.05	2013.94	2060.05
5/1/2000	1.09E+07	2007.91	2049.57	2018.14	2060.05	2018.06	2060.05	2013.73	2060.05
5/1/2000	1.09E+07	2007.97	2049.57	2018.21	2060.04	2018.11	2060.04	2013.73	2060.05
5/2/2000	1.08E+07	2008.03	2049.57	2018.27	2060.04	2018.17	2060.04	2013.79	2060.05
5/10/2000	1.05E+07	2008.09	2049.57	2018.33	2060.04	2018.23	2060.04	2013.85	2060.04
5/31/2000	9.53E+06	2008.13	2049.55	2018.36	2060.02	2018.27	2060.02	2013.89	2060.03
6/1/2000	9.53E+06	2008.13	2049.55	2018.36	2060.02	2018.27	2060.02	2013.89	2060.03
6/1/2000	9.53E+06	2022.14	2049.55	2032.45	2060.02	2032.41	2060.02	2029.81	2060.03
6/1/2000	9.53E+06	2007.66	2049.55	2017.89	2060.02	2017.83	2060.02	2013.79	2060.03
6/1/2000	9.54E+06	2007.73	2049.55	2017.96	2060.02	2017.87	2060.02	2013.4	2060.03
6/1/2000	9.54E+06	2007.71	2049.55	2017.94	2060.02	2017.84	2060.02	2013.28	2060.03
6/2/2000	9.56E+06	2007.7	2049.55	2017.92	2060.02	2017.82	2060.02	2013.24	2060.03
6/10/2000	9.66E+06	2007.69	2049.55	2017.91	2060.02	2017.81	2060.02	2013.22	2060.02
6/30/2000	9.92E+06	2007.68	2049.53	2017.9	2060	2017.8	2060	2013.21	2060.01
7/1/2000	9.92E+06	2007.68	2049.53	2017.9	2060	2017.8	2060	2013.21	2060.01
7/1/2000	9.92E+06	2021.71	2049.53	2032.01	2060	2031.97	2060	2029.15	2060.01
7/1/2000	9.92E+06	2007.23	2049.53	2017.45	2060	2017.39	2060	2013.32	2060.01
7/1/2000	9.92E+06	2007.3	2049.53	2017.52	2060	2017.42	2060	2012.79	2060.01
7/1/2000	9.93E+06	2007.29	2049.53	2017.5	2060	2017.4	2060	2012.65	2060.01
7/2/2000	9.95E+06	2007.27	2049.53	2017.49	2060	2017.38	2060	2012.6	2060.01
7/10/2000	1.00E+07	2007.25	2049.52	2017.47	2060	2017.36	2060	2012.57	2060

7/31/2000	1.03E+07	2007.23	2049.51	2017.45	2059.98	2017.34	2059.98	2012.54	2059.99
8/1/2000	1.03E+07	2007.23	2049.51	2017.45	2059.98	2017.34	2059.98	2012.54	2059.99
8/1/2000	1.03E+07	2021.65	2049.51	2031.95	2059.98	2031.9	2059.98	2029.05	2059.99
8/1/2000	1.03E+07	2007.19	2049.51	2017.41	2059.98	2017.36	2059.98	2013.29	2059.99
8/1/2000	1.03E+07	2007.29	2049.51	2017.51	2059.98	2017.41	2059.98	2012.8	2059.99
8/1/2000	1.03E+07	2007.29	2049.51	2017.51	2059.98	2017.4	2059.98	2012.67	2059.99
8/2/2000	1.03E+07	2007.29	2049.51	2017.51	2059.98	2017.4	2059.98	2012.65	2059.99
8/10/2000	1.03E+07	2007.29	2049.5	2017.51	2059.97	2017.4	2059.97	2012.64	2059.98
8/31/2000	1.02E+07	2007.28	2049.49	2017.49	2059.96	2017.39	2059.96	2012.62	2059.97
9/1/2000	1.02E+07	2007.28	2049.49	2017.49	2059.96	2017.39	2059.96	2012.62	2059.97
9/1/2000	1.02E+07	2022.8	2049.49	2033.12	2059.96	2033.08	2059.96	2030.76	2059.97
9/1/2000	1.02E+07	2008.4	2049.49	2018.64	2059.96	2018.59	2059.96	2014.82	2059.97
9/1/2000	1.02E+07	2008.55	2049.49	2018.8	2059.96	2018.72	2059.96	2014.67	2059.97
9/1/2000	1.02E+07	2008.61	2049.49	2018.85	2059.96	2018.77	2059.96	2014.7	2059.96
9/2/2000	1.02E+07	2008.67	2049.49	2018.91	2059.96	2018.83	2059.96	2014.75	2059.96
9/10/2000	9.83E+06	2008.72	2049.48	2018.96	2059.95	2018.88	2059.95	2014.81	2059.96
9/30/2000	8.98E+06	2008.75	2049.47	2018.99	2059.94	2018.91	2059.94	2014.85	2059.94
10/1/2000	8.98E+06	2008.75	2049.47	2018.99	2059.94	2018.91	2059.94	2014.85	2059.94
10/1/2000	8.98E+06	2024.72	2049.47	2035.07	2059.94	2035.06	2059.94	2033.65	2059.94
10/1/2000	8.98E+06	2010.34	2049.47	2020.6	2059.94	2020.56	2059.94	2017.47	2059.94
10/1/2000	8.98E+06	2010.51	2049.47	2020.79	2059.94	2020.74	2059.94	2017.55	2059.94
10/1/2000	8.96E+06	2010.59	2049.47	2020.87	2059.94	2020.82	2059.94	2017.65	2059.94
10/2/2000	8.87E+06	2010.68	2049.47	2020.95	2059.94	2020.9	2059.94	2017.75	2059.94
10/10/2000	8.43E+06	2010.76	2049.46	2021.04	2059.93	2020.98	2059.93	2017.85	2059.94
10/31/2000	7.25E+06	2010.82	2049.45	2021.1	2059.92	2021.04	2059.92	2017.92	2059.92
11/1/2000	7.25E+06	2010.82	2049.45	2021.1	2059.92	2021.04	2059.92	2017.92	2059.92
11/1/2000	7.25E+06	2025	2049.45	2035.36	2059.92	2035.35	2059.92	2034.11	2059.92
11/1/2000	7.25E+06	2010.51	2049.45	2020.77	2059.92	2020.73	2059.92	2017.62	2059.92
11/1/2000	7.25E+06	2010.59	2049.45	2020.86	2059.92	2020.81	2059.92	2017.58	2059.92
11/1/2000	7.25E+06	2010.58	2049.45	2020.86	2059.92	2020.8	2059.92	2017.56	2059.92
11/2/2000	7.26E+06	2010.58	2049.44	2020.85	2059.92	2020.79	2059.92	2017.55	2059.92
11/10/2000	7.32E+06	2010.58	2049.44	2020.85	2059.91	2020.79	2059.91	2017.56	2059.92
11/30/2000	7.47E+06	2010.59	2049.43	2020.86	2059.9	2020.8	2059.9	2017.57	2059.9
12/1/2000	7.47E+06	2010.59	2049.43	2020.86	2059.9	2020.8	2059.9	2017.57	2059.9
12/1/2000	7.47E+06	2025.75	2049.43	2036.11	2059.9	2036.11	2059.9	2035.17	2059.9
12/1/2000	7.47E+06	2011.31	2049.43	2021.58	2059.9	2021.54	2059.9	2018.71	2059.9
12/1/2000	7.47E+06	2011.44	2049.43	2021.73	2059.9	2021.68	2059.9	2018.84	2059.9
12/1/2000	7.46E+06	2011.48	2049.43	2021.77	2059.9	2021.72	2059.9	2018.9	2059.9
12/2/2000	7.42E+06	2011.52	2049.43	2021.81	2059.9	2021.76	2059.9	2018.95	2059.9
12/10/2000	7.21E+06	2011.56	2049.42	2021.85	2059.89	2021.8	2059.89	2018.99	2059.9
12/31/2000	6.64E+06	2011.59	2049.41	2021.88	2059.88	2021.83	2059.88	2019.03	2059.88
1/1/2001	6.64E+06	2011.59	2049.41	2021.88	2059.88	2021.83	2059.88	2019.03	2059.88
1/1/2001	6.64E+06	2026.54	2049.41	2036.91	2059.88	2036.92	2059.88	2036.33	2059.88
1/1/2001	6.64E+06	2012.08	2049.41	2022.36	2059.88	2022.32	2059.88	2019.74	2059.88
1/1/2001	6.63E+06	2012.2	2049.41	2022.5	2059.88	2022.46	2059.88	2019.92	2059.88
1/1/2001	6.63E+06	2012.23	2049.41	2022.53	2059.88	2022.49	2059.88	2019.97	2059.88
1/2/2001	6.60E+06	2012.26	2049.41	2022.55	2059.88	2022.52	2059.88	2020.01	2059.88
1/10/2001	6.45E+06	2012.29	2049.4	2022.59	2059.87	2022.55	2059.87	2020.05	2059.88
1/31/2001	6.04E+06	2012.33	2049.39	2022.62	2059.86	2022.58	2059.86	2020.09	2059.86
2/1/2001	6.04E+06	2012.33	2049.39	2022.62	2059.86	2022.58	2059.86	2020.09	2059.86
2/1/2001	6.04E+06	2026.41	2049.39	2036.79	2059.86	2036.79	2059.86	2036.15	2059.86
2/1/2001	6.04E+06	2011.9	2049.39	2022.18	2059.86	2022.14	2059.86	2019.48	2059.86
2/1/2001	6.04E+06	2011.98	2049.39	2022.27	2059.86	2022.23	2059.86	2019.57	2059.86
2/1/2001	6.04E+06	2011.97	2049.39	2022.26	2059.86	2022.21	2059.86	2019.56	2059.86
2/2/2001	6.06E+06	2011.95	2049.39	2022.24	2059.86	2022.2	2059.86	2019.54	2059.86
2/10/2001	6.16E+06	2011.95	2049.38	2022.24	2059.85	2022.19	2059.85	2019.53	2059.86
2/28/2001	6.37E+06	2011.95	2049.37	2022.24	2059.84	2022.19	2059.84	2019.53	2059.85
3/1/2001	6.37E+06	2011.95	2049.37	2022.24	2059.84	2022.19	2059.84	2019.53	2059.85

3/1/2001	6.37E+06	2026.81	2049.37	2037.18	2059.84	2037.19	2059.84	2036.71	2059.85
3/1/2001	6.37E+06	2012.34	2049.37	2022.63	2059.84	2022.58	2059.84	2020.09	2059.85
3/1/2001	6.37E+06	2012.46	2049.37	2022.76	2059.84	2022.72	2059.84	2020.28	2059.85
3/1/2001	6.37E+06	2012.48	2049.37	2022.78	2059.84	2022.74	2059.84	2020.32	2059.85
3/2/2001	6.34E+06	2012.51	2049.37	2022.81	2059.84	2022.77	2059.84	2020.36	2059.85
3/10/2001	6.22E+06	2012.53	2049.37	2022.83	2059.84	2022.79	2059.84	2020.39	2059.84
3/31/2001	5.87E+06	2012.55	2049.35	2022.85	2059.82	2022.81	2059.82	2020.41	2059.83
4/1/2001	0	2012.55	2049.35	2022.85	2059.82	2022.81	2059.82	2020.41	2059.83

Table C.4: CMG IMEX Numerical simulation results for assumed Skin 33.3.

		Skin 33.3							
		Darcy Flow		Non-Darcy Flow FG1		Non-Darcy Flow FG2		Non-Darcy Flow Geertsma	
DATE	Gas Rate SC - Monthly	Pbh	Pr	Pbh	Pr	Pbh	Pr	Pbh	Pr
	(ft3/day)	(psi)	(psi)	(psi)	(psi)	(psi)	(psi)	(psi)	(psi)
8/31/1997	0	0	0	0	0	0	0	0	0
9/1/1997	90.2957	0	2050.01	0	2060.53	0	2060.53	0	2060.53
9/1/1997	112.87	2034.48	2050.01	2044.89	2060.53	2044.89	2060.53	2045.09	2060.53
9/1/1997	225.739	2019.98	2050.01	2030.32	2060.53	2030.32	2060.53	2030.17	2060.53
9/1/1997	790.087	2020.07	2050.01	2030.41	2060.53	2030.41	2060.53	2030.29	2060.53
9/1/1997	3611.83	2020.05	2050.01	2030.39	2060.53	2030.39	2060.53	2030.28	2060.53
9/2/1997	17720.5	2020.04	2050.01	2030.38	2060.53	2030.38	2060.53	2030.27	2060.53
9/10/1997	88264.1	2020.03	2050.01	2030.37	2060.52	2030.37	2060.52	2030.25	2060.52
9/30/1997	270887	2020.02	2050.01	2030.36	2060.48	2030.36	2060.48	2030.24	2060.48
10/1/1997	272432	2020.02	2050.01	2030.36	2060.48	2030.36	2060.48	2030.24	2060.48
10/1/1997	272819	2023.66	2050.01	2034.05	2060.48	2034.05	2060.48	2033.07	2060.48
10/1/1997	274750	2008.95	2050.01	2019.26	2060.48	2019.24	2060.48	2016.57	2060.48
10/1/1997	284406	2008.82	2050.01	2019.12	2060.48	2019.1	2060.48	2015.72	2060.48
10/1/1997	332688	2008.6	2050.01	2018.9	2060.48	2018.87	2060.48	2015.26	2060.48
10/2/1997	574098	2008.38	2050.01	2018.68	2060.48	2018.65	2060.48	2014.94	2060.48
10/10/1997	1.78E+06	2008.16	2050.01	2018.46	2060.48	2018.43	2060.48	2014.68	2060.48
10/31/1997	5.06E+06	2007.99	2050.01	2018.3	2060.48	2018.27	2060.48	2014.49	2060.48
11/1/1997	5.06E+06	2007.99	2050.01	2018.3	2060.48	2018.27	2060.48	2014.49	2060.48
11/1/1997	5.06E+06	2020.53	2050.01	2030.89	2060.48	2030.88	2060.48	2028.3	2060.48
11/1/1997	5.06E+06	2006.06	2050.01	2016.36	2060.48	2016.34	2060.48	2012.33	2060.48
11/1/1997	5.06E+06	2006.12	2050.01	2016.41	2060.48	2016.37	2060.48	2012	2060.48
11/1/1997	5.07E+06	2006.08	2050.01	2016.37	2060.48	2016.33	2060.48	2011.86	2060.48
11/2/1997	5.11E+06	2006.03	2050.01	2016.32	2060.48	2016.28	2060.48	2011.79	2060.48
11/10/1997	5.32E+06	2005.96	2050.01	2016.25	2060.48	2016.21	2060.48	2011.7	2060.48
11/30/1997	5.86E+06	2005.87	2050.01	2016.16	2060.48	2016.12	2060.48	2011.6	2060.48
12/1/1997	5.86E+06	2005.87	2050.01	2016.16	2060.48	2016.12	2060.48	2011.6	2060.48
12/1/1997	5.86E+06	2019.42	2050.01	2029.78	2060.48	2029.75	2060.48	2026.76	2060.48
12/1/1997	5.87E+06	2004.99	2050.01	2015.28	2060.48	2015.25	2060.48	2010.82	2060.48
12/1/1997	5.87E+06	2005.06	2050.01	2015.35	2060.48	2015.31	2060.48	2010.56	2060.48
12/1/1997	5.87E+06	2005.05	2050.01	2015.33	2060.48	2015.29	2060.48	2010.47	2060.48
12/2/1997	5.89E+06	2005.02	2050.01	2015.31	2060.48	2015.27	2060.48	2010.43	2060.48
12/10/1997	5.97E+06	2004.98	2050.01	2015.27	2060.48	2015.22	2060.48	2010.38	2060.48
12/31/1997	6.21E+06	2004.92	2050.01	2015.21	2060.48	2015.16	2060.48	2010.31	2060.48
1/1/1998	6.21E+06	2004.92	2050.01	2015.21	2060.48	2015.16	2060.48	2010.31	2060.48
1/1/1998	6.21E+06	2019.4	2050.01	2029.75	2060.48	2029.72	2060.48	2026.71	2060.48
1/1/1998	6.21E+06	2004.98	2050.01	2015.27	2060.48	2015.25	2060.48	2010.84	2060.48
1/1/1998	6.21E+06	2005.08	2050.01	2015.36	2060.48	2015.33	2060.48	2010.62	2060.48
1/1/1998	6.21E+06	2005.08	2050.01	2015.37	2060.48	2015.32	2060.48	2010.55	2060.48
1/2/1998	6.21E+06	2005.08	2050.01	2015.36	2060.48	2015.32	2060.48	2010.54	2060.48
1/10/1998	6.19E+06	2005.06	2050.01	2015.35	2060.48	2015.31	2060.48	2010.52	2060.48
1/31/1998	6.14E+06	2005.03	2050.01	2015.31	2060.48	2015.27	2060.48	2010.47	2060.48
2/1/1998	6.14E+06	2005.03	2050.01	2015.31	2060.48	2015.27	2060.48	2010.47	2060.48
2/1/1998	6.14E+06	2019.48	2050.01	2029.84	2060.48	2029.81	2060.48	2026.85	2060.48
2/1/1998	6.14E+06	2005.07	2050.01	2015.36	2060.48	2015.33	2060.48	2010.99	2060.48
2/1/1998	6.14E+06	2005.16	2050.01	2015.45	2060.48	2015.41	2060.48	2010.76	2060.48
2/1/1998	6.14E+06	2005.16	2050.01	2015.45	2060.48	2015.41	2060.48	2010.69	2060.48
2/2/1998	6.14E+06	2005.16	2050.01	2015.45	2060.48	2015.41	2060.48	2010.68	2060.48
2/10/1998	6.12E+06	2005.16	2050	2015.44	2060.48	2015.4	2060.48	2010.66	2060.48

2/28/1998	6.09E+06	2005.13	2050	2015.42	2060.47	2015.38	2060.47	2010.63	2060.47
3/1/1998	6.08E+06	2005.13	2050	2015.42	2060.47	2015.38	2060.47	2010.63	2060.47
3/1/1998	6.08E+06	2020.44	2050	2030.79	2060.47	2030.77	2060.47	2028.14	2060.47
3/1/1998	6.08E+06	2006.04	2050	2016.33	2060.47	2016.31	2060.47	2012.41	2060.47
3/1/1998	6.08E+06	2006.15	2050	2016.44	2060.47	2016.41	2060.47	2012.17	2060.47
3/1/1998	6.08E+06	2006.17	2050	2016.46	2060.47	2016.43	2060.47	2012.11	2060.47
3/2/1998	6.06E+06	2006.19	2050	2016.48	2060.47	2016.44	2060.47	2012.11	2060.47
3/10/1998	5.95E+06	2006.2	2050	2016.49	2060.47	2016.45	2060.47	2012.12	2060.47
3/31/1998	5.65E+06	2006.19	2050	2016.48	2060.47	2016.45	2060.47	2012.1	2060.47
4/1/1998	5.65E+06	2006.19	2050	2016.48	2060.47	2016.45	2060.47	2012.1	2060.47
4/1/1998	5.65E+06	2016.76	2050	2027.1	2060.47	2027.07	2060.47	2023.3	2060.47
4/1/1998	5.65E+06	2002.26	2050	2012.54	2060.47	2012.5	2060.47	2007.02	2060.47
4/1/1998	5.66E+06	2002.28	2050	2012.54	2060.47	2012.49	2060.47	2006.7	2060.47
4/1/1998	5.67E+06	2002.2	2050	2012.47	2060.47	2012.41	2060.47	2006.53	2060.47
4/2/1998	5.76E+06	2002.12	2050	2012.39	2060.47	2012.33	2060.47	2006.42	2060.47
4/10/1998	6.20E+06	2002.04	2049.99	2012.31	2060.46	2012.25	2060.46	2006.32	2060.47
4/30/1998	7.32E+06	2001.97	2049.99	2012.24	2060.46	2012.18	2060.46	2006.24	2060.46
5/1/1998	7.32E+06	2001.97	2049.99	2012.24	2060.46	2012.18	2060.46	2006.24	2060.46
5/1/1998	7.32E+06	2016.77	2049.99	2027.11	2060.46	2027.07	2060.46	2023.11	2060.46
5/1/1998	7.32E+06	2002.38	2049.99	2012.66	2060.46	2012.62	2060.46	2007.19	2060.46
5/1/1998	7.32E+06	2002.48	2049.99	2012.75	2060.46	2012.7	2060.46	2007.04	2060.46
5/1/1998	7.32E+06	2002.49	2049.99	2012.76	2060.46	2012.71	2060.46	2006.99	2060.46
5/2/1998	7.31E+06	2002.5	2049.99	2012.77	2060.46	2012.71	2060.46	2006.99	2060.46
5/10/1998	7.25E+06	2002.49	2049.99	2012.76	2060.46	2012.7	2060.46	2006.98	2060.46
5/31/1998	7.11E+06	2002.46	2049.98	2012.73	2060.45	2012.68	2060.45	2006.95	2060.45
6/1/1998	7.11E+06	2002.46	2049.98	2012.73	2060.45	2012.68	2060.45	2006.95	2060.45
6/1/1998	7.11E+06	2011.66	2049.98	2021.98	2060.45	2021.92	2060.45	2016.27	2060.45
6/1/1998	7.11E+06	1997.17	2049.98	2007.4	2060.45	2007.33	2060.45	1999.77	2060.45
6/1/1998	7.11E+06	1997.15	2049.98	2007.38	2060.45	2007.29	2060.45	1999.43	2060.45
6/1/1998	7.14E+06	1997.05	2049.98	2007.27	2060.45	2007.18	2060.45	1999.23	2060.45
6/2/1998	7.25E+06	1996.94	2049.98	2007.17	2060.45	2007.07	2060.45	1999.09	2060.45
6/10/1998	7.85E+06	1996.83	2049.98	2007.05	2060.45	2006.96	2060.45	1998.95	2060.45
6/30/1998	9.38E+06	1996.73	2049.97	2006.96	2060.44	2006.86	2060.44	1998.84	2060.45
7/1/1998	9.38E+06	1996.73	2049.97	2006.96	2060.44	2006.86	2060.44	1998.84	2060.45
7/1/1998	9.38E+06	2009.82	2049.97	2020.11	2060.44	2020.03	2060.44	2013.42	2060.45
7/1/1998	9.38E+06	1995.43	2049.97	2005.65	2060.44	2005.57	2060.44	1997.26	2060.45
7/1/1998	9.38E+06	1995.5	2049.97	2005.71	2060.44	2005.61	2060.44	1997.11	2060.45
7/1/1998	9.39E+06	1995.47	2049.97	2005.69	2060.44	2005.58	2060.44	1997.03	2060.45
7/2/1998	9.41E+06	1995.44	2049.97	2005.65	2060.44	2005.55	2060.44	1996.99	2060.44
7/10/1998	9.54E+06	1995.39	2049.97	2005.6	2060.44	2005.5	2060.44	1996.93	2060.44
7/31/1998	9.91E+06	1995.33	2049.96	2005.54	2060.43	2005.43	2060.43	1996.85	2060.44
8/1/1998	9.91E+06	1995.33	2049.96	2005.54	2060.43	2005.43	2060.43	1996.85	2060.44
8/1/1998	9.91E+06	2013.96	2049.96	2024.26	2060.43	2024.2	2060.43	2019.04	2060.44
8/1/1998	9.91E+06	1999.68	2049.96	2009.94	2060.43	2009.88	2060.43	2003.39	2060.44
8/1/1998	9.90E+06	1999.86	2049.96	2010.12	2060.43	2010.05	2060.43	2003.43	2060.44
8/1/1998	9.88E+06	1999.95	2049.96	2010.2	2060.43	2010.14	2060.43	2003.51	2060.44
8/2/1998	9.78E+06	2000.03	2049.96	2010.29	2060.43	2010.22	2060.43	2003.61	2060.43
8/10/1998	9.29E+06	2000.1	2049.96	2010.36	2060.43	2010.29	2060.43	2003.69	2060.43
8/31/1998	7.97E+06	2000.13	2049.95	2010.38	2060.42	2010.31	2060.42	2003.72	2060.42
9/1/1998	7.97E+06	2000.13	2049.95	2010.38	2060.42	2010.31	2060.42	2003.72	2060.42
9/1/1998	7.97E+06	2008.05	2049.95	2018.34	2060.42	2018.26	2060.42	2011.29	2060.42
9/1/1998	7.97E+06	1993.54	2049.95	2003.74	2060.42	2003.65	2060.42	1994.61	2060.42
9/1/1998	7.97E+06	1993.5	2049.95	2003.69	2060.42	2003.58	2060.42	1994.23	2060.42
9/1/1998	8.00E+06	1993.37	2049.95	2003.56	2060.42	2003.44	2060.42	1993.99	2060.42
9/2/1998	8.15E+06	1993.25	2049.95	2003.44	2060.42	2003.31	2060.42	1993.82	2060.42
9/10/1998	8.89E+06	1993.12	2049.95	2003.31	2060.42	2003.18	2060.42	1993.67	2060.42
9/30/1998	1.08E+07	1993.02	2049.94	2003.21	2060.41	2003.08	2060.41	1993.55	2060.41
10/1/1998	1.08E+07	1993.02	2049.94	2003.21	2060.41	2003.08	2060.41	1993.55	2060.41

10/1/1998	1.08E+07	2007.06	2049.94	2017.32	2060.41	2017.22	2060.41	2009.45	2060.41
10/1/1998	1.08E+07	1992.72	2049.94	2002.91	2060.41	2002.8	2060.41	1993.37	2060.41
10/1/1998	1.08E+07	1992.8	2049.94	2002.99	2060.41	2002.87	2060.41	1993.28	2060.41
10/1/1998	1.08E+07	1992.8	2049.94	2002.98	2060.41	2002.86	2060.41	1993.24	2060.41
10/2/1998	1.08E+07	1992.79	2049.94	2002.97	2060.41	2002.84	2060.41	1993.22	2060.41
10/10/1998	1.08E+07	1992.76	2049.94	2002.94	2060.41	2002.81	2060.41	1993.18	2060.41
10/31/1998	1.09E+07	1992.7	2049.93	2002.89	2060.4	2002.76	2060.4	1993.12	2060.4
11/1/1998	1.09E+07	1992.7	2049.93	2002.89	2060.4	2002.76	2060.4	1993.12	2060.4
11/1/1998	1.09E+07	2005.92	2049.93	2016.17	2060.4	2016.06	2060.4	2007.88	2060.4
11/1/1998	1.09E+07	1991.56	2049.93	2001.74	2060.4	2001.63	2060.4	1991.72	2060.4
11/1/1998	1.09E+07	1991.63	2049.93	2001.81	2060.4	2001.67	2060.4	1991.59	2060.4
11/1/1998	1.09E+07	1991.61	2049.93	2001.78	2060.4	2001.65	2060.4	1991.53	2060.4
11/2/1998	1.09E+07	1991.58	2049.93	2001.76	2060.4	2001.62	2060.4	1991.49	2060.4
11/10/1998	1.10E+07	1991.55	2049.92	2001.72	2060.39	2001.58	2060.39	1991.45	2060.39
11/30/1998	1.14E+07	1991.5	2049.91	2001.67	2060.38	2001.53	2060.38	1991.39	2060.39
12/1/1998	1.14E+07	1991.5	2049.91	2001.67	2060.38	2001.53	2060.38	1991.39	2060.39
12/1/1998	1.14E+07	2004.68	2049.91	2014.92	2060.38	2014.8	2060.38	2006.11	2060.39
12/1/1998	1.14E+07	1990.33	2049.91	2000.5	2060.38	2000.38	2060.38	1989.94	2060.39
12/1/1998	1.14E+07	1990.4	2049.91	2000.57	2060.38	2000.42	2060.38	1989.82	2060.39
12/1/1998	1.14E+07	1990.38	2049.91	2000.54	2060.38	2000.39	2060.38	1989.76	2060.39
12/2/1998	1.14E+07	1990.35	2049.91	2000.52	2060.38	2000.37	2060.38	1989.72	2060.38
12/10/1998	1.15E+07	1990.32	2049.91	2000.48	2060.38	2000.33	2060.38	1989.68	2060.38
12/31/1998	1.18E+07	1990.27	2049.9	2000.43	2060.37	2000.28	2060.37	1989.62	2060.37
1/1/1999	1.18E+07	1990.27	2049.9	2000.43	2060.37	2000.28	2060.37	1989.62	2060.37
1/1/1999	1.18E+07	2005.95	2049.9	2016.2	2060.37	2016.08	2060.37	2007.81	2060.37
1/1/1999	1.18E+07	1991.66	2049.9	2001.84	2060.37	2001.73	2060.37	1991.89	2060.37
1/1/1999	1.18E+07	1991.78	2049.9	2001.96	2060.37	2001.83	2060.37	1991.87	2060.37
1/1/1999	1.18E+07	1991.81	2049.9	2001.99	2060.37	2001.85	2060.37	1991.89	2060.37
1/2/1999	1.18E+07	1991.83	2049.89	2002.01	2060.37	2001.88	2060.37	1991.92	2060.37
1/10/1999	1.16E+07	1991.85	2049.89	2002.03	2060.36	2001.89	2060.36	1991.93	2060.36
1/31/1999	1.12E+07	1991.83	2049.88	2002.01	2060.35	2001.88	2060.35	1991.92	2060.35
2/1/1999	1.12E+07	1991.83	2049.88	2002.01	2060.35	2001.88	2060.35	1991.92	2060.35
2/1/1999	1.12E+07	2005.3	2049.88	2015.54	2060.35	2015.43	2060.35	2007.02	2060.35
2/1/1999	1.12E+07	1990.95	2049.88	2001.13	2060.35	2001.01	2060.35	1990.89	2060.35
2/1/1999	1.12E+07	1991.02	2049.88	2001.2	2060.35	2001.06	2060.35	1990.77	2060.35
2/1/1999	1.12E+07	1991.01	2049.88	2001.18	2060.35	2001.04	2060.35	1990.72	2060.35
2/2/1999	1.12E+07	1990.99	2049.88	2001.16	2060.35	2001.02	2060.35	1990.69	2060.35
2/10/1999	1.13E+07	1990.97	2049.87	2001.14	2060.34	2001	2060.34	1990.66	2060.35
2/28/1999	1.15E+07	1990.94	2049.86	2001.11	2060.33	2000.97	2060.33	1990.63	2060.34
3/1/1999	1.15E+07	1990.94	2049.86	2001.11	2060.33	2000.97	2060.33	1990.63	2060.34
3/1/1999	1.15E+07	2005.39	2049.86	2015.64	2060.33	2015.52	2060.33	2007.11	2060.34
3/1/1999	1.15E+07	1991.07	2049.86	2001.25	2060.33	2001.13	2060.33	1991.07	2060.34
3/1/1999	1.15E+07	1991.16	2049.86	2001.34	2060.33	2001.2	2060.33	1991	2060.34
3/1/1999	1.15E+07	1991.17	2049.86	2001.34	2060.33	2001.2	2060.33	1990.97	2060.34
3/2/1999	1.15E+07	1991.17	2049.86	2001.34	2060.33	2001.2	2060.33	1990.97	2060.34
3/10/1999	1.15E+07	1991.16	2049.86	2001.34	2060.33	2001.2	2060.33	1990.97	2060.33
3/31/1999	1.14E+07	1991.14	2049.84	2001.32	2060.31	2001.17	2060.31	1990.94	2060.32
4/1/1999	1.14E+07	1991.14	2049.84	2001.32	2060.31	2001.17	2060.31	1990.94	2060.32
4/1/1999	1.14E+07	2006.65	2049.84	2016.91	2060.31	2016.8	2060.31	2008.88	2060.32
4/1/1999	1.14E+07	1992.35	2049.84	2002.54	2060.31	2002.43	2060.31	1992.94	2060.32
4/1/1999	1.14E+07	1992.46	2049.84	2002.65	2060.31	2002.53	2060.31	1992.91	2060.32
4/1/1999	1.14E+07	1992.49	2049.84	2002.68	2060.31	2002.55	2060.31	1992.92	2060.32
4/2/1999	1.14E+07	1992.51	2049.84	2002.7	2060.31	2002.57	2060.31	1992.95	2060.32
4/10/1999	1.12E+07	1992.53	2049.84	2002.72	2060.31	2002.59	2060.31	1992.97	2060.31
4/30/1999	1.09E+07	1992.53	2049.82	2002.72	2060.3	2002.59	2060.3	1992.97	2060.3
5/1/1999	1.09E+07	1992.53	2049.82	2002.72	2060.3	2002.59	2060.3	1992.97	2060.3
5/1/1999	1.09E+07	2006.36	2049.82	2016.62	2060.3	2016.51	2060.3	2008.57	2060.3
5/1/1999	1.09E+07	1992.02	2049.82	2002.21	2060.3	2002.1	2060.3	1992.48	2060.3

5/1/1999	1.09E+07	1992.1	2049.82	2002.28	2060.3	2002.16	2060.3	1992.38	2060.3
5/1/1999	1.09E+07	1992.09	2049.82	2002.27	2060.3	2002.14	2060.3	1992.33	2060.3
5/2/1999	1.09E+07	1992.08	2049.82	2002.26	2060.29	2002.13	2060.29	1992.32	2060.3
5/10/1999	1.09E+07	1992.07	2049.82	2002.25	2060.29	2002.12	2060.29	1992.3	2060.29
5/31/1999	1.10E+07	1992.05	2049.8	2002.23	2060.27	2002.1	2060.27	1992.28	2060.28
6/1/1999	1.10E+07	1992.05	2049.8	2002.23	2060.27	2002.1	2060.27	1992.28	2060.28
6/1/1999	1.10E+07	2006.76	2049.8	2017.01	2060.27	2016.91	2060.27	2009.1	2060.28
6/1/1999	1.10E+07	1992.43	2049.8	2002.62	2060.27	2002.52	2060.27	1993.08	2060.28
6/1/1999	1.10E+07	1992.53	2049.8	2002.72	2060.27	2002.6	2060.27	1993.02	2060.28
6/1/1999	1.10E+07	1992.54	2049.8	2002.73	2060.27	2002.6	2060.27	1993	2060.28
6/2/1999	1.10E+07	1992.55	2049.8	2002.74	2060.27	2002.61	2060.27	1993.01	2060.28
6/10/1999	1.10E+07	1992.55	2049.8	2002.74	2060.27	2002.61	2060.27	1993.01	2060.27
6/30/1999	1.08E+07	1992.54	2049.78	2002.73	2060.25	2002.6	2060.25	1993	2060.26
7/1/1999	1.08E+07	1992.54	2049.78	2002.73	2060.25	2002.6	2060.25	1993	2060.26
7/1/1999	1.08E+07	2007.56	2049.78	2017.82	2060.25	2017.73	2060.25	2010.25	2060.26
7/1/1999	1.08E+07	1993.24	2049.78	2003.44	2060.25	2003.34	2060.25	1994.27	2060.26
7/1/1999	1.08E+07	1993.34	2049.78	2003.54	2060.25	2003.43	2060.25	1994.21	2060.26
7/1/1999	1.08E+07	1993.36	2049.78	2003.56	2060.25	2003.44	2060.25	1994.2	2060.26
7/2/1999	1.08E+07	1993.37	2049.78	2003.57	2060.25	2003.45	2060.25	1994.22	2060.26
7/10/1999	1.07E+07	1993.38	2049.78	2003.58	2060.25	2003.46	2060.25	1994.23	2060.25
7/31/1999	1.05E+07	1993.38	2049.76	2003.58	2060.23	2003.46	2060.23	1994.23	2060.24
8/1/1999	1.05E+07	1993.38	2049.76	2003.58	2060.23	2003.46	2060.23	1994.23	2060.24
8/1/1999	1.05E+07	2008.41	2049.76	2018.68	2060.23	2018.59	2060.23	2011.48	2060.24
8/1/1999	1.05E+07	1994.08	2049.76	2004.29	2060.23	2004.2	2060.23	1995.5	2060.24
8/1/1999	1.05E+07	1994.19	2049.76	2004.39	2060.23	2004.29	2060.23	1995.44	2060.24
8/1/1999	1.05E+07	1994.2	2049.76	2004.41	2060.23	2004.3	2060.23	1995.43	2060.24
8/2/1999	1.05E+07	1994.22	2049.76	2004.42	2060.23	2004.31	2060.23	1995.44	2060.24
8/10/1999	1.04E+07	1994.23	2049.76	2004.44	2060.23	2004.32	2060.23	1995.46	2060.23
8/31/1999	1.02E+07	1994.23	2049.74	2004.44	2060.21	2004.32	2060.21	1995.46	2060.22
9/1/1999	1.02E+07	1994.23	2049.74	2004.44	2060.21	2004.32	2060.21	1995.46	2060.22
9/1/1999	1.02E+07	2007.45	2049.74	2017.72	2060.21	2017.63	2060.21	2010.22	2060.22
9/1/1999	1.02E+07	1993.08	2049.74	2003.29	2060.21	2003.19	2060.21	1994.07	2060.22
9/1/1999	1.02E+07	1993.15	2049.74	2003.35	2060.21	2003.23	2060.21	1993.94	2060.22
9/1/1999	1.02E+07	1993.13	2049.74	2003.33	2060.21	2003.21	2060.21	1993.87	2060.22
9/2/1999	1.02E+07	1993.11	2049.74	2003.31	2060.21	2003.18	2060.21	1993.84	2060.22
9/10/1999	1.03E+07	1993.09	2049.73	2003.28	2060.21	2003.16	2060.21	1993.81	2060.21
9/30/1999	1.06E+07	1993.07	2049.72	2003.26	2060.19	2003.14	2060.19	1993.78	2060.2
10/1/1999	1.06E+07	1993.07	2049.72	2003.26	2060.19	2003.14	2060.19	1993.78	2060.2
10/1/1999	1.06E+07	2007.48	2049.72	2017.75	2060.19	2017.65	2060.19	2010.2	2060.2
10/1/1999	1.06E+07	1993.15	2049.72	2003.35	2060.19	2003.25	2060.19	1994.16	2060.2
10/1/1999	1.06E+07	1993.24	2049.72	2003.44	2060.19	2003.32	2060.19	1994.08	2060.2
10/1/1999	1.06E+07	1993.24	2049.72	2003.44	2060.19	2003.32	2060.19	1994.05	2060.2
10/2/1999	1.06E+07	1993.24	2049.72	2003.44	2060.19	2003.32	2060.19	1994.05	2060.2
10/10/1999	1.06E+07	1993.24	2049.71	2003.44	2060.19	2003.32	2060.19	1994.04	2060.19
10/31/1999	1.05E+07	1993.23	2049.7	2003.42	2060.17	2003.3	2060.17	1994.02	2060.18
11/1/1999	1.05E+07	1993.23	2049.7	2003.42	2060.17	2003.3	2060.17	1994.02	2060.18
11/1/1999	1.05E+07	2007.17	2049.7	2017.43	2060.17	2017.33	2060.17	2009.78	2060.18
11/1/1999	1.05E+07	1992.82	2049.7	2003.02	2060.17	2002.92	2060.17	1993.7	2060.18
11/1/1999	1.05E+07	1992.9	2049.7	2003.1	2060.17	2002.98	2060.17	1993.59	2060.18
11/1/1999	1.05E+07	1992.9	2049.7	2003.09	2060.17	2002.97	2060.17	1993.55	2060.18
11/2/1999	1.05E+07	1992.89	2049.7	2003.08	2060.17	2002.96	2060.17	1993.54	2060.18
11/10/1999	1.06E+07	1992.88	2049.69	2003.07	2060.16	2002.95	2060.16	1993.52	2060.17
11/30/1999	1.07E+07	1992.86	2049.68	2003.05	2060.15	2002.93	2060.15	1993.5	2060.16
12/1/1999	1.07E+07	1992.86	2049.68	2003.05	2060.15	2002.93	2060.15	1993.5	2060.16
12/1/1999	1.07E+07	2006.59	2049.68	2016.85	2060.15	2016.75	2060.15	2008.96	2060.16
12/1/1999	1.07E+07	1992.24	2049.68	2002.43	2060.15	2002.32	2060.15	1992.86	2060.16
12/1/1999	1.07E+07	1992.32	2049.68	2002.51	2060.15	2002.38	2060.15	1992.75	2060.16
12/1/1999	1.07E+07	1992.31	2049.68	2002.49	2060.15	2002.37	2060.15	1992.7	2060.16

12/2/1999	1.07E+07	1992.29	2049.68	2002.48	2060.15	2002.35	2060.15	1992.68	2060.15
12/10/1999	1.08E+07	1992.28	2049.67	2002.46	2060.14	2002.34	2060.14	1992.66	2060.15
12/31/1999	1.09E+07	1992.25	2049.66	2002.44	2060.13	2002.31	2060.13	1992.63	2060.13
1/1/2000	1.09E+07	1992.25	2049.66	2002.44	2060.13	2002.31	2060.13	1992.63	2060.13
1/1/2000	1.09E+07	2005.49	2049.66	2015.74	2060.13	2015.63	2060.13	2007.41	2060.13
1/1/2000	1.09E+07	1991.13	2049.66	2001.31	2060.13	2001.2	2060.13	1991.26	2060.13
1/1/2000	1.09E+07	1991.2	2049.66	2001.38	2060.13	2001.24	2060.13	1991.13	2060.13
1/1/2000	1.09E+07	1991.18	2049.66	2001.36	2060.13	2001.22	2060.13	1991.07	2060.13
1/2/2000	1.09E+07	1991.16	2049.66	2001.33	2060.13	2001.19	2060.13	1991.04	2060.13
1/10/2000	1.11E+07	1991.13	2049.65	2001.3	2060.12	2001.16	2060.12	1991	2060.13
1/31/2000	1.14E+07	1991.1	2049.64	2001.27	2060.11	2001.13	2060.11	1990.97	2060.11
2/1/2000	1.14E+07	1991.1	2049.64	2001.27	2060.11	2001.13	2060.11	1990.97	2060.11
2/1/2000	1.14E+07	2004.72	2049.64	2014.96	2060.11	2014.85	2060.11	2006.29	2060.11
2/1/2000	1.14E+07	1990.38	2049.64	2000.56	2060.11	2000.43	2060.11	1990.17	2060.11
2/1/2000	1.14E+07	1990.46	2049.64	2000.63	2060.11	2000.49	2060.11	1990.07	2060.11
2/1/2000	1.14E+07	1990.44	2049.64	2000.61	2060.11	2000.47	2060.11	1990.02	2060.11
2/2/2000	1.14E+07	1990.43	2049.64	2000.6	2060.11	2000.45	2060.11	1990	2060.11
2/10/2000	1.15E+07	1990.41	2049.63	2000.58	2060.1	2000.43	2060.1	1989.97	2060.11
2/29/2000	1.16E+07	1990.38	2049.62	2000.55	2060.09	2000.4	2060.09	1989.93	2060.09
3/1/2000	1.16E+07	1990.38	2049.62	2000.55	2060.09	2000.4	2060.09	1989.93	2060.09
3/1/2000	1.16E+07	2005.08	2049.62	2015.32	2060.09	2015.2	2060.09	2006.75	2060.09
3/1/2000	1.16E+07	1990.76	2049.62	2000.94	2060.09	2000.82	2060.09	1990.74	2060.09
3/1/2000	1.16E+07	1990.86	2049.62	2001.03	2060.09	2000.9	2060.09	1990.68	2060.09
3/1/2000	1.16E+07	1990.87	2049.62	2001.04	2060.09	2000.9	2060.09	1990.66	2060.09
3/2/2000	1.16E+07	1990.88	2049.61	2001.05	2060.09	2000.91	2060.09	1990.67	2060.09
3/10/2000	1.16E+07	1990.87	2049.61	2001.05	2060.08	2000.91	2060.08	1990.67	2060.09
3/31/2000	1.14E+07	1990.86	2049.59	2001.03	2060.07	2000.89	2060.07	1990.65	2060.07
4/1/2000	1.14E+07	1990.86	2049.59	2001.03	2060.07	2000.89	2060.07	1990.65	2060.07
4/1/2000	1.14E+07	2006.32	2049.59	2016.58	2060.07	2016.47	2060.07	2008.53	2060.07
4/1/2000	1.14E+07	1992.02	2049.59	2002.21	2060.07	2002.11	2060.07	1992.59	2060.07
4/1/2000	1.14E+07	1992.14	2049.59	2002.32	2060.07	2002.2	2060.07	1992.56	2060.07
4/1/2000	1.14E+07	1992.16	2049.59	2002.35	2060.07	2002.22	2060.07	1992.56	2060.07
4/2/2000	1.14E+07	1992.18	2049.59	2002.37	2060.06	2002.24	2060.06	1992.59	2060.07
4/10/2000	1.12E+07	1992.2	2049.59	2002.39	2060.06	2002.26	2060.06	1992.61	2060.07
4/30/2000	1.09E+07	1992.2	2049.57	2002.39	2060.05	2002.26	2060.05	1992.61	2060.05
5/1/2000	1.09E+07	1992.2	2049.57	2002.39	2060.05	2002.26	2060.05	1992.61	2060.05
5/1/2000	1.09E+07	2009.47	2049.57	2019.75	2060.05	2019.67	2060.05	2012.97	2060.05
5/1/2000	1.09E+07	1995.19	2049.57	2005.42	2060.05	2005.34	2060.05	1997.2	2060.05
5/1/2000	1.09E+07	1995.35	2049.57	2005.57	2060.05	2005.47	2060.05	1997.22	2060.05
5/1/2000	1.09E+07	1995.41	2049.57	2005.63	2060.04	2005.53	2060.04	1997.28	2060.05
5/2/2000	1.08E+07	1995.47	2049.57	2005.69	2060.04	2005.59	2060.04	1997.35	2060.05
5/10/2000	1.05E+07	1995.53	2049.57	2005.75	2060.04	2005.65	2060.04	1997.42	2060.04
5/31/2000	9.53E+06	1995.56	2049.55	2005.79	2060.02	2005.69	2060.02	1997.46	2060.03
6/1/2000	9.53E+06	1995.56	2049.55	2005.79	2060.02	2005.69	2060.02	1997.46	2060.03
6/1/2000	9.53E+06	2008.96	2049.55	2019.24	2060.02	2019.16	2060.02	2012.46	2060.03
6/1/2000	9.53E+06	1994.58	2049.55	2004.8	2060.02	2004.72	2060.02	1996.33	2060.03
6/1/2000	9.54E+06	1994.66	2049.55	2004.87	2060.02	2004.77	2060.02	1996.2	2060.03
6/1/2000	9.54E+06	1994.64	2049.55	2004.85	2060.02	2004.74	2060.02	1996.13	2060.03
6/2/2000	9.56E+06	1994.62	2049.55	2004.83	2060.02	2004.73	2060.02	1996.11	2060.03
6/10/2000	9.66E+06	1994.61	2049.55	2004.82	2060.02	2004.72	2060.02	1996.09	2060.02
6/30/2000	9.92E+06	1994.6	2049.53	2004.81	2060	2004.71	2060	1996.08	2060.01
7/1/2000	9.92E+06	1994.6	2049.53	2004.81	2060	2004.71	2060	1996.08	2060.01
7/1/2000	9.92E+06	2008.04	2049.53	2018.31	2060	2018.23	2060	2011.13	2060.01
7/1/2000	9.92E+06	1993.67	2049.53	2003.88	2060	2003.79	2060	1995.01	2060.01
7/1/2000	9.92E+06	1993.74	2049.53	2003.95	2060	2003.84	2060	1994.88	2060.01
7/1/2000	9.93E+06	1993.73	2049.53	2003.93	2060	2003.82	2060	1994.82	2060.01
7/2/2000	9.95E+06	1993.71	2049.53	2003.91	2060	2003.8	2060	1994.79	2060.01
7/10/2000	1.00E+07	1993.69	2049.52	2003.89	2060	2003.78	2060	1994.77	2060

7/31/2000	1.03E+07	1993.67	2049.51	2003.87	2059.98	2003.76	2059.98	1994.74	2059.99
8/1/2000	1.03E+07	1993.67	2049.51	2003.87	2059.98	2003.76	2059.98	1994.74	2059.99
8/1/2000	1.03E+07	2008.05	2049.51	2018.33	2059.98	2018.24	2059.98	2011.1	2059.99
8/1/2000	1.03E+07	1993.71	2049.51	2003.92	2059.98	2003.83	2059.98	1995.07	2059.99
8/1/2000	1.03E+07	1993.8	2049.51	2004.01	2059.98	2003.9	2059.98	1994.98	2059.99
8/1/2000	1.03E+07	1993.8	2049.51	2004.01	2059.98	2003.9	2059.98	1994.95	2059.99
8/2/2000	1.03E+07	1993.81	2049.51	2004.01	2059.98	2003.9	2059.98	1994.95	2059.99
8/10/2000	1.03E+07	1993.8	2049.5	2004.01	2059.97	2003.89	2059.97	1994.94	2059.98
8/31/2000	1.02E+07	1993.79	2049.49	2003.99	2059.96	2003.88	2059.96	1994.93	2059.97
9/1/2000	1.02E+07	1993.79	2049.49	2003.99	2059.96	2003.88	2059.96	1994.93	2059.97
9/1/2000	1.02E+07	2010.86	2049.49	2021.15	2059.96	2021.08	2059.96	2014.99	2059.97
9/1/2000	1.02E+07	1996.57	2049.49	2006.81	2059.96	2006.73	2059.96	1999.2	2059.97
9/1/2000	1.02E+07	1996.72	2049.49	2006.95	2059.96	2006.87	2059.96	1999.21	2059.97
9/1/2000	1.02E+07	1996.77	2049.49	2007.01	2059.96	2006.92	2059.96	1999.25	2059.96
9/2/2000	1.02E+07	1996.83	2049.49	2007.06	2059.96	2006.97	2059.96	1999.32	2059.96
9/10/2000	9.83E+06	1996.88	2049.48	2007.12	2059.95	2007.03	2059.95	1999.38	2059.96
9/30/2000	8.98E+06	1996.91	2049.47	2007.15	2059.94	2007.06	2059.94	1999.41	2059.94
10/1/2000	8.98E+06	1996.91	2049.47	2007.15	2059.94	2007.06	2059.94	1999.41	2059.94
10/1/2000	8.98E+06	2015.09	2049.47	2025.41	2059.94	2025.36	2059.94	2020.93	2059.94
10/1/2000	8.98E+06	2000.79	2049.47	2011.06	2059.94	2011.02	2059.94	2005.26	2059.94
10/1/2000	8.98E+06	2000.97	2049.47	2011.23	2059.94	2011.18	2059.94	2005.26	2059.94
10/1/2000	8.96E+06	2001.05	2049.47	2011.31	2059.94	2011.25	2059.94	2005.32	2059.94
10/2/2000	8.87E+06	2001.13	2049.47	2011.39	2059.94	2011.33	2059.94	2005.41	2059.94
10/10/2000	8.43E+06	2001.21	2049.46	2011.48	2059.93	2011.42	2059.93	2005.51	2059.94
10/31/2000	7.25E+06	2001.27	2049.45	2011.54	2059.92	2011.48	2059.92	2005.58	2059.92
11/1/2000	7.25E+06	2001.27	2049.45	2011.54	2059.92	2011.48	2059.92	2005.58	2059.92
11/1/2000	7.25E+06	2015.07	2049.45	2025.4	2059.92	2025.36	2059.92	2021.1	2059.92
11/1/2000	7.25E+06	2000.67	2049.45	2010.93	2059.92	2010.89	2059.92	2005.08	2059.92
11/1/2000	7.25E+06	2000.75	2049.45	2011.01	2059.92	2010.95	2059.92	2004.9	2059.92
11/1/2000	7.25E+06	2000.74	2049.45	2011	2059.92	2010.94	2059.92	2004.84	2059.92
11/2/2000	7.26E+06	2000.73	2049.44	2010.99	2059.92	2010.93	2059.92	2004.82	2059.92
11/10/2000	7.32E+06	2000.73	2049.44	2011	2059.91	2010.94	2059.91	2004.82	2059.92
11/30/2000	7.47E+06	2000.75	2049.43	2011.01	2059.9	2010.95	2059.9	2004.83	2059.9
12/1/2000	7.47E+06	2000.75	2049.43	2011.01	2059.9	2010.95	2059.9	2004.83	2059.9
12/1/2000	7.47E+06	2016.92	2049.43	2027.26	2059.9	2027.23	2059.9	2023.57	2059.9
12/1/2000	7.47E+06	2002.57	2049.43	2012.85	2059.9	2012.81	2059.9	2007.78	2059.9
12/1/2000	7.47E+06	2002.7	2049.43	2012.97	2059.9	2012.93	2059.9	2007.66	2059.9
12/1/2000	7.46E+06	2002.73	2049.43	2013.01	2059.9	2012.96	2059.9	2007.66	2059.9
12/2/2000	7.42E+06	2002.77	2049.43	2013.05	2059.9	2013	2059.9	2007.69	2059.9
12/10/2000	7.21E+06	2002.81	2049.42	2013.09	2059.89	2013.04	2059.89	2007.74	2059.9
12/31/2000	6.64E+06	2002.85	2049.41	2013.13	2059.88	2013.08	2059.88	2007.78	2059.88
1/1/2001	6.64E+06	2002.85	2049.41	2013.13	2059.88	2013.08	2059.88	2007.78	2059.88
1/1/2001	6.64E+06	2018.5	2049.41	2028.85	2059.88	2028.83	2059.88	2025.78	2059.88
1/1/2001	6.64E+06	2004.13	2049.41	2014.42	2059.88	2014.39	2059.88	2010.01	2059.88
1/1/2001	6.63E+06	2004.24	2049.41	2014.53	2059.88	2014.49	2059.88	2009.83	2059.88
1/1/2001	6.63E+06	2004.27	2049.41	2014.56	2059.88	2014.52	2059.88	2009.8	2059.88
1/2/2001	6.60E+06	2004.3	2049.41	2014.59	2059.88	2014.55	2059.88	2009.82	2059.88
1/10/2001	6.45E+06	2004.34	2049.4	2014.62	2059.87	2014.58	2059.87	2009.85	2059.88
1/31/2001	6.04E+06	2004.37	2049.39	2014.65	2059.86	2014.61	2059.86	2009.88	2059.86
2/1/2001	6.04E+06	2004.37	2049.39	2014.65	2059.86	2014.61	2059.86	2009.88	2059.86
2/1/2001	6.04E+06	2017.93	2049.39	2028.28	2059.86	2028.26	2059.86	2025.07	2059.86
2/1/2001	6.04E+06	2003.51	2049.39	2013.79	2059.86	2013.76	2059.86	2009.11	2059.86
2/1/2001	6.04E+06	2003.58	2049.39	2013.86	2059.86	2013.82	2059.86	2008.87	2059.86
2/1/2001	6.04E+06	2003.57	2049.39	2013.85	2059.86	2013.8	2059.86	2008.79	2059.86
2/2/2001	6.06E+06	2003.55	2049.39	2013.83	2059.86	2013.79	2059.86	2008.75	2059.86
2/10/2001	6.16E+06	2003.54	2049.38	2013.83	2059.85	2013.78	2059.85	2008.74	2059.86
2/28/2001	6.37E+06	2003.54	2049.37	2013.83	2059.84	2013.78	2059.84	2008.74	2059.85
3/1/2001	6.37E+06	2003.54	2049.37	2013.83	2059.84	2013.78	2059.84	2008.74	2059.85

3/1/2001	6.37E+06	2019	2049.37	2029.35	2059.84	2029.33	2059.84	2026.46	2059.85
3/1/2001	6.37E+06	2004.61	2049.37	2014.9	2059.84	2014.88	2059.84	2010.7	2059.85
3/1/2001	6.37E+06	2004.73	2049.37	2015.02	2059.84	2014.98	2059.84	2010.49	2059.85
3/1/2001	6.37E+06	2004.75	2049.37	2015.04	2059.84	2015	2059.84	2010.45	2059.85
3/2/2001	6.34E+06	2004.77	2049.37	2015.06	2059.84	2015.02	2059.84	2010.46	2059.85
3/10/2001	6.22E+06	2004.8	2049.37	2015.09	2059.84	2015.05	2059.84	2010.48	2059.84
3/31/2001	5.87E+06	2004.81	2049.35	2015.1	2059.82	2015.07	2059.82	2010.5	2059.83
4/1/2001	0	2004.81	2049.35	2015.1	2059.82	2015.07	2059.82	2010.5	2059.83

Table C.5: Results for pseudo steady state radial gas flow at reservoir by Sawyer-Brown Method.

Date	Pr, psi	Pwf, psi	$(\Delta P)^2 = Pr^2 - Pwf^2$	q, MMscf/D	$(\Delta P)^2/q$	μg(at Pr)	z(at Pr)	ρ(at Pr)	Re(Pr)	Ar	Dr (E-5)	Sm at re	ST at re
1997/10	2003	1971	124978	5.06	24697	0.0141	0.8779	0.200	0.11024	538.6	188	51.8	51.97
1997/11	1999	1967	126271	5.86	21531	0.0141	0.8780	0.200	0.09875	538.4	188	60.2	60.31
1997/12	1995	1963	126553	6.21	20379	0.0141	0.8781	0.199	0.10439	538.1	188	57.1	57.20
1998/01	1990	1959	125893	6.14	20494	0.0141	0.8782	0.199	0.10310	537.8	188	57.4	57.52
1998/02	1987	1955	125382	6.09	20605	0.0141	0.8783	0.198	0.10198	537.6	188	57.8	57.88
1998/03	1983	1951	124005	5.65	21947	0.0141	0.8783	0.198	0.12213	537.3	188	46.1	46.27
1998/04	1978	1946	127012	7.32	17343	0.0141	0.8784	0.197	0.12657	537.0	188	47.0	47.14
1998/05	1973	1941	126040	7.11	17737	0.0141	0.8785	0.197	0.11848	536.7	188	50.0	50.11
1998/06	1967	1934	130133	9.38	13876	0.0141	0.8787	0.196	0.15601	536.3	188	39.5	39.63
1998/07	1960	1927	130494	9.91	13172	0.0141	0.8788	0.196	0.16436	535.9	188	37.6	37.78
1998/08	1955	1923	125746	7.97	15786	0.0140	0.8789	0.195	0.13186	535.5	188	44.7	44.87
1998/09	1948	1914	130918	10.80	12122	0.0140	0.8791	0.194	0.17831	535.1	189	34.8	35.00
1998/10	1946	1912	130800	10.83	12078	0.0140	0.8791	0.194	0.19206	534.9	189	31.8	32.06
1998/11	1933	1899	130345	11.35	11481	0.0140	0.8794	0.193	0.18634	534.1	189	33.1	33.33
1998/12	1926	1891	130464	11.82	11036	0.0140	0.8796	0.192	0.19344	533.7	189	32.0	32.18
1999/01	1918	1885	128236	11.18	11475	0.0140	0.8798	0.191	0.18232	533.2	189	33.1	33.34
1999/02	1912	1878	128128	11.52	11121	0.0140	0.8799	0.190	0.18746	532.8	189	32.2	32.39
1999/03	1905	1871	127134	11.43	11128	0.0139	0.8801	0.190	0.18537	532.4	190	32.2	32.42
1999/04	1899	1865	125195	10.86	11529	0.0139	0.8802	0.189	0.17575	532.0	190	33.3	33.47
1999/05	1893	1859	124783	11.04	11299	0.0139	0.8804	0.188	0.17828	531.6	190	32.6	32.84
1999/06	1887	1854	123659	10.84	11409	0.0139	0.8805	0.188	0.17455	531.3	190	32.9	33.12
1999/07	1881	1848	122243	10.50	11648	0.0139	0.8807	0.187	0.17423	530.9	190	32.3	32.46
1999/08	1875	1843	120809	10.15	11901	0.0139	0.8808	0.187	0.16270	530.6	190	34.2	34.40
1999/09	1870	1837	121069	10.61	11409	0.0139	0.8809	0.186	0.16969	530.3	190	32.9	33.07
1999/10	1864	1832	120178	10.54	11404	0.0139	0.8811	0.185	0.16809	529.9	190	32.8	33.03
1999/11	1858	1826	119737	10.68	11215	0.0139	0.8812	0.185	0.16990	529.6	191	32.3	32.50
1999/12	1852	1820	119495	10.91	10954	0.0138	0.8814	0.184	0.17314	529.3	191	31.6	31.79
2000/01	1846	1813	119634	11.36	10531	0.0138	0.8815	0.184	0.17982	528.9	191	30.4	30.65
2000/02	1840	1807	119425	11.63	10266	0.0138	0.8817	0.183	0.18366	528.6	191	29.7	29.92

2000/03	1834	1801	118222	11.43	10346	0.0138	0.8819	0.182	0.17992	528.2	191	29.9	30.10
2000/04	1828	1796	116409	10.88	10699	0.0138	0.8820	0.182	0.17087	527.9	191	30.8	31.01
2000/05	1823	1792	113099	9.53	11862	0.0138	0.8822	0.181	0.15437	527.6	191	32.6	32.81
2000/06	1818	1786	113234	9.92	11411	0.0138	0.8823	0.181	0.15043	527.3	191	33.9	34.09
2000/07	1812	1780	113307	10.29	11011	0.0138	0.8825	0.180	0.16047	527.0	192	31.6	31.79
2000/08	1806	1775	112492	10.23	10992	0.0138	0.8826	0.179	0.15918	526.7	192	31.5	31.71
2000/09	1802	1771	109429	8.98	12184	0.0137	0.8828	0.179	0.14420	526.4	192	33.3	33.52
2000/10	1798	1768	105578	7.25	14569	0.0137	0.8829	0.179	0.11226	526.2	192	41.3	41.40
2000/11	1794	1764	105555	7.47	14129	0.0137	0.8830	0.178	0.11554	526.0	192	40.0	40.18
2000/12	1790	1761	103508	6.64	15597	0.0137	0.8831	0.178	0.10245	525.8	192	44.1	44.22
2001/01	1787	1758	101978	6.04	16889	0.0137	0.8832	0.177	0.09618	525.6	192	45.9	46.05
2001/02	1784	1755	102254	6.37	16040	0.0137	0.8833	0.177	0.10991	525.4	192	39.7	39.88
2001/03	1780	1752	100948	5.87	17200	0.0137	0.8834	0.177	0.13318	525.2	192	30.8	30.94
2001/04	1778	1750	97736	4.36	22424	0.0137	0.8834	0.176	0.11808	525.1	192	33.0	33.11

Table C.6: Results for pseudo steady state radial gas flow at bottom-hole by Sawyer-Brown Method.

Date	Pr, psi	Pwf, psi	$(\Delta P)^2=Pr^2-Pwf^2$	q, MMscf/D	$(\Delta P)^2/q$	μg(at Pwf)	z(at Pwf)	ρ(at Pwf)	Re(Pwf)	Awf	Dwf (E-7)	Sm at bh	ST at bh
1997/10	2003	1971	124978	5.06	24697	0.01408	0.8786	0.197	2.85228	536.6	188	52.1	52.19
1997/11	1999	1967	126271	5.86	21531	0.01407	0.8787	0.196	2.55449	536.3	188	60.5	60.57
1997/12	1995	1963	126553	6.21	20379	0.01406	0.8788	0.196	2.70018	536.0	188	57.3	57.45
1998/01	1990	1959	125893	6.14	20494	0.01406	0.8789	0.195	2.66680	535.7	189	57.7	57.77
1998/02	1987	1955	125382	6.09	20605	0.01405	0.8789	0.195	2.63784	535.5	189	58.0	58.12
1998/03	1983	1951	124005	5.65	21947	0.01404	0.8790	0.195	3.15925	535.3	189	46.3	46.47
1998/04	1978	1946	127012	7.32	17343	0.01403	0.8791	0.194	3.27275	534.9	189	47.2	47.34
1998/05	1973	1941	126040	7.11	17737	0.01402	0.8792	0.194	3.06365	534.6	189	50.2	50.33
1998/06	1967	1934	130133	9.38	13876	0.01401	0.8794	0.193	4.03189	534.2	189	39.6	39.82
1998/07	1960	1927	130494	9.91	13172	0.01399	0.8796	0.192	4.24705	533.7	189	37.8	37.95
1998/08	1955	1923	125746	7.97	15786	0.01398	0.8797	0.192	3.40861	533.5	189	44.9	45.06
1998/09	1948	1914	130918	10.80	12122	0.01397	0.8799	0.191	4.60634	532.9	190	35.0	35.17
1998/10	1946	1912	130800	10.83	12078	0.01396	0.8799	0.190	4.96116	532.8	190	32.0	32.21
1998/11	1933	1899	130345	11.35	11481	0.01394	0.8802	0.189	4.81261	532.0	190	33.3	33.49
1998/12	1926	1891	130464	11.82	11036	0.01392	0.8804	0.188	4.99512	531.6	190	32.1	32.33
1999/01	1918	1885	128236	11.18	11475	0.01391	0.8806	0.188	4.70844	531.2	190	33.3	33.50
1999/02	1912	1878	128128	11.52	11121	0.01389	0.8807	0.187	4.84059	530.8	190	32.3	32.54
1999/03	1905	1871	127134	11.43	11128	0.01388	0.8809	0.186	4.78646	530.4	190	32.4	32.57
1999/04	1899	1865	125195	10.86	11529	0.01387	0.8811	0.186	4.53841	530.0	191	33.4	33.62
1999/05	1893	1859	124783	11.04	11299	0.01386	0.8812	0.185	4.60356	529.7	191	32.8	32.99
1999/06	1887	1854	123659	10.84	11409	0.01385	0.8814	0.184	4.50737	529.3	191	33.1	33.27
1999/07	1881	1848	122243	10.50	11648	0.01384	0.8815	0.184	4.49922	529.0	191	32.4	32.60
1999/08	1875	1843	120809	10.15	11901	0.01383	0.8816	0.183	4.20169	528.7	191	34.3	34.54
1999/09	1870	1837	121069	10.61	11409	0.01382	0.8818	0.183	4.38145	528.4	191	33.0	33.21
1999/10	1864	1832	120178	10.54	11404	0.01381	0.8819	0.182	4.34018	528.1	191	33.0	33.17
1999/11	1858	1826	119737	10.68	11215	0.01379	0.8821	0.181	4.38653	527.7	191	32.4	32.63
1999/12	1852	1820	119495	10.91	10954	0.01378	0.8823	0.181	4.46996	527.4	192	31.7	31.93
2000/01	1846	1813	119634	11.36	10531	0.01377	0.8824	0.180	4.64159	527.1	192	30.6	30.78
2000/02	1840	1807	119425	11.63	10266	0.01376	0.8826	0.180	4.74039	526.7	192	29.8	30.05

2000/03	1834	1801	118222	11.43	10346	0.01375	0.8828	0.179	4.64380	526.4	192	30.0	30.23
2000/04	1828	1796	116409	10.88	10699	0.01374	0.8829	0.178	4.41077	526.1	192	30.9	31.14
2000/05	1823	1792	113099	9.53	11862	0.01373	0.8830	0.178	3.98602	525.8	192	32.7	32.94
2000/06	1818	1786	113234	9.92	11411	0.01372	0.8832	0.177	3.88381	525.6	192	34.0	34.23
2000/07	1812	1780	113307	10.29	11011	0.01371	0.8834	0.177	4.14249	525.2	192	31.7	31.92
2000/08	1806	1775	112492	10.23	10992	0.01370	0.8835	0.176	4.10916	525.0	192	31.6	31.83
2000/09	1802	1771	109429	8.98	12184	0.01369	0.8836	0.176	3.72362	524.7	192	33.5	33.64
2000/10	1798	1768	105578	7.25	14569	0.01369	0.8837	0.175	2.90002	524.6	193	41.4	41.55
2000/11	1794	1764	105555	7.47	14129	0.01368	0.8838	0.175	2.98448	524.4	193	40.2	40.32
2000/12	1790	1761	103508	6.64	15597	0.01367	0.8839	0.175	2.64705	524.2	193	44.2	44.37
2001/01	1787	1758	101978	6.04	16889	0.01367	0.8840	0.174	2.48527	524.0	193	46.1	46.21
2001/02	1784	1755	102254	6.37	16040	0.01366	0.8841	0.174	2.83981	523.9	193	39.9	40.02
2001/03	1780	1752	100948	5.87	17200	0.01366	0.8842	0.174	3.44129	523.7	193	30.9	31.05
2001/04	1778	1750	97736	4.36	22424	0.01365	0.8842	0.174	3.05235	523.6	193	33.1	33.22

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1997 - Present	Fernas Construction Co. Inc.	Project Manager
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1992 – 1993	Aladin Middle East Oil Co.	Drilling Engineer
1989 – 1992	C & G Testing Co.	Testing Engineer
1987 – 1989	Oklahoma Univ. Petroleum Eng.	Teach. & Research Assist.
1983 – 1987	Turkish Petroleum Inc.	Research Engineer

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Chilingarian G.V., Alp E., Caenn R, Al Salem M., Uslu S., Gonzales S., Dorovi R.J., Mathur R.M., Yen T.F. “Drilling Fluid Evaluation Using Yield Point - Plastic Viscosity Correlation”, Energy Sources, Volume 8, Issue 2-3, (1986).

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